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THEORETICAL AND METHODOLOGICAL PROBLEMS

ENVIRONMENTAL POLICY AND MANAGEMENT

STUDIES AND MATERIALS

GENERAL ENVIRONMENTAL AND SOCIAL PROBLEMS

THEORETICAL AND METHODOLOGICAL PROBLEMS

Danuta SZPILKO • JOANNA EJDYS

EUROPEAN GREEN DEAL — RESEARCH DIRECTIONS. A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT: The article provided a classification of scientific research relating to European Green Deal (EGD) issues to assess their compatibility with areas identified in the EGD strategy document and identify emerging future research directions. A systematic literature review was based on bibliometric analysis and focused on articles in Scopus and Web of Science databases. The systematic literature review aimed to identify, integrate and evaluate research on the selected topic based on clearly defined criteria. Research query included (TITLE-ABS-KEY ("EU" OR europ*) AND TITLE-ABS-KEY ("green deal")) in the case of Scopus and TS = ("EU" OR europ*) AND "green deal") in the case of Web of Science. In total, 641 publication records were qualified for analysis. The bibliometric analysis allowed identifying eight thematic clusters and linking them to the eight areas of the European Green Deal strategy. The bibliometric analysis enabled the identification of eight thematic areas of international research undertaken in relation to the European Green Deal. These cover a variety of topics from social sciences, engineering, agriculture, sciences and natural sciences. Clusters included: Energy, circular economy, industry, building, mobility, food, biodiversity and pollution.

KEYWORDS: European Green Deal, energy, smart and sustainable mobility, circular economy, biodiversity, food, pollution

Introduction

The ongoing degradation of the environment and new environmental threats caused by human activity drive many international, national and local organisations to undertake large-scale initiatives counteracting environmental damages. Such action requires an integrated approach to solving shared problems affecting all communities regardless of location, wealth or level of socio-economic development. There is a global consensus that social and economic development depends on the sustainable management of our planet's natural resources (United Nations, 2015).

The European Environment Agency (EEA) highlighted 12 main problems of particular European concern. Among these significant environmental issues, the EEA emphasised the following:

1. Climate change, caused by rising CO_2 levels in the atmosphere, already exceeding pre-industrial times by 50%. Between 1990 and 2018, greenhouse gas emissions were reduced by 23%, while the economy grew by 61%.
2. Stratospheric ozone depletion, caused by the release of the chemicals known as chloro- and bromofluorocarbons, used as refrigerants, industrial cleaners, foaming agents and fire extinguishers.
3. The loss of biodiversity in European ecosystems having more than 2 500 habitat types and some 215 000 species, of which 90% are invertebrates, and almost every European country faced with endemic species (found nowhere else).
4. Major accidents that cause serious environmental damage.
5. Acidification resulting from the combustion of fossil fuels and sulphur and nitrogen dioxide emissions into the atmosphere where the gases are converted into acids and, after deposition, leading to a series of undesired changes in terrestrial and aquatic ecosystems.
6. Tropospheric ozone and other photochemical oxidants exceed Air Quality Guidelines for ozone in many European regions.
7. The management of freshwater resources, resulting in water losses due to distribution systems, water pollution and deterioration of aquatic habitats, severely hampering the water use for human consumption and wildlife.
8. Forest degradation, resulting from air pollution and seriously threatening the sustainability of forest resources in Central and Eastern regions and from fire in Southern Europe.
9. Threats to coastal zones and their management in connection with human activities creating physical modifications of the coastline and

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emissions of contaminants which have led to the deterioration of habitats and water quality.

10. Waste production and management caused by the steady increase in the quantity of waste and its toxic components.
11. Urban stress, such as environmental stress due to poor air quality, excessive noise and traffic congestion.
12. Chemical risk connected with excessive chemical loading. More than 10 million chemical compounds have been identified, of which about 100 000 are produced commercially (European Environment Agency, 2020; Communication…, 2019).

In response to the growing problems, the European Union has taken strategic actions to eliminate or reduce the negative impact of human activity on the environment in the long-term perspective. The 2020 European Green Deal (EGD) strategy implements the European Union's strategy, making the EU climate neutral by 2050 and indicating directions of economic development without increasing the consumption of natural resources. The Green Deal is an integral part of the strategy developed by the current Commission to implement the UN 2030 Agenda for Sustainable Development and the Sustainable Development Goals (United Nations, 2015). The European Green Deal strategy is one of the European Commission's six priorities for 2019–2024, also including a Europe fit for the digital age, an economy that works for people, a stronger Europe in the world, promoting our European way of life and a new push for European democracy (The European Commission, 2022). The European Green Deal is a form of a roadmap showing the way to a sustainable economy in Europe. The strategy implementation intends to ensure resource efficiency in a circular economy, protect biodiversity and reduce pollution (Rowan & Galanakis, 2020).

The main objective of the European Green Deal strategy is connected with the reduction of net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels and achieving climate neutrality in 2050 (Communication…, 2019). The transition towards a climate-neutral economy is one of the most significant challenges faced by our generation and those that will follow (Amoroso et al., 2021; Montanarella & Panagos, 2021).

The main goal of the European Green Deal strategy is to place sustainability and human well-being at the centre of economic policy and as a fundamental dimension of all policy decisions and the resulting actions. Achieving the goal of climate neutrality will only be possible with the participation of all stakeholders from different sectors, such as construction, biodiversity, energy, transport, agriculture and food. Fields of European Green Deal strategy interest are presented in Figure 1.

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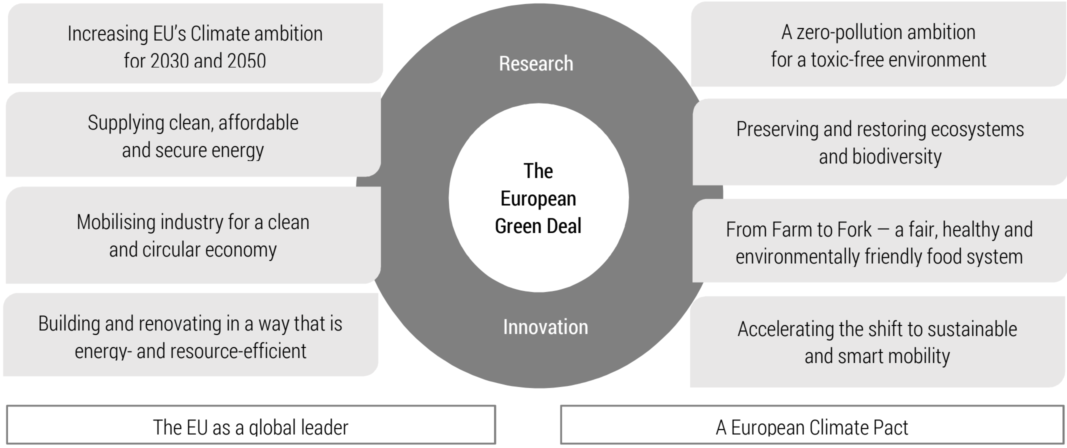

Figure 1. The European Green Deal

Source: Communication..., 2019.

Specific action plans are provided for implementation within the areas indicated in Figure 1. For example, the area of clean, affordable and secure energy plans the implementation of the Renovation Wave Initiative for the building sector and the offshore wind energy strategy. The industrial strategy for a clean and circular economy will encompass the circular economy action plan. Greening the Common Agricultural Policy will be based on the Farm to Fork Strategy, assuming a significant reduction in the use and risk of chemical pesticides, fertilisers and antibiotics. A detailed content description of the EGD areas based on keywords from the strategic document is presented in Table 1.

A comprehensive analysis of the scope of the EGD strategy areas has shown that the implementation of the European Green Deal strategy will require: (i) dialogue, solidarity and involvement of all stakeholders; (ii) revision and reformulation of the legal framework for action relating to all identified areas; (iii) application of innovation and new technological solutions and, in particular, digital technologies; and (iv) widespread application of the circular economy and sustainable development principles. Successful implementation of the European Green Deal strategy, according to Pe'er et al. (2020), will also require political courage to overcome resistance to change and the introduction of many political, economic and social measures (Brodny & Tutak, 2020; Montanarella & Panagos, 2021), and financial commitment (Brodny & Tutak, 2020; Chiaramonti & Maniatis, 2020; Brauers & Oei, 2020).

DOI: 10.34659/eis.2022.81.2.455

Table 1. Description of European Green Deal fields activities and scope

European Green Deal fields	Keywords describing EGD fields
Supplying clean, affordable and secure energy	decarbonising the energy, energy efficiency, renewable sources, clean energy, offshore wind production, decarbonisation at the lowest possible cost, smart integration, decarbonised gases, energy-related methane emissions. household renovation, innovative technologies and infrastructure, such as smart grids, hydrogen networks or carbon capture, storage and utilisation, energy storage
Mobilising industry for a clean and circular economy	circular economy, sustainable model of inclusive growth, green and the digital transformation of industry, energy-intensive industries modernisation, circular economy, reducing and reusing materials before recycling them, new business models, prevention against environmentally harmful products, producer responsibility, resource-intensive sectors modernisation, reusable or recyclable packaging, biodegradable and bio-based plastics, single use plastics, reusable, durable and repairable products on the market, tackle false green claims, product passport, green public purchasing, sustainable product policy, over-packaging and waste generation, market for secondary raw materials and by-products, cooperation across value chains, separate waste collection, waste shipments and illegal exports, diversifying supply from both primary and secondary sources, climate and resource frontrunners, breakthrough technologies such us include clean hydrogen, fuel cells and other alternative fuels, energy storage, and carbon capture, storage and utilisation, clean steel breakthrough technologies, zero-carbon steel making, collaboration with industry, safe, circular and sustainable battery value chain, growing market of electric vehicles, Digital technologies such us artificial intelligence, 5G, cloud and edge computing and the internet of things, distance monitoring of pollution, transparency on the environmental impact, incentivise people to return unwanted devices
Building and renovating in an energy- and resource-efficient way	renovation of public and private buildings, construction sector, energy performance of buildings, construction products regulation, circular economy, digitalisation, building stock, platform bringing together the buildings and construction sector, architects and engineers and local authorities, innovative financing schemes, renovation of social housing, schools and hospitals
Accelerating the shift to sustainable and smart mobility	multimodal transport, efficiency of the transport system, inland freight, rail and inland waterways, combined transport, rail and waterborne transport, short-sea shipping, single European sky, aviation emissions, Automated and connected multimodal mobility, smart traffic management systems, digitalisation, sustainable mobility, congestion and pollution, Connected Europe Facility funding instruments, energy taxation, emissions trading to the maritime sector, effective road pricing, sustainable alternative transport fuels, public recharging, refuelling points, long-distance travel, less polluting in cities, urban congestion, public transport, CO_2 emission performance standards, emissions of pollutants by aeroplanes and airport operations.
From Farm to Fork: designing a fair, healthy and environmentally-friendly food system	food value chain, sustainable food, climate change, protect the environment and preserve biodiversity, common agricultural policy, common fisheries policy, precision agriculture, organic farming, agro-ecology, agro-forestry animal welfare standards, eco-schemes performance, managing and storing carbon in the soil, nutrient management to improve water quality and reduce emissions, sustainable seafood, low-carbon food, reduce use and risk of chemical pesticides, fertilisers and antibiotics, organic farming, harvests protection from pests and diseases, circular economy, food waste management, combat food fraud, new innovative food and feed products, such as seafood based on algae, sustainable food consumption, affordable healthy food, healthy and sustainable diets, digital means for better food information, source of food, nutritional value, environmental footprint

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European Green Deal fields	Keywords describing EGD fields
Preserving and restoring ecosystems and biodiversity	halt biodiversity loss, biodiversity strategy, protected biodiversity-rich land, protected sea areas, Natura 2000 network, cross-border cooperation, restore damaged ecosystems, green European cities, increase biodiversity in urban spaces, nature restoration plan, natural capital, common fisheries policy, sensitive areas, well-managed marine protected areas, forest ecosystems, reforestation, afforestation, restoration of degraded forests, increase absorption of CO_2, circular bio-economy, EU forest strategy, effective afforestation, forest fires, bio-economy, forests sustainably, a sustainable "blue economy", oceans, aquatic and marine resources, nature-based solutions including healthy and resilient seas and oceans, maritime space sustainably management
A zero-pollution ambition for a toxic-free environment	toxic-free environment, monitor, report, prevent and remedy pollution from the air, water, soil, and consumer products, zero pollution action plan for air, water and soil, natural functions of ground and surface water, biodiversity in lakes, rivers, wetlands and estuaries, limit damage from floods, excess nutrients, urban runoff, micro plastics, chemicals, including pharmaceuticals, combined effects of different pollutants, air quality plans, cleaner air, local communities, air quality standards, pollution from large industrial installations, prevention of industrial accidents, chemicals strategy for sustainability, sustainable alternatives, "one substance – one assessment", transparency, endocrine disruptors, hazardous chemicals in products

Source: author's work based on Communication…, 2019.

The effects of the Strategy will impact every area of human activities. For example, the activities proposed under the European Green Deal strategy will significantly impact the EU economy and labour market. In particular, the development of sustainable and job-intensive activities is expected in the areas of low-emission technologies (Jäger-Waldau et al., 2020).

Ambitious goals of the European Green Deal strategy will be possible to achieve by developing new technologies, sustainable solutions and breakthrough innovations. This requires a tremendous amount of intellectual effort and financial support to the research and innovation system. The Green Deal strategy is linked to Horizon Europe in supporting public and private investment through the financial support of research and innovation in transport technologies, including batteries, clean hydrogen, low-carbon steel making, circular bio-based sectors and the built environment (Communication…, 2019).

Implementation of the European Green Deal strategy will require significant structural changes towards the intensive use of low-carbon technologies that are already available and yet emerging and not currently available on the market (Amoroso et al., 2021). According to the International Energy Agency (IEA), half of the global reductions in energy-related CO_2 emissions by 2050 will have to come from technologies that are currently in the demonstration or prototype phase (IEA, 2021). This will require an intensification of research and development activities. According to the results of a joint study carried out by the European Commission's Joint Research Centre (JRC), which is the

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EC's science and knowledge service, and the Organisation for Economic Co-operation and Development (OECD), Scientific R&D is one of the top ten sectors in terms of R&D intensity sector. The following sectors in terms of R&D intensity are pharmaceuticals, publishing & broadcasting, IT services, computers & electronics, other manufacturers, electrical equipment, transport equipment and machinery (Amoroso et al., 2021).

Many authors express their hope and indicate the need to start a broad discussion on an effective EU climate policy (Brodny & Tutak, 2020). The scientific discussion is all the more desirable as EGD is a horizontal and sectoral strategy requiring action at the level of global, European, regional, national, and local levels in a diverse context (Ciot, 2021).

Identifying the state of scientific research relating to the European Green Deal strategy is a key element enabling, on the one hand, the assessment of the current scope of research and, on the other, the identification of potentially new emerging research directions. This article aims to provide a classification of scientific research relating to EGD issues, assess their compatibility with the areas identified in the EGD strategy document, and identify emerging research directions. It seems important to stimulate a science-based discussion around the European Green Deal strategy. The next part of the article describes the research methodology, the research results and the discussion of the findings.

Research Methods

A bibliometric analysis method was used to review the literature on the European Green Deal. Authors often use this method, particularly at the initial stage of interest in a particular research topic. With many publications available, it enables the identification, synthesis, analysis and critical evaluation of their content (Bornmann & Haunschild, 2017; Keathley-Herring et al., 2016; Szymczak et al., 2018). Quantitative techniques allow identifying the current state and development trends in a given research area. The obtained results provide knowledge about the main research directions in a given area, research trends and changes in the number of publications in a specific period. They also enable the construction of rankings of the most productive authors, journals, research units, and countries in a given research area (Niñerola et al., 2019; Szum, 2021). The bibliometric analysis targeted well-established research areas in the literature (Glińska & Siemieniako, 2018; Gudanowska, 2017; Halicka, 2017; Winkowska et al., 2019; Leończuk et al., 2019; Ejdys et al., 2019) and those emerging (Siderska & Jadaan, 2018; Szpilko, 2014; Tomaszewska & Florea, 2018; Nazarko et al., 2009).

DOI: 10.34659/eis.2022.81.2.455

The operationalisation of the process used in this article with the bibliometric analysis method is presented in Figure 2.

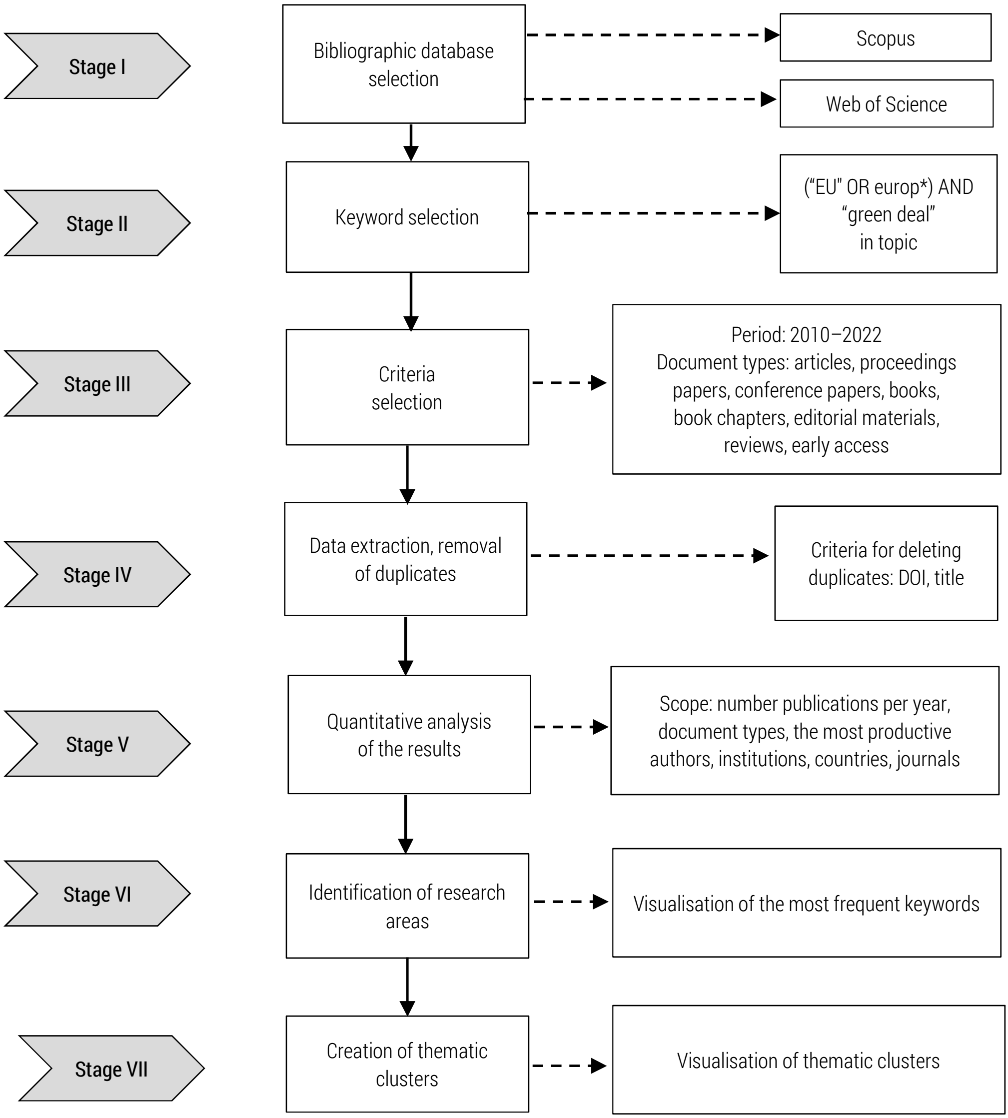

Figure 2. Methodology of bibliometric analysis

Source: author's work.

The methodology according to which the research process was conducted consists of seven phases, including the selection of bibliographic databases (I), the selection of keywords (II) and criteria limiting the search for publications (III), data extraction and selection (IV) and the analysis of the set of publications (V). The final two phases consisted of identifying research areas (VI) and then defining thematic clusters (VII) (Figure 2).

The first stage of the study selected Scopus and Web of Science bibliographic databases presenting a wide spectrum of scientific publications. The choice of databases was dictated by their availability and thematic breadth within all scientific disciplines. The bibliometric analysis initially included publications containing the phrase "European Green Deal". The initial search in the first sample included publications containing the indicated phrase in the entire range of documents, while the second sample – in titles, abstracts and keywords. Selected restriction criteria were then applied. Materials published between 2010 and 2022 were searched. Articles, conference proceedings, books, book chapters, reviews, editorials and early access were qualified for further analysis. Other publication types (retracted publications, conference reviews, notes, letters) were discarded. The results of the initial search are shown in Table 2.

A search for the phrase "European Green Deal" across the range of papers in the first sample generated 2718 records in Scopus and 308 records in Web of Science. The initial analysis of the results showed that many publications were irrelevant to the study area. Therefore, in the second attempt, the search was limited only to publications containing the indicated phrase in the titles, abstracts and keywords. After searching for the phrase in titles, abstracts and keywords, 390 records were obtained in Scopus and 306 in Web of Science. After adopting limiting criteria, 376 and 302 records were obtained. The search results are presented in Table 2.

Table 2. Preliminary search results

Stage	Scopus	Web of Science
First search		
Research query	ALL ("european green deal")	ALL="european green deal"
Number of articles before inclusion criteria	2718	308
Number of articles after inclusion criteria	2665	304
Second search		
Research query	TITLE-ABS-KEY ("european green deal")	TS="european green deal"
Number of articles before inclusion criteria	390	306
Number of articles after inclusion criteria	376	302

Source: author's work based on Scopus and Web of Science databases.

DOI: 10.34659/eis.2022.81.2.455

The preliminary analysis of the collected records in the first and second search attempts provided vital information from the study's point of view. It was noted that the record of the phrase "European Green Deal" also appears in the form of the following alternative phrases: EU Green Deal, European New Green Deal, European Union Green Deal, European Unions (EU) Green Deal, Europe's Green Deal, European "Green New Deal", European Union's Green Deal, Green Deal of the European Union, New Green Deal. Therefore, the authors reformulated the phrase by dividing it into two parts, the first one concerning the word "European" in the form of notation: "EU" OR europ* and the second: "green deal".

Table 3. Principal search results

Stage	Scopus	Web of Science
Research query	(TITLE-ABS-KEY ("EU" OR europ*) AND TITLE-ABS-KEY ("green deal")	TS = ("EU" OR europ*) AND "green deal")
Number of articles before inclusion criteria	605	475
Number of articles after inclusion criteria	579	469

Source: author's work based on the Scopus and Web of Science databases.

A search for the modified phrase generated 605 records in Scopus and 475 in Web of Science. Finally, after applying the accepted limitation on document type, 579 and 469 records were obtained, respectively (Table 3). Files containing the full description of the records in *csv format were downloaded from each database. A single aggregated file containing 1048 records was then created. After removing duplicates, a set of 641 records was qualified for further analysis.

Based on the obtained data set, analyses were made concerning the number of publications in a specific period, the most productive authors, organisations, countries and journals. The most recognisable, i.e., the most frequently cited articles, were also identified. The most frequently occurring keywords were also detected, and a map reflecting the co-occurrence of keywords related to the European Green Deal was prepared in the VOSviewer software (version 1.6.18). To eliminate different types of terms with the same meaning (e.g., EU, European Union) or irrelevant to the study (e.g., article, state, research, time), a thesaurus file was additionally prepared (Gudanowska, 2017; van Eck & Waltman, 2018). Then, based on keyword analysis and an in-depth review of the publication collection, thematic clusters depicting the main and emerging research directions were identified.

DOI: 10.34659/eis.2022.81.2.455

Results of the Research

The first stage of the research included an analysis of interest in the subject over the years, identification of the dominant types of publications and their affiliation with the main subject areas in the Scopus and Web of Science databases.

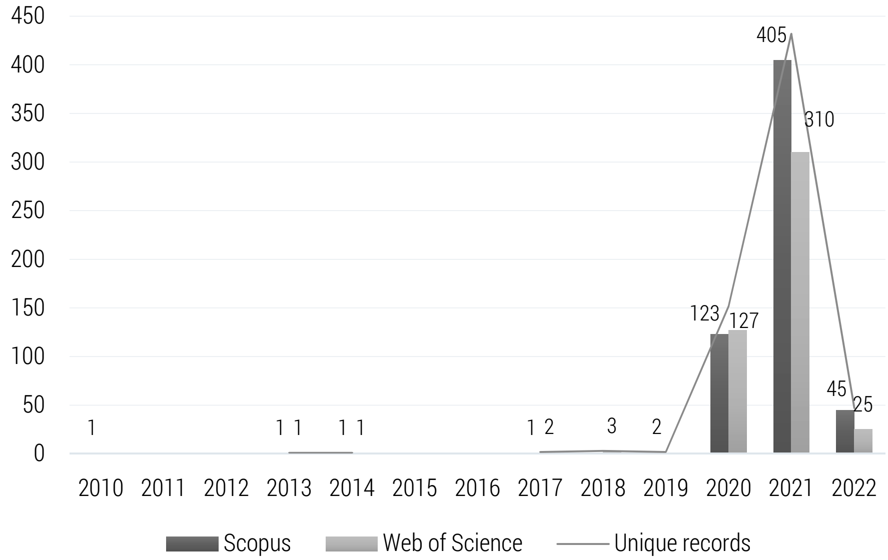

Figure 3. Number of publications in the field of European Green Deal in Scopus and Web of Science databases (indexed from January 2010 to January 2022)

Source: author's work based on the Scopus and Web of Science databases.

For both databases, numerous European Green Deal (EGD) publications appeared between 2020 and 2021 (Figure 3). In earlier years, references to EGD were sporadic and rather "emerging thematic". The total number of citations for publications indexed in the Scopus database was 1966, while in Web of Science – 1802. The number of uncited publications was 271 and 208, respectively.

Both in Scopus (77.5%) and Web of Science (83%) databases, most publications were articles and conference papers (10.7%, 8.7%, respectively). Reviews, editorials and book chapters constituted a small part. The structure of publications by document type is presented in Figure 4.

The majority of publications in Scopus and Web of Science databases are assigned to the areas of Environmental Sciences and Energy (Energy Fuels), comprising 40.1% and 37.0% in the former and 29.0% and 22.4% in the lat-

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ter. A significant proportion of publications in Scopus are also assigned to the areas Social Sciences (34.5%) and Engineering (25.4%), while in Web of Science, to Environmental Studies (22.2%), Green Sustainable Science Technology (21.1%). However, the naming of areas differs in Scopus and Web of Science databases.

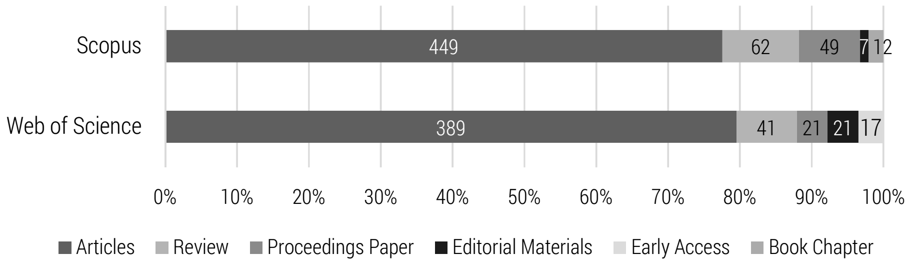

Figure 4. Type of documents of publications in the field of European Green Deal in Scopus and Web of Science databases (indexed from January 2010 to January 2022)

Source: author's work based on the Scopus and Web of Science databases.

The author with the highest number (ten) of publications was Blumberga, and the most cited articles were "Economic growth in contrast to GHG emission reduction measures in Green Deal context" from 2021 and "GHG Performance Evaluation in Green Deal Context" from 2020 (in WoS with three citations each). Next, Brodny, Smol, Tutak and Zorpas had six publications each. Brodny and Tutak had the highest average number of citations per publication in each database due to joint publishing. Their most cited publication (43 citations in WoS) was "Analyzing Similarities between the European Union Countries in Terms of the Structure and Volume of Energy Production from Renewable Energy Sources", published in Energies from 2020. Zorpas' most cited article (55 citations in WoS) was "Strategy development in the framework of waste management" from 2020, published in Science of the Total Environment. A detailed list of the most productive authors is presented in Table 4.

The highest number of publications were from Italy (119 publications), Poland (92) and Germany (78). Considering the authors' affiliation, the highest number of publications were from the European Commission's Joint Research Centre (31), Wageningen University & Research (17) and Riga Technical University (15). The ranking of ten most productive units had four units from Poland: the Polish Academy of Sciences (11), the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences (11), the Silesian University of Technology (8), and the Warsaw University of Life Sciences (8). Publications from the Silesian University of Technology were the most highly cited (13.8 in Scopus, 16.3 in WoS). In comparison with other

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organisations in the ranking, it had by far the highest average number of citations in Scopus and Web of Science databases.

In the ranking of the most productive journals, Sustainability (Switzerland) ranked first (63 publications). This was followed by Energies (57) and Politics and Governance (12). However, the journal Science of the Total Environment achieved the highest average number of citations in each database (22 in Scopus, 16.4 in WoS).

Table 4. Most productive authors, organisations, countries and journals

No.	Item	NP	[%]	Average citation count	
				Scopus	Web of Science
Authors					
1	Blumberga, D.	10	1.6	1.2	1.1
2	Brodny, J.	6	0.9	18.2	16.3
3	Smol, M.	6	0.9	6.5	6.0
4	Tutak, M.	6	0.9	18.2	16.3
5	Zorpas, A. A.	6	0.9	17.0	15.2
6	Simionescu, M.	5	0.8	2.8	3.0
7	Sánchez-Bayón, A.	5	0.8	1.8	1.4
8	Jager-Waldau A.	5	0.8	0.5	10.0
9	Dupont, C.	4	0.6	5.3	6.0
10	Fragkos, P.	4	0.6	3.3	2.5
11	Prussi, M.	4	0.6	4.8	6.5
12	Scarlat, N.	4	0.6	4.8	6.5
13	Streimikiene, D.	4	0.6	2.0	1.5
14	Taylor, N.	4	0.6	13.8	10.5
15	Voukkali, I.	4	0.6	8.0	8.5
Countries					
16	Italy	119	18.6	5.3	5.1
17	Poland	92	14.4	3.0	2.7
18	Germany	78	12.2	4.5	4.3
19	Spain	69	10.8	3.8	3.3
20	Netherlands	50	7.8	3.7	3.6
21	United Kingdom	48	7.5	4.1	7.7
22	Belgium	48	7.5	5.0	3.0

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No.	Item	NP	[%]	Average citation count	
				Scopus	Web of Science
23	Greece	35	5.5	5.8	5.7
24	France	32	5.0	4.0	2.8
25	Austria	28	4.4	7.7	7.5
Organisations					
26	European Commission's Joint Research Centre	31	4.8	10.1	8.8
27	Wageningen University & Research	17	2.7	4.1	4.9
28	Riga Technical University	15	2.3	1.5	1.5
29	INRAE – National Research Institute for Agriculture, Food and Environment	12	1.9	4.4	3.8
30	Polish Academy of Sciences	11	1.7	4.2	3.8
31	Mineral and Energy Economy Research Institute of the Polish Academy of Sciences	11	1.7	3.7	3.7
32	Technical University of Berlin	9	1.4	5.6	6.0
33	European Commission	9	1.4	6.6	8.2
34	Silesian University of Technology	8	1.2	13.8	16.3
35	Warsaw University of Life Sciences	8	1.2	1.4	1.4
Journals					
36	Sustainability (Switzerland)	63	9.8	3.7	3.2
37	Energies	57	8.9	4.4	4.0
38	Politics and Governance	12	1.9	2.5	1.3
39	Environmental and Climate Technologies	10	1.6	0.8	0.7
40	Energy Policy	10	1.6	5.7	7.6
41	Science of the Total Environment	8	1.2	22	16.4
42	Energy	7	1.1	4.9	3.1
43	Applied Sciences	6	0.9	1.7	1.2
44	Energy and Buildings	6	0.9	9.7	7.8
45	Journal of Cleaner Production	6	0.9	5.8	5.2

Note: NP – number of publications, [%] – the percentage of the total number of publications (641), N/A – not applicable.

Source: author's work based on the Scopus and Web of Science databases.

The total number of citations of publications on the European Green Deal was 1791 for WoS and 1963 for Scopus. The top ten publications included two articles published in Science of the Total Environment and one each in People and Nature, Energy Research & Social Science, Land Use Policy, Energies, Applied Energy, Energy Policy, Renewable & Sustainable Energy Reviews and Energy and Buildings. The eight most cited publications were from 2020.

Table 5. The most cited articles on the European Green Deal area

Authors	Article title	Journal	Number of citations	
			Scopus	Web of Science
(Pe'er et al., 2020)	Action needed for the EU Common Agricultural Policy to address sustainability challenges	People and Nature	85	83
(Rowan & Galanakis, 2020)	Unlocking challenges and opportunities presented by COVID-19 pandemic for cross-cutting disruption in agri-food and green deal innovations: Quo Vadis?	Science of the Total Environment	71	57
(Zorpas, 2020)	Strategy development in the framework of waste management	Science of the Total Environment	68	55
(Kern et al., 2017)	Policy packaging or policy patching? The development of complex energy efficiency policy mixes	Energy Research & Social Science	N/A	120
(Montanarella & Panagos, 2021)	The relevance of sustainable soil management within the European Green Deal	Land Use Policy	54	43
(Brodny & Tutak, 2020)	Analyzing Similarities between the European Union Countries in Terms of the Structure and Volume of Energy Production from Renewable Energy Sources	Energies	44	43
(Chiaramonti & Maniatis, 2020)	Security of supply, strategic storage and Covid19: Which lessons learnt for renewable and recycled carbon fuels, and their future role in decarbonizing transport?	Applied Energy	45	36
(Brauers & Oei, 2020)	The political economy of coal in Poland: Drivers and barriers for a shift away from fossil fuels	Energy Policy	39	37
(Jäger-Waldau et al., 2020)	How photovoltaics can contribute to GHG emission reductions of 55% in the EU by 2030	Renewable & Sustainable Energy Reviews	43	32
(Pohoryles et al., 2020)	Energy performance of existing residential buildings in Europe: A novel approach combining energy with seismic retrofitting	Energy and Buildings	35	30

Note: N/A – not applicable.

Source: author's work based on the Scopus and Web of Science databases.

The most cited publication (85 in Scopus, 83 in WoS) was the article by Pe'er et al. (2020), "Action needed for the EU Common Agricultural Policy to address sustainability challenges". This was followed by the articles "Unlocking challenges and opportunities presented by COVID-19 pandemic for cross-cutting disruption in agri-food and green deal innovations: Quo Vadis?" by Rowan and Galanakis (2020) and "Strategy development in the framework of waste management" by Zorpas (2020). The total number of citations was slightly lower than the first publication (71 and 68 in Scopus; 57 and 55 in WoS). Both articles were published in the journal Science of the Total Environment (Table 5).

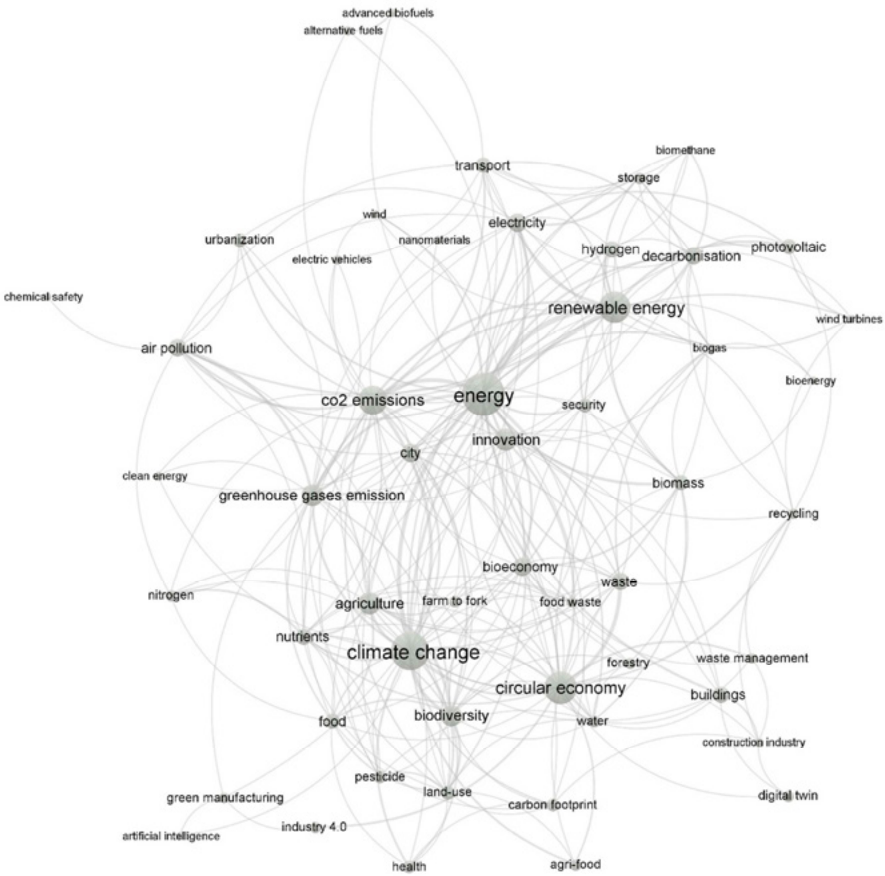

Figure 5. Keyword co-occurrence map on the European Green Deal area

Source: author's work using VOSviewer software.

The most frequent keywords related to the topic of the European Green Deal were also extracted as part of the bibliometric analysis. The VOSviewer software was used during the analysis. The generated set contained a total of 310 words or phrases, which appeared at least three times in the keywords included in 641 analysed articles. The set included words with the same meaning as abbreviations or repetitions (e.g., land use, land-use) and words directly unrelated to the analysis subject (e.g., article, analysis). A thesaurus file was prepared and used to organise the set of words. Keywords used in the search (e.g., EGD, European Green Deal) were excluded from the collection. The notation of terms and abbreviations with the same meaning was also standardised, and terms irrelevant to the analyses conducted were removed. The final set contained 53 keywords. The most frequent terms and the links between them are presented in Figure 5.

Among the most frequent keywords related to the European Green Deal were terms related to energy (energy had 98 occurrences of the word in the set, renewable energy – 49), climate (climate change – 79), air pollution (CO_2 emission – 41, greenhouse gas emission – 24), closed-loop economy (54) and agriculture (23). The larger the circle in Figure 6, the greater the number of occurrences for a given keyword. It should be noted that these terms also show the most links to other terms. It is also worth noting the frequent occurrence of the word innovation (23) and its linkage being weaker than previously mentioned words and mainly centred on energy-related issues.

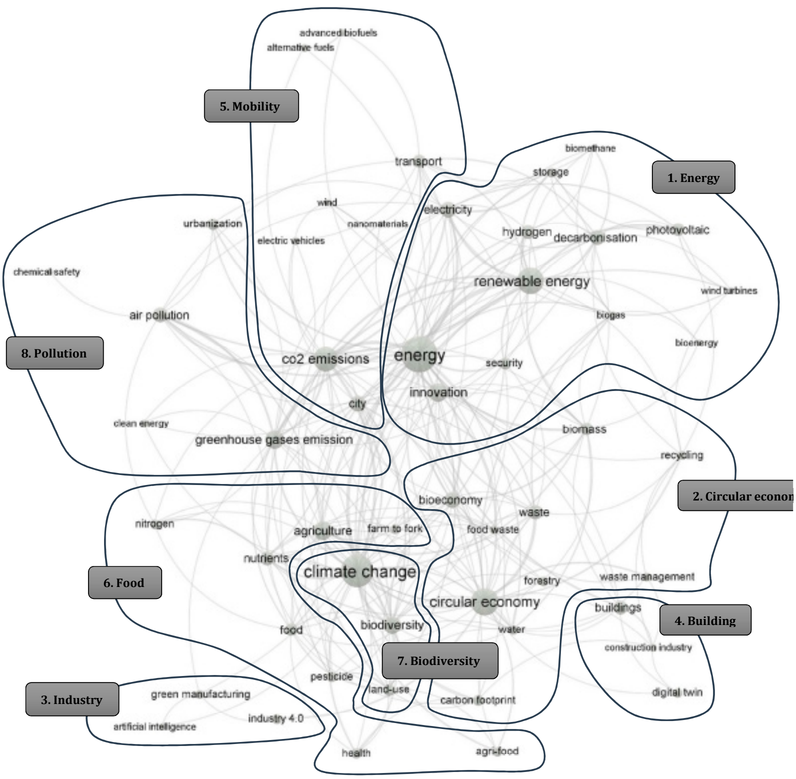

Figure 6. Thematic clusters on the European Green Deal

Source: elaborated by the authors using the VOSviewer software.

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An in-depth analysis of the most frequently occurring keywords made it possible to identify eight thematic clusters and link them to eight assumptions (elements) underpinning the European Green Deal (Figure 6, Table 6).

Table 6. Subareas of the European Green Deal research

Cluster number	Cluster name	Words	Transformative policies of European Green Deal	
1	Energy	energy, renewable energy, bioenergy, biogas, biomethane, decarbonisation, electricity, hydrogen, photovoltaic, innovation, security, storage, wind turbines	2. Supplying clean, affordable and secure energy	
2	Circular Economy	bioeconomy, circular economy, food waste, recycling, waste, waste management, biomass, forestry, water, carbon footprint	3. Mobilising industry for a clean and circular economy	1. Increasing the EU's climate ambition for 2030 and 2050
3	Industry	artificial intelligence, green manufacturing, industry 4.0		
4	Building	buildings, construction industry, digital twin	4. Building and renovating in an energy- and resource-efficient way	
5	Mobility	advance biofuels, alternative fuels, electric vehicles, city, nanomaterials, transport, CO_2 emissions, wind	5. Accelerating the shift to sustainable and smart mobility	
6	Food	agriculture, agri-food, farm to fork, food, health, nitrogen, nutrients, pesticide	6. From Farm to Fork: designing a fair, healthy and environmentally-friendly food system	
7	Biodiversity	biodiversity, climate change, land-use	7. Preserving and restoring ecosystems and biodiversity	
8	Pollution	air pollution, chemical safety, clean energy, greenhouse gases emission, urbanisation	8. A zero-pollution ambition for a toxic-free environment	

Source: author's work.

The first cluster, "Energy", refers primarily to technological solutions enabling the efficient and secure supply and storage of energy from renewable sources (e.g., renewable energy, bioenergy, biogas, biomethane, decarbonisation, electricity, hydrogen, photovoltaic, security, storage, and wind turbines). This cluster is closely linked to the European Green Deal's transformational policy for providing clean, affordable and secure energy. The second cluster, "Circular Economy", is focused on leaving products in the economy for as long as possible and minimising waste generation. It includes such keywords as bioeconomy, food waste, recycling, waste, waste management, biomass, forestry, water, and carbon footprint. The third cluster, "Industry", is represented by such keywords as artificial intelligence, green manufacturing, and Industry 4.0. It simultaneously focuses on Industry 4.0 based on artificial intelligence and environmentally-friendly manufacturing. It seems to be an emerg-

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ing research area, so far poorly recognised in the literature. Both the "Circular Economy" and "Industry" clusters are closely linked to the EGD policy on mobilising industry to move towards a clean, circular economy. The fourth cluster, "Building", covers issues related to construction and the use of virtual technologies. It includes such keywords as buildings, construction industry, and digital twin. Like the "Industry" cluster, this research area can also be considered emerging. This cluster is closely connected to the EGD focus on building and renovating in an energy- and resource-efficient way. The fifth cluster, "Mobility", is related to the development of innovative vehicles and fuels to enable mobility while reducing CO_2 emissions. It is associated with such keywords as advanced biofuels, alternative fuels, electric vehicles, city, nanomaterials, transport, CO_2 emissions, and wind. This cluster is closely associated with the European Green Deal's transformational policy on the transition to sustainable and intelligent mobility. The sixth cluster, "Food", is centred on the production of fresh health-friendly food. It is represented by keywords agriculture, agri-food, farm to fork, food, health, nitrogen, nutrients, and pesticides. Within EGD, the themes relate to the premise of designing a fair, healthy and environmentally-friendly food system. The penultimate cluster was named "Biodiversity" as the themes within it related to the preservation of biodiversity (biodiversity, climate change, land-use). It strongly focuses on the protection and restoration of ecosystems and biodiversity, which are also the object of the EGD transformation policy. The last cluster, "Pollution", contains keywords on various pollutants and especially air pollution (greenhouse gases emission, air pollution, chemical safety, clean energy, and urbanisation). It is closely related to the zero-pollution aim and the toxin-free environment enshrined in the EGD. It is important to mention that all the listed clusters directly or indirectly relate to the achievement of the EU climate targets for 2030 and 2050.

Discussion of the Results

The bibliometric analysis enabled the identification of eight thematic areas of international research undertaken in relation to the European Green Deal. These cover a variety of topics from social sciences, engineering, agriculture, sciences and natural sciences.

Negative climate change, associated with the high carbon intensity of the hydrocarbon-burning economy and growing public awareness, has prompted the search for green energy sources (Brodny et al., 2020). EGD targets will require introducing countless renewable energy sources at an unprecedented speed (Kougias et al., 2021). There is, therefore, a strong emphasis in publications on finding solutions to generate energy efficiently and safely

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from renewable sources. Biomass (Tzelepi et al., 2020) and biogas (Brémond et al., 2021) are energy sources that can meet the growing demand for clean, long-life energy sources. Many authors are also conducting research relating to solar energy – photovoltaic installations (Jäger-Waldau et al., 2020; Sweetnam et al., 2013) and wind energy (Hrnčić et al., 2021).

Despite global growth in renewable energy consumption, global energy-related carbon emissions are increasing, and there are still significant differences in the share of renewable energy consumption in national energy portfolios. These issues require further efforts at the policy level, especially in countries that rely heavily on energy imports. These countries could improve their lack of energy independence by using renewable energy sources (RES) (Marra & Colantonio, 2021). There are numerous publications in the literature on the comparison of EU countries by the structure of energy production, including from RES, useful for the development of energy and climate policies of EU countries (Brodny et al., 2021; Brodny & Tutak, 2020; Hafner & Raimondi, 2021; Kochanek, 2021; Tutak et al., 2021; Włodarczyk et al., 2021). There are also a number of articles available on aspects of strategic energy management planning in the European Union (Bouzarovski et al., 2021; Hafner & Raimondi, 2021; Nikas et al., 2021; Skjærseth, 2021), as well as in individual countries, e.g., reducing coal-fired generation in Poland (Brauers & Oei, 2020). The publications also provide a comprehensive discussion of the changes to the European Union's climate and energy law introduced by the Climate and Energy Policy Framework 2030 (Kulovesi & Oberthür, 2020).

In the European Green Deal context, the bioeconomy is also high on the policy agenda. The bioeconomy includes several related concepts (e.g., the bio-based economy, the green economy and the circular economy), between which there are clear synergies (Kardung et al., 2021). The circular economy has a significant place in EGD-related research. It assumes a shift from a take–make–dispose linear model to a circular model where waste, if produced, becomes a valuable resource (Smol et al., 2020). This theme in the literature is directed towards waste management, particularly recycling (Goel et al., 2021; Vardopoulos et al., 2021) and biomass production (Loizia et al., 2021). The shift towards a more sustainable society is intertwined with the economy's production, use and disposal of plastics. Emissions generated by plastic production, plastic waste, littering and leakage in nature, insufficient recycling are just some of the challenges of a circular economy (di Bartolo et al., 2021). The literature presents approaches to develop, implement, monitor and improve strategies in the framework of waste management at the local or central level (Zorpas, 2020). Publications also address the issue of carbon footprint (Attia et al., 2021) and water footprint (Trubetskaya et al., 2021).

DOI: 10.34659/eis.2022.81.2.455

An emerging topic that is directly related to the circular economy is Industry 4.0. The shift of European production systems towards carbon neutrality requires a wider range of "green" industrial policies that should collectively address environmental sustainability, structural change and equitable economic performance in Europe (Pianta & Lucchese, 2020). In the literature related to EGD, the focus is on the industrial application of artificial intelligence and technological solutions focused on green manufacturing, including energy efficiency (Walther & Weigold, 2021).

The current European building stock is ageing and requires significant renovation efforts to improve its energy performance and meet climate and environmental challenges (Gangolells et al., 2020). In the European Union, buildings are responsible for 40% of energy consumption and 36% of greenhouse gas (GHG) emissions resulting from their construction, use, renovation and demolition (Bonoli et al., 2021). As a key EGD action, more building renovations are required to ensure that the EU's energy-saving and decarbonisation targets are met (Pohoryles et al., 2020). Building-related topics in relation to EGD are an emerging area. Research focuses on energy-efficient construction (Buckley et al., 2021; Figueiredo et al., 2020; Ibañez Iralde et al., 2021; Napoli et al., 2020) and the use of virtual technologies. An example of the use of virtual technologies is the application of the digital twin to assess the sustainability of an educational building. This approach allows real-time control of a wide range of sustainability criteria from the user's point of view. The building adapts to the students' daily activities through continuous interaction with sensory resources monitoring indoor comfort and air quality conditions, as well as energy needs linked to renewable energy production. The digital twin approach can be used to support sustainability-related decision-making throughout the building life cycle (Tagliabue et al., 2021).

Mobility is also a research topic inextricably linked to the European Green Deal. The transport sector, particularly road transport, is one of the most significant segments of national economies in the EU, dependent on fossil fuels (Savickis et al., 2020). It is also a major cause of global climate change. While overall EU carbon emissions are decreasing, transport-related emissions are higher than in 1990 (Haas & Sander, 2020). Road transport is responsible for about 73% of total transport GHG emissions, as more than 308.3 million road vehicles in Europe rely on conventional fuels, such as diesel and petrol, for more than 90% of their emissions. In contrast, there are low-carbon alternative fuels that can reduce GHG emissions from road transport. The literature indicates that biofuels will make a significant contribution to meeting EU targets, with a gradual shift to advanced raw materials (Chiaramonti et al., 2021; Chiaramonti & Maniatis, 2020; Panoutsou et al., 2021).

Digital technologies that transform traditional mobility concepts are also used to reduce transport emissions. Innovative mobility services are emerg-

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ing, including online platforms for car-sharing, bicycles and cars, freight transport (Tsakalidis et al., 2020). The electrification of transport and the move towards public acceptance of electric cars is also playing a key role in research (Omahne et al., 2021). In the European Union, approximately 80% of the urban population is exposed to air pollution above levels recommended by the World Health Organization (WHO). Air pollution is considered a major threat to public health, causing a 7% increase in overall mortality for every 10 $\mu g/m^3$ increase in annual average PM2.5 (Iriti et al., 2020). Therefore, research and innovation on pollution are extremely important. Related to the EGD topic are many publications on air pollution issues and greenhouse gas emissions (Ćetković et al., 2021; Dolge & Blumberga, 2021; Paprocki, 2021; Prussi et al., 2021; Zlaugotne et al., 2020), as well as on chemical safety and related risk assessment (Dulio et al., 2020).

Sustainable food systems play an essential role in policy and research agendas (Vanham & Leip, 2020). Research topics on food within the EGD are primarily focused on issues of healthy food production on agricultural land. By 2030, at least 25% of agricultural land in the EU should be farmed organically (Purnhagen et al., 2021). Sustainable agriculture is a global challenge, and, therefore, research and innovation are needed to ensure sustainable food production on agricultural land, biodiversity conservation and climate change mitigation. The literature also raises issues related to the pursuit of pesticide-free crop greening. The European Union and global sustainability policies emphasise the need to replace pesticides with safe, efficient and cost-effective alternatives to ensure sustainable food production. However, research and development on alternatives to pesticides is delayed and needs to be expanded (Taning et al., 2021). Research is also addressing the impact of the COVID-19 pandemic on the EU agri-food sector (Barcaccia et al., 2020; Rowan & Galanakis, 2020). It is important to stress that research and innovation are key factors in accelerating the transition towards sustainable, healthy and inclusive food systems, from primary production to consumption (Riccaboni et al., 2021).

Topics related to biodiversity conservation and climate change in the EGD literature are primarily considered in the context of the strategic actions and challenges facing the European Union in this regard (Hermoso et al., 2022; Montanarella & Panagos, 2021; Dupont et al., 2020) as well as individual countries, such as Greece (Kougioumoutzis et al., 2021). The challenge facing the European Union is to transform an ambitious climate agenda into effective legal and economic instruments. The EGD is an outstanding opportunity, but to be implemented successfully, it needs to be firmly grounded in the constitutional framework of the EU legal order, in particular the concepts of solidarity, sustainable development and a high level of environmental protection (Sikora, 2020).

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Conclusions

The study mostly focused on the identification of current and future directions for research relating to the issues of the European Green Deal. The European Green Deal strategy, adopted by the European Commission in 2019, requires simultaneous action in many areas, including research and application of the proposed solutions. Achieving the ambitious goal of climate neutrality in 2050 will depend on the level of achievement of sub-targets relating to the 8 EGD areas: energy, circular economy, industry, building, mobility, food, biodiversity and pollution.

Within the area of energy, research to date has focused in particular on the study of green energy sources and renewable energy sources. An important area of research is energy efficiency and security of energy production from renewable sources. All categories of renewable energy: biomass, biogas, solar energy and wind energy are of interest to researchers.

The circular economy has a significant place in EGD-related research. Research relating to the circular economy addresses waste management, in particular plastic waste. The challenge for a circular economy is to build effective recycling systems and avoid littering and leakage in nature. The literature points to the need to develop strategies at local, regional and central level focused on waste management.

The concept of Industry 4.0 as an object of scientific research now seems to be crucial also in relation to the circular economy. Many researchers point to the need for a green industrial policy, based on artificial intelligence and environmental technological solutions.

An emerging area of research is the area of construction mainly in the context of improving the energy efficiency of buildings responsible for 40% of energy consumption. Research in this area is focused on: on energy-efficient construction and use of virtual technologies which allow real-time control of a wide range of sustainability criteria from the user's point of view. Digital twin are indicated in the research as methods and decision-making tools enabling the application of digital replica showing potential and actual physical assets use (not only for educational purposes).

The transport sector, particularly road transport, is another research area relating to the EGD strategy. Research in this area focuses in particular on low-carbon alternative fuels and advanced raw materials. A challenge from both a scientific and a practical point of view are the research involved in the electrification of transport and innovative mobility services such as online platforms for car-sharing, bicycles and cars, freight transport.

Due to the lack of significant results in improving the state of air pollution, mainly in urban areas, research and innovation on pollution are

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extremely important. The main research themes concern greenhouse gas emissions, chemical safety and risk assessment.

Sustainable food systems play an essential role in policy and research agendas mainly in the context of problems generated by pesticides. Research in the area related to sustainable food focuses mainly on the search for pesticide-free crop greening, development on alternatives to pesticides and accelerating the transition towards sustainable, healthy and inclusive food systems as well.

The conducted research allowed drawing scientific and practical conclusions and identifying horizontal research directions, including digitalisation and innovations. The two identified study areas overlap with other areas identified in the EGD. From the practical point of view, the conducted analyses and studies related to EGD (including the one presented in this article) provide insights into important problems that require wider consideration and development of solutions in this area. The currently available research results can help inform decisions related to legislation and the allocation of funding in future research and innovation framework programmes.

The research results obtained have also identified key and emerging areas where further research and in-depth analysis should be carried out. These are necessary if the objectives set out in the European Green Deal are to be achieved. This will only be possible by combining knowledge from research with its practical application.

The identification of priority research directions relating to the EGD strategy can provide a basis for scholars, governments and businesses to set their own development strategies and directions for action in the long term. The indicated research directions have a huge application potential.

The research findings indicate directions for future research. After the period of planning the implementation of the EGD strategy and the implementation of specific actions, it will be necessary to measure the effectiveness and efficiency of the initiatives undertaken, which will undoubtedly be a new research direction. Research on the development of new forms and methods of social participation and involvement of various stakeholder groups for common and important goals will continue to be relevant.

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The contribution of the authors

Conceptualisation, D.S. and J.E.; literature review, D.S. and J.E.; methodology, D.S.; formal analysis, D.S.; data collection, D.S.; writing, D.S. and J.E.; conclusions and discussion D.S. and J.E. Both authors have read and agreed to the published version of the manuscript.

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ENVIRONMENTAL POLICY AND MANAGEMENT

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EXEMPLIFYING THE ZERO-WASTE CONCEPT IN SMART CITIES

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ABSTRACT: Due to the environmental imbalance on our planet, the concept of zero waste is gaining importance day by day. It is essential in the aspect of production and consumption cycle management and responsible waste management in urban space. The aim of this article is to exemplify methods of reducing waste in smart cities according to the author's Waste Management for Generation, Environment, and Gains (WM2GEG) scheme. A structured interview method was used to collect data, and the research sample was selected using the Smart City Index 2020. The study identified environmentally, socially friendly, and economically beneficial methods of rational waste management, such as composting organic waste, creating underground waste containers, and incinerating waste with energy recovery. Specific ways to reduce waste are also presented, such as banning disposable packaging and obtaining energy from renewable sources.

KEYWORDS: zero waste, waste management, smart cities

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Introduction

The amount of rubbish generated by people increased massively with the rapid increase in consumption in the 2nd half of the 20th century. Companies all over the world, in order to increase their sales, started to produce more and more consumer-friendly, lightweight products, often disposable ones. Too much packaging serving an aesthetic function only began to be used. The societies of all countries quickly became accustomed to this convenience, and the consumption of perishable products and their packaging increased significantly (Szaky, 2013, p. 8). As R. Murray points out (2002, p. 1), waste is the dark side of the economy. Rubbish is not only generated by the final consumer by throwing away unnecessary packaging or used products. They are also created at all stages of production, regardless of the industry of operation.

For some time, rubbish was treated only as a threat to human health, to be removed quickly and effectively from urban space. Most often, waste was sent to a variety of landfills. As environmental awareness grew, people began to think more and more about the sustainable use of limited natural resources (Nizar, 2018, p. 2). Terms such as zero waste, sustainability, or smart cities increasingly appeared in the scientific literature, referring, among other things, to the need to take care of a kind of symbiosis between economic and social development and the natural environment.

The paper aimed to exemplify waste reduction methods in smart cities in line with the author's WM2GEG scheme. The presented study is an extension of previous scientific research related to the fight against ever-growing rubbish heaps. It may also be of great cognitive value to municipal authorities and organisations supporting the waste management process in urban centres. Learning about the practices and methods used by other cities around the world may inspire the creation of new organisational and technological solutions for rational waste management. The information collected in this paper may also be relevant to city dwellers, especially those with pro-ecological interests.

An overview of the literature

The smart city concept emerged in literary theory in the late 20th century. R. Hall et al. (2000), among others, wrote about smart cities, claiming that the smart city is the urban space of the future, which is, above all, environmentally safe and efficient. All systems and processes within it are coordinated electronically. The key for smart cities is the enrichment of urban

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systems with an array of sensors connected via computer networks and configured with databases. An infrastructure coordinated in this way greatly facilitates the management and decision-making processes (Hall et al., 2000, p. 1). Among others, Singapore was cited as an example of a smart city of the time (Mahizhnan, 1999).

Over the years, researchers have put forward different explications of smart cities. According to Forrester Research, a smart city is a place where information and ICT are used to improve the efficiency of public safety, administration, communication, and education (Bélissent 2010, p. 3). The anthropocentric aspect is also highlighted, i.e. the maximum comfort of life for residents (Shapiro, 2006) with the minimum use of resources simultaneously. In turn, M. Zuccalà and E. Verga (2016, p. 826) consider the smart city as a sustainable urban centre, characterised by the support of ICT in all areas of life and by the integrated management of building resources, energy systems, mobility, and ecological systems.

Administration, transport, construction, heating and cooling systems, health care, education, waste management, and spaces for leisure and recreation are usually cited as the main infrastructure elements in smart cities (Bélissent, 2010, p. 8). The key to defining a city as smart is to achieve a high level of efficiency in all these elements of the urban infrastructure and thus increase the well-being of the inhabitants. In addition to creating appropriate urban infrastructure, preferably one that is fully self-sufficient (e.g. by using energy generated from renewable sources), smart cities are characterised by intelligent management. Authorities should pay attention to all infrastructure sectors at every stage of city management. When planning the budget and making executive decisions, the representatives of the administration must not overlook any of the sectors that are important for the life of the city (Jelonek, et al., 2020). A very important element in this aspect is the circulation of information and the possibility to quickly finalise official matters, e.g. thanks to digitalisation (Bokolo, 2021), the creation of special electronic platforms, and the use of robotic process automation (RPA) (Sobczak & Ziora, 2021).

B. Cohen (2015) distinguishes three generations of smart cities. The smart city 1.0 generation is an initial stage of development characterised by the technological modernisation of urban space. The most important thing here is the implementation of modern information technologies that enable the proper shaping of the city. Technology companies are mainly active at this stage. Smart city 2.0 generation – a phase of city development in which the authorities play the leading role. At this stage, they are initiators of the implementation of new technologies, the use of which should positively affect the improvement of citizens' lives (Vishnivetskaya & Alexandrova, 2019).

The next stage is smart city 3.0. An important aspect here is the strong involvement of residents in the development of their city. This involvement is manifested, inter alia, through the participation of citizens in making decisions by representatives of public administration and acting in accordance with the policy adopted by the authorities (Bednarska-Olejniczak, Olejniczak, 2016, p. 760). Internet platforms enabling citizens to participate in the creation of a smart city 3.0, such as Taipei Smart City Project Management Office (Smart Taipei), are becoming more and more common.

To create intelligent urban infrastructure systems, it is necessary to ensure the integration of infrastructure systems (Stepniak, et al*.,* 2021) and access to sustainable energy resources (Zuccalà & Verga, 2016, pp. 827-830). Energy is indispensable for all economic activities and, thus, for developing individual territorial units (Hajduk & Jelonek, 2021, p. 2).

The activities aimed at the implementation of the idea of sustainable urban development (Khan et al., 2020), implementation of the green economy concept (Addanki & Venkataraman, 2017), circular economy concept (Sobol, 2019), waste management (Esmaeilian et al., 2018), or reducing the carbon footprint (Turek et al., 2021) are of particular importance in the smart cities development. Seeing the problem of huge amounts of rubbish created every year in urban spaces, scientists have created a new concept that can be a recipe for the growing mountains of rubbish – Zero Waste. As emphasised by Ch. Cole et al. (2014, p. 65), there are many different definitions of Zero Waste (ZW), depending on the primary purpose of the activities in question. Some of these explications refer to reducing landfill waste, while others to avoiding waste in marine waters. For the purpose of this article, it is assumed that ZW is the management of products and processes that allows for the systematic avoidance of waste or its treatment to recover all resources (Zaman & Lehmann, 2011, p. 177). ZW implies the continuous elimination of waste at each stage of a product – from production, through distribution, to consumption and disposal of product residues (packaging, leftovers). Actions in line with ZW support the transition of countries or regions to a closed-loop economy (Kerdlap et al., 2019).

One of the concepts of rational waste management is the Zero Waste Hierarchy of Highest and Best Use. The model consists of seven levels. The first level, Rethink/Redesign, refers to the thoughtful design and purchase of products. The next level is Reduce, which encourages producers and consumers to carefully plan the consumption of the goods and services they purchase. This applies especially to perishable products such as perishable food. Producers and consumers should reduce waste, especially non–recyclable or non-reusable waste. The need for such restrictions has been recognised by scientists and some politicians for several decades – an example of a country that has successfully reduced the amount of non-reusable or recyclable rub-

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bish in England. Between 2000 and 2010, it decreased the amount of such waste produced by households by as much as 29%, from 22.2 million tonnes to 15.8 million tonnes (Phillips et al., 2011, p. 336).

The third level is Reuse, which, according to ZWIA (2018), involves maximising the reuse of materials and products by keeping them in good condition, repairing, refurbishing, or – alternatively – putting them to alternative uses. The necessity of the reuse principle is pointed out, among others, by Kerdlap et al. (2019, p. 3). In smart cities, it should be used both by businesses (e.g. restaurateurs ordering fruit and vegetables in reusable boxes) and by individuals (e.g. by donating unnecessary equipment, clothes and textbooks to other users).

The fourth level – Recycling/compost, refers to the creation of systems, enabling materials to be conserved and kept in their original product loop (ZWIA, 2018). This refers to recycling materials, i.e. processing them to make new products (Cole et al., 2014, p. 66). Recycled materials can be glass, plastic, paper, or metal. In doing so, it is essential that the plastics being recycled have the right chemical composition and do not contain components harmful to the environment. The starting point for effective recycling is the proper selection of waste. Organic waste, in turn, should be composted, which after a suitable period of time can be used as a high-quality natural fertiliser for gardening.

On the other hand, material recovery involves trying to extract valuable materials from mixed waste by screening them in specialised sorting facilities. Where conditions allow, it is also acceptable to recover energy from residual waste sorting but only using systems that operate at biological temperature and pressure.

The next level is Residuals management. This means, first and foremost, examining the residual waste in order to improve the management system and minimise the impact of fermented materials by stabilising them biologically. It is essential to answer the following questions: What waste remains and why? Which materials should be removed from circulation? How should residual waste be managed after all the previous steps have been taken in accordance with the ZW Hierarchy?

The last level – Unacceptable – can be interpreted as unacceptable actions. It refers to the non-acceptance of policies and systems that contradict the previous levels. Destruction of recyclable materials and energy disposal systems that depend on continuous waste production should not be encouraged. It is also important not to allow toxic substances into consumer goods.

W. Zulfikar et al. (2021, p. 17) point to 5 main principles of the ZW concept, defined as the 5Rs. These principles are refuse, reduce, reuse, recycle, and rot. The refuse principle calls for consciously making choices about the

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goods and services purchased and forgoing those harmful to the environment. The reduce principle reduces unnecessary use of resources and products, e.g. through thoughtful purchasing. While both principles refer to reducing waste by not purchasing a particular product or service, the last three (reuse, recycle, and rot) refer to products or services that the consumer/producer has purchased.

Various approaches to the R-principles of ZW can be found in the literature. For example, F. Compagno (2020) shows reduce, reuse, and recycle as the most essential principles of ZW, while B. Johnson (2013), and R. Müller and S. Schönbauer (2020) mention refuse, reduce, reuse, and recycle.

However, irrespective of the number and type of R-principles mentioned by individual researchers, the main aim of ZW activities is to reduce the impact of man-made waste on the environment as much as possible (Phillips et al., 2011, p. 336). All principles stem from a common-sense approach to the issue of rational consumption of goods and services. It is worth introducing them in all regions of the world, but above all, they should be the hallmark of cities defined as smart cities.

As research shows, rational waste management is important for at least several reasons. First of all, reducing waste is good for society. Less rubbish means reduced concentrations of pathogens (Ross, 2011, p. 778). At the same time, reducing waste minimises the production of greenhouse gases, saves energy, and conserves renewable environmental resources (Heimlich et. al., 2007; Chen et al., 2011).

Research methods

The main rationale for this study was to try to answer the question: why apply the zero waste concept in the urban waste management process? This question was considered primarily in relation to further questions and objectives related to the research process. However, it inspired the creation of the author's scheme for the purpose of applying the zero waste concept, which was referred to as WM2GEG (the name is an acronym for Waste Management for Generation, Environment, and Gains). It is presented in Figure 1.

According to WM2GEG, rational waste management has three main types of beneficiaries. The beneficiaries of rational waste management are the people ('for a generation'), both those who have started these activities and future generations. In view of the rapidly growing population on Earth and increasing consumption, it is crucial to stop the changes resulting from the increasing amounts of rubbish produced by society.

DOI: 10.34659/eis.2022.81.2.462

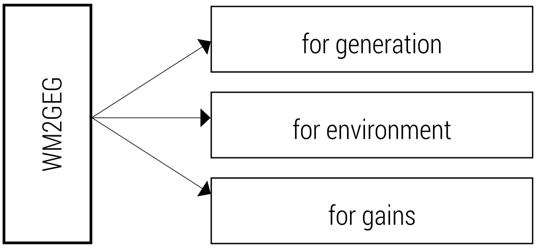

Figure 1. WM2GEG waste management target scheme
Source: authors' work.

Another beneficiary is the environment ('for environment'), which survives provided that factors harmful to the ecosystem are reduced, e.g. greenhouse gases, toxic substances used in the production of chemicals, etc., and non-renewable natural resources are conserved. Some of the waste management activities may produce visible results within a few years or so.

A third aspect included in the WM2GEG scheme is economic consideration, referred to as ('for gains'). Skilful waste management in a given territorial unit may increase savings of consumers and producers, e.g. by buying energy-efficient equipment and replacing more expensive in the long run disposable packaging by ecological reusable packaging, and of entire territorial units, e.g. savings resulting from recycling part of the waste or recovering energy from waste as a result of its processing.

Given the above, the aim of the study was set to identify concrete proposals for waste reduction in smart cities in line with the author's WM2GEG scheme. Concerning the above objective, two research hypotheses were formulated:

H1: Waste management focused on waste reduction benefits all components of the WM2GEG scheme.

H2: The use of modern methods of waste management significantly increases the aesthetics of the city.

A structured interview with representatives of selected cities identified as smart was used as the primary research method. Due to geographical distance and different time zones, the main form of contact was via e-mail or the official website of the territorial unit. The interview questionnaire in the electronic version was sent to mayors of the cities ranked in the top 60 of the Smart City Index 2020.

The survey was conducted between June 15, 2021, and July 31, 2021. The survey consisted of two stages, briefly referred to as mailing (stage 1) and data processing (stage 2). The mailing stage consisted of the following activities: selection of intelligent cities, preparation of a set of questions, finding

DOI: 10.34659/eis.2022.81.2.462

an optimal form of contact to representatives of individual cities, and mailing the questions. The second stage consisted of collecting the answers, carefully reading their content, sending thank-you notes, and processing the data received.

It was decided to contact 60 cities ranked between 1 and 60 in the global Smart City Index 2020 (2021). These cities are Singapore, Helsinki, Zurich, Auckland, Oslo, Copenhagen, Geneva, Taipei City, Amsterdam, New York, Munich, Washington, Düsseldorf, Brisbane, London, Stockholm, Manchester, Sydney, Vancouver, Melbourne, Montreal, Hamburg, Newcastle, Bilbao, Vienna, Los Angeles, San Francisco, The Hague, Rotterdam, Toronto, Gothenburg, Hongkong, Hannover, Dublin, Denver, Boston, Seattle, Berlin, Phoenix, Birmingham, Chicago, Abu Dhabi, Dubai, Prague, Madrid, Busan, Seoul, Zaragoza, Barcelona, Tel Aviv, Lyon, Philadelphia, Riyadh, Kuala Lumpur, Warsaw, Moscow, Ankara, Krakow, Tallinn, and Brussels. Communication took place in three languages: English (52 cities), Polish (2 cities), and German (6 cities). Questions were addressed to the mayors of each city. The official websites were used to find information about the current president/mayor. Then, using the search engine www.google.pl and the websites www.linkedin.com and www.facebook.com, the e-mail addresses of 49 mayors were found. In the case of the remaining 11 smart cities, no direct e-mails to the city mayors were found, so questions were sent via the contact form available on the official city website.

The following questions about the waste management process were sent to the city authorities:

1. What is the waste collection process (households)?
2. How often is garbage collected from residents?
3. Do the residents segregate rubbish?
4. Is rubbish recycled (if so what types of rubbish)?
5. What happens to the mixed waste?
6. How do you fight plastic? Are there any regulations in line with the zero waste concept in the city of ..., e.g. restrictions on the use of plastic packaging?
7. Have you introduced any special programs in accordance with the zero-waste concept in your city, reducing the amount of energy and waste (e.g. subsidies, programs informing residents about the need to select rubbish, etc.)?

The main focus of the survey was related to waste management. However, questions were also asked about electricity consumption (question 1 and partly question 4). This was due to the strong link between the process of obtaining electrical energy and the generation of waste. This is especially true for energy extraction from fossil resources. The questions about energy were, therefore, a kind of motivator to develop the topic of waste creation in

DOI: 10.34659/eis.2022.81.2.462

the urban space. In the case of the questions on rubbish, particular attention was paid to plastic, as this is what has contributed to such a drastically increasing amount of waste over recent years. In 2016, around 60 million tonnes of plastic were produced in European countries and as much as 335 million tonnes worldwide (Drzyzga & Prieto, 2019, p. 66). A significant proportion of these plastics become waste in a very short time.

The research was extended with a face-to-face interview with the owner of the odWAŻnik shop (http://odwaznik.com.pl/index.php/o-nas/) based in Warsaw, which aims to promote the concept of ZW. During the interview, she was asked about specific practices in line with ZW that can be used every day by residents of all territorial units, regardless of geolocation.

Results of the research

During the survey period, responses were received from 12 smart cities: Oslo, Copenhagen, Geneva, Taipei, Amsterdam, Düsseldorf, Brisbane, Bilbao, Vienna, the Hague, Hong Kong, and Warsaw. Responses were collected in MS Word. Due to the volume of material collected, it was necessary to select the most crucial information related to waste management. This information is presented in Table 2.

Table 2. Waste management in Smart Cities – examples

City/number in SCI2020 ranking	1. Is waste segregated and recycled? 2. What happens to mixed waste? 3. Selected solutions for reducing the amount of waste, energy consumption and waste management?
Oslo/5 (Norway)	1. Yes. 2. Mixed waste is incinerated with energy recovery. 3. a) Division of waste in optical sorters. b) Emphasis on the composting of organic waste. c) Action Plan to Reduce Plastic Pollution: by 2022, all use of unnecessary disposable plastic articles in Oslo will be phased out. d) Regular cleaning of beaches, fjords and waterways etc. e) Collaborate with research institutes to identify sources of microplastics dispersion on city waterways and the Oslo Fjord.
Copenhagen/6 (Denmark)	1. Yes. 2. Mixed waste is incinerated (the municipality of Copenhagen is the owner of all landfills and co-owner of the incineration plant). 3. a) Promote the setting up of photovoltaic installations and heat pumps. b) Ban on the use of disposable cups during festivals (from 2020 they can only be reusable). c) Exclusion of plastic bottles – tap water as still. d) Supporting the implementation at national level of the plastic packaging design manual. e) Tests of introducing self-propelled vehicles to the streets of the city.

DOI: 10.34659/eis.2022.81.2.462

Geneva/7 (Switzerland)	1. Yes. 2. Mixed waste is incinerated. 3. a) The heat from incineration is used to generate electricity and is also used in a „remote heating system" that supplies hot water and heat to multi-apartment buildings in the city. b) It is forbidden to use disposable plastic dishes in public administration units
Taipei/8 (Taiwan)	1. Yes (kitchen waste is divided into 2 types: pig feed and other kitchen waste) 2. No information. 3. a) The ban on the use of disposable tableware by public institutions, private schools, department stores, hypermarkets, shops, restaurants and fast food chains. b) Reduction in consumption of PET, PS, PVC, PE, PP containers and plastic pallets and packaging boxes that are coated with vegetable fibers. c) Ban on the use of plastic carrier bags in 14 industries (including the public sector and shops). d) Promoting the Age-Friendly City concept in response to the rapidly progressing aging of the population. e) Promoting the collection of rainwater. f) Building alliances of smart cities „GO SMART" (international scale). g) „Love Taipei App" to check the time of garbage collection, the address of the collection points and the telephone number of nearby cleaning teams in order to arrange the direct collection of more rubbish. h) Promoting the installation of photovoltaic installations by public administration and households.
Amsterdam/9 (Netherlands)	1. Yes. 2. They are incinerated with energy recovery. 3. a) There are no disposable products at events (if they are: then with a deposit). b) Affiliation to the global nature fund of the Plastic Smart program.
Düsseldorf/13 (Germany)	1. Yes. 2. No information 3. a) Construction waste is used in processing plants. b) Sorting of waste (e.g. old clothes). c) Promoting the establishment of photovoltaic installations. d) Convenient mobile collections (e.g. of medicines). e) Emphasis on the composting of organic waste.
Brisbane/14 (Australia)	1. Yes (only 7% of the waste from the recycling bin is not suitable for recovery, it is sorted in sorting plants and sent to landfills). 2. Collected in landfills. 3. a) Lots of bins for waste (3 bins of 240 l). Garbage for recovery collected in containers (limitation of the number of bags). b) Strong emphasis on the composting of organic waste. c) Use landfill gas from landfills to produce energy. d) Act restricting plastics and other plastics: e.g. ban on the use of disposable tableware. e) Promoting the installation of photovoltaic installations. f) Constant improvement of education.
Bilbao/24 (Spain)	1. Yes. 2. The waste goes to the treatment plant. They are sorted (plastic, etc.) and the rest goes to an energy recovery plant. Then some of the waste is used in the cement industry. The remaining waste goes to a controlled landfill. 3. a) Cooperation with the non-profit organization Ecoembes (specializing in recycling) in the field of raising the awareness of residents about the use of plastic.

Vienna/25 (Austria)	1. Yes. 2. They are incinerated with heat recovery. 3. a) The waste residues (ash and slag) are freed from ferrous and non-ferrous metals and solidified, and then disposed of in an environmentally friendly manner in a landfill (approx. 30% by weight and approx. 10% by volume of the original material). b) Hazardous waste can be delivered at mobile collection points. c) Strong emphasis on composting. d) Possibility to rent reusable tableware. e) It is forbidden to use disposable dishes in public administration points and in the case of events exceeding 1 thousand. people. f) Out of oil and gas renovation campaign (aim: to facilitate the transition from fossil fuels to a sustainable heating system). g) Constant improvement of citizens' education.
Hague/28 (Netherlands)	1. Yes. 2. They are incinerated after separating the plastics and the cans. The heat generated is used to produce energy while metals are pulled from the ashes. 3. a) Creating a mini-station of underground waste containers (at least 1 / district) equipped with filling sensors (this limits the departures of garbage trucks). b) Possibility to arrange an online collection of bulky waste. c) Increasing the responsibility of companies producing plastic (they cover part of the costs related to the collection and processing of plastics).
Hong Kong/32 (Hong Kong)	1. Yes. 2. Mixed garbage is deposited in landfills. 3. Increasing the responsibility of companies producing plastic (they cover part of the costs related to the collection and processing of plastics).
Warsaw/55 (Poland)	1. Yes. 2. 80% of waste goes to MBP (mechanical – biological installations treatment of municipal waste); the remainder is burned. 3. a) Cyclical outdoor educational campaigns, such as the Zero Waste Fair, Eco-arranged. b) International Project "Capital Cities – capitals cooperating in the field of common challenges in hazardous waste management – Yerevan, Warsaw, Tirana. c) Promoting the setting up of photovoltaic installations and heat pumps through subsidies.

Source: authors' work.

As shown in Table 2, in all cities that actively participated in the survey (i.e. answered the questions sent electronically), waste is segregated and recycled. Initial segregation takes place directly in households. The following fractions are most often segregated: plastics, metals, glass, paper and cardboard, and bio-waste. Rubbish is collected by a special fleet of rubbish trucks directly from the residents' homes or designated points in the vicinity of their homes. Smart city citizens also have the option of bringing some of their waste (e.g. medicines, old clothes) to special collection points or using mobile collections. The remaining rubbish is collected from residents as mixed waste. In Oslo, Amsterdam, Düsseldorf, Brisbane, Bilbao, and Warsaw, waste undergoes additional checks at specialised sorting facilities. This sorting can be carried out both for garbage that has already been sorted (e.g. in Bris-

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bane) and in order to extract from mixed waste those fractions that can be recycled and that were mistakenly put in the mixed waste bin (Bilbao). As the Brisbane representative admits, from the mixed waste bin, only 7% is not recyclable. In Warsaw, mixed waste is sorted during mechanical-biological processing (MBP). This consists of crushing, screening, sorting, separation of ferrous and non-ferrous metals, etc., in order to select those fractions that are suitable for recovery.

Mixed waste after final sorting is, in most cases, incinerated with energy recovery (Oslo, Copenhagen, Geneva, Amsterdam, Vienna, the Hague, 20% of Warsaw's mixed waste is also incinerated) or sent to controlled landfills (Brisbane, Bilbao, Hong Kong). The City of Brisbane uses landfill gas for energy production – according to interview information, landfill gas can produce 46,000-megawatt-hours of electricity per year.

Table 2 also shows selected methods for reducing total rubbish in the cities participating in the study. Examples of such methods include:

- a ban on disposable plastic utensils (Oslo, Copenhagen, Geneva, Taipei, Brisbane, Vienna);
- introduction of a deposit for some plastic packaging (Amsterdam);
- possibility to rent reusable crockery during larger events (Vienna);
- plastic bag ban (Taipei);
- replacing bottled water with tap water (Copenhagen);
- promoting the installation of photovoltaic panels and heat pumps (Copenhagen, Taipei, Brisbane, Warsaw);
- composting of organic waste (Oslo, Düsseldorf, Brisbane, Vienna);
- cooperation with research institutions and other cities/countries to develop new solutions for waste reduction (Oslo, Taipei, Amsterdam, Bilbao, Warsaw)
- systematic raising of environmental awareness of the inhabitants (Vienna, Warsaw);
- introducing solutions which make it easier for residents to hand over their waste, e.g. mobile collections, apps for making waste collection appointments (Taipei, the Hague);
- making plastic companies more responsible (the Hague, Hong Kong);
- recycling of waste (all cities);
- use of waste for energy production through incineration or use of landfill gas (Oslo, Geneva, Amsterdam, Vienna, the Hague, Brisbane, Bilbao, Hong Kong).

Representatives of individual cities confirmed that creating plans to reduce the amount of waste in urban space and enforcing the positive behaviours and practices presented in the plan is a solution beneficial both for the ecosystem, as well as for the inhabitants and the city budget. Thus, after collecting and processing the data, the H1 verification was performed – waste

DOI: 10.34659/eis.2022.81.2.462

management focused on waste reduction benefits all components of the WM2GEG scheme. This focused on the waste management methods listed above and the resulting benefits for all components of the WM2GEG scheme – for generations, for nature, and for profits.

The methods listed by the representatives of the individual smart cities aim to improve the environment by reducing waste, reusing waste, recycling suitable fractions, or using waste to produce energy. All technologies based on renewable energy sources are important here – photovoltaics, wind farms, heat pumps, or the creation of buildings with low energy consumption. Composting organic waste, which can further be used to feed crops in the form of natural compost, is also extremely beneficial for the environment.

The measures outlined above are also beneficial from an economic point of view. For example, the use of solar energy – apart from the initial installation cost – does not require an additional financial outlay from the residents. Additional savings can also be made by changing small daily habits – pouring tap water into a reusable bottle is much cheaper than buying water in a plastic bottle every day. In the long term, it is also cheaper to use reusable crockery at city events than to buy plastic cutlery and crockery every time. The municipality can also make significant savings if it has the right infrastructure to produce energy from waste incineration and use it to heat buildings in the city.

At the same time, in part of the smart cities section, the attention was drawn to the need to adjust the infrastructure related to waste management to the aesthetics of urban space and the convenience of its inhabitants. Examples of such solutions include mini stations of underground waste bins, sensors informing when the bins are full, equipping waste incinerators with special filters, specialised landfill sites as clusters of pathogens, or special applications for contacting residents with waste collection services.

The above examples fully support hypothesis H1 – waste management focused on waste reduction has a beneficial effect on all components of the WM2GEG scheme.

It then proceeded to verify H2 – The use of modern methods of waste management significantly increases the aesthetics of the city. A detailed waste management plan is in place in the cities covered by the study. Some of these types of plans are available online for citizens in the form of prospectuses or extensive brochures (e.g. Circular Copenhagen. Resource and Waste Management Plan 2024 in Copenhagen & Enveileder for plassering og valg av renovasjonslosninger in Oslo), and some in the form of guidelines and regulations which can be found after prior contact with a designated unit of the city or commune office. Representatives of the cities described unanimously admit that the creation of a waste management plan based on modern methods and technologies has significantly increased the level of the city's aesthetics.

DOI: 10.34659/eis.2022.81.2.462

In this aspect, four main factors contributing to the enhancement of the city's aesthetics were identified:
1) introducing solutions resulting in the improvement of air quality in a smart city;
2) ensuring the appropriate number and form of bins and garbage containers in the city;
3) appropriate organisation of waste collection by designated services;
4) resignation or reduction of the number of landfills.

An example of activities related to the improvement of air quality is the use of renewable energy sources by companies and private households. Thanks to the use of solar or wind energy, and also thanks to the promotion of heat pump installations, waste resulting from the combustion of, e.g. coal, is significantly reduced. Electric cars are becoming more and more popular in the surveyed smart cities, and Copenhagen intends to conduct tests related to the introduction of self-propelled vehicles to the city streets. These innovations significantly reduce airborne waste that is not visible to the naked eye, such as CO_2. They also reduce the amount of dust and dirt that reduces the urban aesthetics.

Another factor concerns the proper number and form of rubbish containers. A well-thought-out arrangement of litter bins significantly reduces the amount of paper, plastic bottles or cans on the streets or in dedicated green areas. The mere adjustment of the number of baskets to the city's needs improves the aesthetics of the surroundings and increases the quality of life of the residents. The aesthetics is additionally enhanced by the use of modern technologies, such as underground garbage cans or sensors that indicate that the containers are full.

An important role is also played by the appropriate organisation of waste collection from private homes or public institutions. Setting specific and tailored to the needs of residents' waste collection hours means that unsightly bins or garbage bags are displayed in front of the property for a short time. Noteworthy are also applications, thanks to which residents can order a team responsible for the collection of, e.g. bulky waste, used, e.g. in Taipei.

An important factor is the replacement of traditional landfills with modern incinerators, existing in some of the smart cities studied: Oslo, Copenhagen, Geneva, Amsterdam, Vienna and The Hague. The combustion process is accompanied not only by the reduction of the amount of waste in the urban space but also by the recovery of energy used for the needs of the city and its residents. And the lack of traditional landfills significantly increases the aesthetics of the city and the comfort of the life of its inhabitants.

The practices and solutions described in the above paragraphs confirm H2. The use of modern methods of waste management significantly increases the aesthetics of the city. This benefits both the environment, society, and the

DOI: 10.34659/eis.2022.81.2.462

budget of the territorial unit. The presented solutions are also largely 100% in line with the ZW hierarchy. The main differences are visible in the final stages of management – while most cities prefer incineration or landfilling of mixed waste, cleared of recyclable fractions, the current ZW hierarchy focuses mainly on excluding non-recyclable waste.

Most of the activities listed above can only be implemented by municipal authorities and special waste management support organisations. However, a number of practices can be applied by people interested in the concept of ZW. An example of such solutions is given by the owner of the Warsaw shop odWAŻnik, which promotes ZW activities. Actions of this type include using a reusable bag or sack for everyday shopping, buying vegetables and fruit in bulk, choosing cosmetics in glass, carrying water in a reusable bottle instead of buying bottled water, buying accessories made of ecological materials (e.g. a bamboo toothbrush), and giving cardboard boxes and parcel fillers back for reuse (e.g. to mail-order shops).

Conclusions

Smart cities 3.0 are ideal models for creating urban spaces in the 21st century. Thanks to a systematic approach to the management of individual elements of infrastructure, a focus on sustainable economic development, and environmentally friendly social and financial solutions, smart cities can serve as an example for other centres of the population.

The process of rational waste management in urban space can be reduced to three general commands: plan, apply, and motivate! However, only the appropriate execution of these commands gives a chance to manage waste in accordance with the WM2GEG scheme. The creation of a plan tailored to the needs of the city and its inhabitants was identified as an initial stage in the process of rational waste management.

After the plan is prepared, the waste reduction methods indicated in the plan should be applied. The study identified a number of waste management methods in smart cities 3.0. The most important of these include low-energy buildings, renewable energy, reduction of plastic production, smart rubbish containers integrated into the urban landscape and equipped with sensors indicating when they are full, specialised rubbish sorting, public education campaigns on the need to act ecologically, applications enabling citizens to contact waste disposal services, and the treatment of non-recyclable rubbish combined with energy recovery. Based on interviews with representatives of specific smart cities, it was shown that waste management focused on waste reduction has a positive impact on all components of the WM2GEG scheme, which include society ('for a generation'), environment ('for the environ-

DOI: 10.34659/eis.2022.81.2.462

ment'), and economic benefits ('for gains'). The representatives of the cities studied also confirmed that the use of modern methods of waste management significantly increases the aesthetics of the city.

The key step is to motivate residents to apply the desired practices in the waste management process. The primary forms of motivation identified during the study are: educating residents from an early age in the field of responsible waste management, conducting social campaigns promoting behaviours that reduce the amount of waste and strengthening private businesses and initiatives related to promoting Zero Waste behaviour. The article presents examples of solutions in accordance with the ZW available to all city residents, such as the use of reusable bags, resignation from purchasing bottled water in favour of a reusable water bottle, or changing consumer habits (e.g. choosing loose fruit and vegetables, without additional foil nets and bags).

The article also presents ZW-compliant solutions available to all city dwellers, such as the use of reusable bags, abandoning the bottled water purchase in favour of a reusable bottle, or changing consumer habits (e.g. choosing fruit and vegetables in bulk, without extra plastic nets and bags).

From a holistic point of view, creating an urban infrastructure that is 100% compatible with the zero waste concept is very difficult (Zaman & Lehmann, 2011, p. 177). At the moment, most attempts to recover rubbish leave some waste. Therefore, it seems essential to carry out further research towards improving waste management systems and introducing appropriate recommendations for administrations, companies, and individual consumers related to sustainable consumption. At the same time, it is important to periodically check the level of public awareness of the danger posed by waste that is growing too fast and ensure that citizens are systematically educated in this area. Perhaps it is also worth considering whether today's reality in any city in the world really includes entirely zero waste activities? Are the examples of rational waste management indicated in the paper not yet an element of the less waste strategy, which may be interpreted as a kind of introduction to the ideal state of zero waste?

Another aspect worth exploring is whether innovative technological solutions that reduce rubbish and urban pollution today will result in a sharp increase in waste in the future. For example, electric cars are considered environmentally friendly solutions, especially when combined with renewable energy sources. However, it would already be worthwhile to test the recyclability of electric motors in individual urban centres. The same goes for photovoltaics – using renewable solar energy is very beneficial for the environment. However, cities must be prepared for a sharp increase in waste in the form of used photovoltaic panels over the next few to several dozen years.

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The contribution of the authors

Dorota Jelonek – 50% (conception, data analysis, interpretation, discussion).
Dorota Walentek – 50% (literature review, acquisition of data, data analysis).

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URBAN REGENERATION AND SUSTAINABLE DEVELOPMENT – AN ATTEMPT TO ASSESS A SUSTAINABLE CHARACTER OF REVITALISATION PROCESSES IN POLAND

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ABSTRACT: A study conducted for the purposes of the article aimed at assessing the degree of sustainable development achieved in the urban regeneration processes carried out in Poland. It covered a study of urban regeneration programmes adopted in cities with poviat rights, where these processes are regularly monitored. Based on the analysis and interpretation of these documents, on the grounds of a methodology created for the purpose, the conducted processes were assessed in the context of the sustainable development principles. The article aims to answer the following questions: (1) to what extent the implemented projects fit into this paradigm, (2) to what extent they contribute to its achievement, and, more generally, (3) how to examine the issue of sustainable development in regeneration processes – as the current study is the first such research in Poland. The study, which proves that, for the moment, the revitalisation activities are not too advanced, nor too harmonious, should lead to further, more in-depth research on the subject.

KEYWORDS: urban regeneration, urban renewal, revitalisation, sustainable development, development policy

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Overview of the literature

The concept of sustainable development (SD) was formulated in the report of the UN World Commission for Environment and Development in 1987 (Report, 2017, p. 41), and popularised at the 1992 Earth Summit in Agenda 21 and Rio Declaration, and by the creation of the UN Committee on Sustainable Development (Siemiński, 2008, p. 1). The final stage was the 2015 proclamation by the UN of 17 Sustainable Development Goals (SDGs) to be achieved by the member states in 2030 (Agenda, 2015) and the Paris Agreement (2015) assuming climate neutrality by 2050. The SD has thus become a new development paradigm, occupying a key place in strategic documents of other bodies, such as the OECD, EU and respective countries. Although there is no special holistic strategy in Poland covering all dimensions of the SD in one document, the concept is referenced in the Constitution (Konstytucja, 1997, Art. 5). The term has also been defined in the Polish legal system (Ustawa, 2001). Generalising and synthesising definitions, it can be stated that the SD is a broad concept meaning development: (1) of a permanent nature, (2) respecting the balance between economic, social and environmental goals, taking into account the preservation of resources for future generations (Fiedor, 2001, pp. 13-17). Development understood in this way requires a comprehensive approach, i.e. equal treatment of all the goals mentioned above.

In turn, urban regeneration (urban renewal, revitalisation, rewitalizacja – in Polish) is a concept that evolved with time to become a city development policy focused on permanent counteracting economic, social, spatial and environmental deficits of a specific area (e. g., Roberts, 2000, p. 17). Similarly, the term is defined under Polish legislation (Ustawa, 2015, Art. 2.1). The current understanding of the term arises from such documents as The New Charter of Athens (2003), Leipzig Charter on Sustainable European Cities (2007), which emphasises the need to conduct an integrated urban policy in crisis areas, or The New Leipzig Charter (2020) which refers to interventions aimed at "just city", "green city" and "productive city". Urban regeneration as a policy that fits into the SD paradigm is widely confirmed by scientists (e. g. Brebbia & Galiano-Garrigos, 2016; Charlot-Valdieu & Outrequin, 2007; Opoku & Akotia, 2020). Although they agree that it plays a crucial role on the road to the cities' sustainable development, they also see barriers, mainly political, that could make such an achievement impossible or incomplete (e. g. Couch & Dennemann, 2000; Evans & Jones, 2008).

Respective studies show methodological differences in assessing the sustainability of revitalisation activities. Broadly, these methods can be divided into two categories. In the first one, the assessment is based on indicators

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derived from the SDGs set in international or national strategic documents, which are analysed in the urban regeneration context (Ye, 2019). It consists of assigning specific categories and selected indicators to each of the SD dimensions. Proponents of this solution rely on various methodologies and propose various types and a number of indicators, e. g. Hemphill et al. (2004): 6 categories and 52 indicators, Peng et al. (2015): 4 categories and 22 indicators, Zheng et al. (2017): 6 categories and 27 indicators.

The second type features the rating that evolved from the building certification systems (e.g. Dussard, 2016; Adewumi, 2020). These systems, such as the UK BREEAM, the US LEED-ND and the German DGNB, were created in the 1990s as an attempt to set standards for designing buildings in the SD spirit. Other systems include the Brazilian AUQA (Cherqui, 2005), the Vietnamese HKTS (Dussard, 2016, pp. 13-14) or the French HQE2R and HQDIL (Charlot-Valdieu & Outrequin, 2007). In the 21st century, these systems, Neighbourhood Sustainability Assessment Frameworks (NSAFs), began to be used to assess the sustainability of entire neighbourhoods (Dussard, 2016, pp. 13-14). Such is also the goal of the "EcoQuartier" certificate, introduced in France in 2009, confirming that the revitalised area meets the SD criteria (Kaczmarek, 2017).

Other assessment methods focus on a selected dimension of the SD (most often the environmental pillar) (Lee & Chan, 2009; Toli & Murtagh, 2017) or qualitative research (Akotia et al., 2020). Among the latest approaches, the model is based on an analytical network process and zero-one goal programming (Nesticò et al., 2020).

In Poland, Borys (2014) is in line with the first presented trend. Since the 21st century, different sets of indicators examining local, regional and national development were developed by Statistics Poland (GUS) as part of the Local Data Bank (BDL). The process of their creation has not been finished, either by the GUS (e.g. GUS, 2011) or scientists (e.g. Gus-Puszczewicz, 2013; Borys, 2014; Kornak & Kostecka, 2018). As for the SD indicators, GUS worked on their creation till 2018, when they were substituted by the new set resulting from the adoption of Agenda 2030 by Poland. A pioneering study based on the LEED-ND system concerned a housing estate in Iława (Modrzewski & Rybak, 2015).

Context, subject and purpose of the study

In Poland, revitalisation needs appeared after the country's accession to the EU. From the very beginning, the instrument was perceived as an important element of the SD (Billert, 2007; Berbesz, 2017; Ciesiółka, 2017, p. 10). Thus, the sustainable development principles should underlie the program-

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ming of Polish revitalisation processes, while the SD indicators are useful in monitoring the achievement of the objectives (Topczewska, 2009). So far, however, no attempt has been made to investigate this issue, although the question of the sustainable nature of the conducted processes, due to legal and financial conditions, seems particularly important.

The legal basis for revitalisation processes was, firstly, the Act on Municipal Self-Government (Ustawa, 1990), then, after 2015, also the Act on Revitalisation (Ustawa o rewitalizacji) (Ustawa, 2015). The latter specifies the rules and procedures for conducting revitalisation processes, from the document preparation to its evaluation (Ibid, Art. 1). The Act does not refer directly to the SD paradigm, but its notion results from the definition of the revitalisation concept stressing its comprehensive and integrated nature (Ibid, Art. 2.1). So, it can be assumed that on the ideological level, i.e. in the revitalisation programme, planned interventions follow the SD spirit, as they counteract dysfunctions diagnosed in various fields and are complex and integrated with other activities.

But due to the existing financial conditions, the assessment should instead concentrate on the sustainability of actually implemented projects. Contrary to the processes carried out, for example, in Germany or France, which involve government and regional financial support, no special fund for revitalisation activities has been established in Poland. Urban regeneration is an optional municipal task, so it is a municipality that is responsible for financing the implementation of the programme. Cities can apply for external funds, mainly from the EU, but without any certainty, at the stage of creating the programme, that they will get them. As a result, a low projects implementation is being observed (Jadach-Sepioło, 2021, p. 62).

The sustainability of Polish urban regeneration processes was the subject of the study, which aimed to answer the following questions: (1) to what extent do the implemented projects fit into the SD paradigm, (2) how do they contribute to its achievement and to what extent. A broader question concerns (3) a possible research method for the subject, as it is the first study of the type in Poland. The research hypothesis that the investigation would like to verify is that the specific Polish conditions may act as a brake in achieving the SD in the degraded areas.

Research methodology

The study was conducted based on data analysis, including, in particular, programme and reporting documents, legal regulations and expert opinions on the urban regeneration processes in Poland. It was of a quantitative and qualitative character, including an interpretation of the studied documents.

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For the purpose of analysis, a research tool in the form of a questionnaire was also created. It consisted of 14 questions, allowing an appropriate assignment of the analysed phenomena. The background for the analysis was the above-presented literary studies, which helped to order the definition issues and to deepen the knowledge about the global trends in examining the SD in the urban regeneration processes.

Several assumptions were made in order to answer the research questions. Firstly, the cities with poviat status (miasta na prawach powiatu) were selected for the study. They are the largest Polish urban centres featuring the longest and most advanced urban regeneration processes. They are also considered the most efficient and effective in financing, thus, the most advanced in implementing planned projects (Jadach-Sepioło, 2021, p. 241). For these reasons, the preliminary analysis included 62 revitalisation programmes.

Secondly, due to the precise preparation and implementation principles, the oldest programmes created based on the Act on Revitalisation (Ustawa, 2015), i. e. in 2016 and 2017, were selected for further analysis. Such revitalisation programmes (gminne programy rewitalizacji) were acknowledged as the most comprehensive and integrated documents, so the most in line with the SD paradigm. They also should be monitored regularly. This criterion was met by 11 examined cities.

Thirdly, for the purpose of the analysis, elements of the methodology developed by Arcadis for the Ranking of Polish Sustainable Cities (Borys et al., 2021) were used. On the one hand, it is based on the Arcadis Sustainable Cities Index (Arcadis, 2018), which fits in with the global trends of the SD assessment, and, on the other, it is the best-known, repeated periodically study in Poland. So, following Borys et al. (2021), a division into 3 dimensions (pillars) of the SD, i. e. society, economy and environment, was adopted, together with specific categories. Then to the latter, the dysfunctions identified in the diagnostic part of the revitalisation programmes and the corresponding remedial projects: (1) planned and (2) implemented (or in progress), i. e., identified in the monitoring reports, were assigned. Afterwards, the implemented projects were compared with the planned ones, which allowed to define the percentage of successfully implemented projects.

It should be noted that not all categories created by Boris et al. (2021) are typical for urban regeneration processes, for demography, tourism and resource consumption related to general development. However, due to the methodological consistency, they were included in the study – as it turned out, they virtually did not influence the results. Then, an achieved balance within a given dimension due to the completed projects was examined. For this purpose, the categories in which the diagnosed dysfunctions were not accompanied by any corrective actions were also taken into account (a reverse situation, i.e. planned/implemented measures despite no dysfunc-

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tion, was not found). They were then compared with the dysfunctional categories, in which projects were designed and implemented, using the following formula:

$$x=\frac{\sum_{i=1}^{i=n} p_i}{n} \cdot 100\%, \qquad (1)$$

where:
x – the percentage of the SD achievement,
n – number of categories with a diagnosed problem,
p – degree of the projects' implementation:
$p = 0 \Leftrightarrow DP = + \wedge \% = x^{*}$
$p \in <0.1>$

* % – percentage share of the implemented projects in the total number of the planned projects in a given category. DP – dysfunction / problem confirmed in the diagnostic part of the revitalisation programme.

Summing up the respective dimensions' results enabled assessing the process's sustainability.

The authors are aware of the methodological challenges they faced. The most important of them is related to the difficulty of assigning dysfunctions (problems) and projects to the categories and even dimensions, mainly because the Act on Revitalisation (Ustawa, 2015) and, consequently, the revitalisation programmes distinguish 5 types of crisis phenomena (social, economic, technical, environmental, and spatial and functional ones). Hence, it was necessary to assign the identified dysfunction / remedial project to the appropriate pillar and category. Inevitably, the choice had to be sometimes arbitrary, though decisions were made consistently, i. e. the same assignment for the same dysfunction/project. Another problem was the number of projects planned to eliminate a dysfunction within a given dimension or category – sometimes it was one project, sometimes several dozen. In this case, it was assumed that the planned number was adequate to restore the balance in a given pillar or category. A significant limitation is also a short implementation period of the programmes, as the oldest were created in 2016 and 2017, and the latest monitoring studies were from 2020.

For this reason, the study covered the most advanced cities with poviat status. All these doubts raise questions as to the objectivity and accuracy of the findings. However, the authors are convinced that despite the methodological limitations, the study shows general trends that characterise the urban regeneration processes in Poland in the SD context and initiate a debate on this subject.

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Research results

The study began with the social dimension, consisting of 7 categories (Table 1). This dimension was the least addressed by the remedial activities. It should be noted that despite the diagnosed problems within the categories of demography and security, no actions were planned. In the case of demography, as explained in the methodological part, it seems justified, although it should be noted that Wałbrzych and Świnoujście planned some pro-demographic activities. It is more surprising that, except for Gdynia, no measures were foreseen to improve security.

Table 1. Assessment of the implemented remedial activities in the social dimension in comparison to the planned ones, taking into account the diagnosis of the dysfunctional categories

City	Demography		Health		Education		Culture		Poverty and living conditions		Safety		Participation of society in creating the city		SD of the dimension [%]
	DP	%	DP	%	DP	%	DP	%	DP	%	DP	%	DP	%	
Poznań	+	x	-	x	+	x	-	100.0	+	100.0	+	x	+	100.0	100.0
Płock	+	x	-	x	+	x	+	66.7	+	66.7	+	x	+	100.0	75.0
Wałbrzych	+	0.0	+	100.0	+	100.0	+	60.0	+	0.0	+	x	+	66.7	70.0
Słupsk	+	x	+	100.0	+	100.0	+	33.3	+	100.0	+	x	+	50.0	69.6
Kalisz	+	x	+	0.0	+	100.0	+	50.0	+	66.7	+	x	+	80.0	64.3
Gdynia	-	x	+	100.0	+	x	-	x	+	75.0	+	9.1	+	83.3	45.5
Leszno	-	x	+	0.0	+	x	+	66.7	+	33.3	+	x	+	50.0	45.5
Koszalin	-	x	+	x	+	50.0	-	x	+	100.0	-	x	+	0.0	42.9
Bytom	+	x	+	30.0	+	30.0	-	x	+	34.5	+	x	+	x	32.7
Gorzów Wielkopolski	-	x	-	x	+	100.0	+	0.0	+	60.0	+	x	+	0.0	30.8
Świnoujście	+	0.0	-	x	+	0.0	-	x	+	20.0	-	x	+	0.0	12.5

DP – dysfunction/problem confirmed in the diagnostic part of the revitalisation programme.
% – percentage share of the implemented projects in the total number of the planned projects in a given category.
\+ – problem diagnosed in the diagnostic part of the revitalisation programme.
\- – a problem not diagnosed in the diagnostic part of the revitalisation programme.
x – no remedial action planned/implemented in a given category.

Source: author's work.

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Poznań, which implemented all planned activities, turned out to be the best for the number of the completed projects. Świnoujście, where only one of 4 planned activities was implemented, was the worst. A detailed list of the categories, dysfunctions and the remedial interventions carried out in relation to the planned activities is presented in Table 1.

Although Poznań is the most advanced in terms of the projects' implementation, it is difficult to talk about the sustainable nature of the activities carried out there, as, in 3 dysfunctional categories, no remedial activities were planned. The same is true for other cities, except for Gdynia, which planned and took action in all dysfunctional categories (Figure 1). Thus, Gdynia achieved a 66.8% of social sustainability. Other cities with relatively balanced interventions are Słupsk (54.7%), Płock (46.8%) and Wałbrzych (46.7%). The least harmonious process is observed in Świnoujście (5.0%). The degree of achieving a balance in the social pillar of the examined cities is presented in Figure 1.

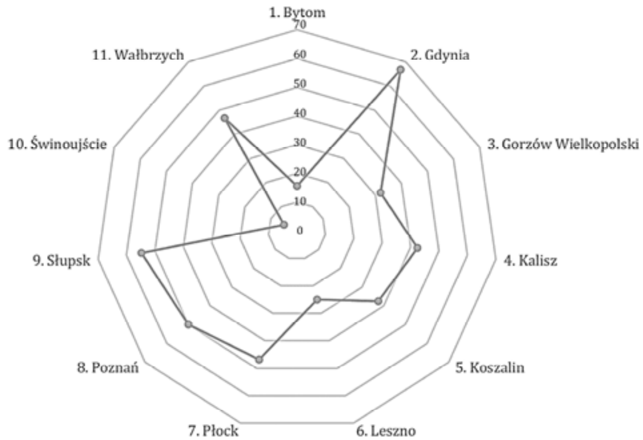

Figure 1. Degree of achieving a balance in the social dimension as the result of the implemented revitalisation activities in the examined cities

Source: author's work.

The economic dimension was examined by 5 domains (Table 2). This dimension should be considered the most important in terms of the activities planned by the cities, as in 8 of them, economic projects constituted the highest percentage of all planned interventions. Poznań deserves, again, attention as the economic projects account there for nearly 74% of the total intervention, and their implementation degree is also the highest. The cities deviating from this rule include Świnoujście, where social projects dominate, and Koszalin and Wałbrzych, with the dominant environmental intervention.

Again, the lowest number of the implemented projects was recorded in Świnoujście, where no attempts were made to solve problems diagnosed in 2 categories. In most of the remaining cities, projects were planned in all dysfunctional categories, suggesting that if the measures are fully implemented, one could speak of achieving a full equilibrium in this dimension. A detailed comparison of the categories, dysfunctions and remedial intervention carried out in the economic pillar is presented in Table 2.

Table 2. Assessment of the implemented remedial activities in the economic dimension in comparison to the planned ones, taking into account the diagnosis of the dysfunctional categories

City	Category										SD of the dimension [%]
	Economic development and employment		Public finance and spatial planning		Transport		Tourism		Access to the labour market		
	DP	%	DP	%	DP	%	DP	%	DP	%	
Poznań	+	x	+	95.7	+	100.0	-	x	-	x	97.1
Słupsk	-	x	+	73.3	+	88.9	-	x	+	80.0	79.3
Kalisz	+	x	+	64.7	+	75.0	-	x	+	100.0	66.7
Płock	+	100.0	+	58.8	+	100.0	-	x	+	0.0	65.2
Leszno	+	100.0	+	63.2	+	66.7	-	x	+	0.0	61.5
Wałbrzych	+	100.0	+	53.1	+	85.0	+	x	+	100.0	59.8
Gdynia	-	x	+	75.0	+	20.0	-	x	+	100.0	52.2
Gorzów Wielkopolski	+	0.0	+	27.3	+	42.9	-	x	+	75.0	39.1
Bytom	+	14.3	+	63.3	-	x	-	x	+	6.3	36.7
Koszalin	+	x	+	14.3	+	0.0	-	x	+	100.0	20.0
Świnoujście	+	x	+	16.7	+	x	-	x	+	0.0	14.3

DP – dysfunction/problem confirmed in the diagnostic part of the revitalisation programme.
%– percentage share of the implemented projects in the total number of the planned projects in a given category.
+ – problem diagnosed in the diagnostic part of the revitalisation programme.
- – a problem not diagnosed in the diagnostic part of the revitalisation programme.
x– no remedial action planned/implemented in a given category.

Source: author's work.

In the case of this pillar, the lack of intervention, despite the diagnosed dysfunctions in some categories, was also identified. The resulting dimension imbalance is visible mainly in Świnoujście (4.3%), Bytom (27.7%) and Koszalin (28.5%). The most balanced approach is featured in Słupsk (80.7%), Wałbrzych (67.6%) and Gdynia (65.0%). The level of equilibrium in the economic dimension of the examined cities is presented in Figure 2.

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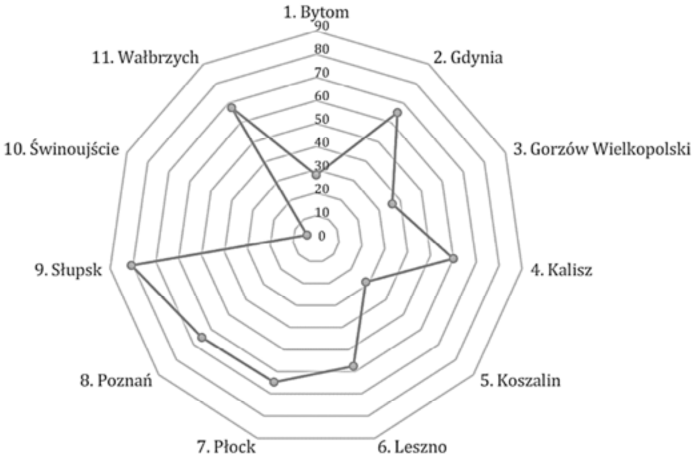

Figure 2. Degree of achieving a balance in the economic dimension as the result of the implemented revitalisation activities in the examined cities

Source: author's work.

Table 3. Assessment of the implemented remedial activities in the environmental dimension in comparison to the planned ones, taking into account the diagnosis of the dysfunctional categories (as in Table 1)

City	Category														SD of the dimension [%]
	Climate change		Air		Biodiversity		Land use		Waste management		Network devices		Resource consumption		
	DP	%	DP	%	DP	%	DP	%	DP	%	DP	%	DP	%	
Poznań	+	100.0	+	x	-	x	+	100.0	+	x	+	x	-	x	100.0
Świnoujście	+	x	+	x	-	x	+	100.0	-	x	-	x	-	x	100.0
Kalisz	+	100.0	+	x	+	100.0	+	91.7	+	x	+	100.0	-	x	95.2
Słupsk	+	100.0	+	x	-	x	+	85.7	-	x	+	66.7	-	x	81.8
Bytom	+	80.0	-	x	-	x	+	66.7	-	x	+	0.0	-	x	66.7
Leszno	+	100.0	+	100.0	-	x	+	45.5	+	x	+	100.0	-	x	62.5
Płock	+	100.0	-	x	-	x	+	50.0	-	x	+	x	-	x	55.6
Gdynia	+	100.0	-	x	-	x	+	20.0	-	x	+	50.0	-	x	44.4
Gorzów Wielkopolski	+	100	+	x	-	x	+	42.9	+	x	+	0.0	-	x	44.4
Wałbrzych	+	40.9	+	100.0	-	x	+	90.0	+	x	+	18.9	-	x	40.1
Koszalin	+	0.0	+	x	-	x	+	50.0	-	x	+	0.0	-	x	9.1

Source: author's work.

In the environmental dimension, 7 areas were distinguished (Table 3). It is worth noting that in this pillar, a smaller number of remedial projects were planned compared to in the economic dimension. In 4 cities, no activities in the category of waste management were planned, despite the problem diagnosis.

Also, in the environmental pillar, the highest degree of projects' implementation was recorded in Poznań, although no intervention was planned in 3 out of 5 categories in which dysfunctions were diagnosed. All scheduled activities in Świnoujście were implemented, but no projects to counteract the crisis in the "climate change" category were foreseen. The least number of implemented projects and the lowest percentage of achieving sustainability in the pillar was noticed in Koszalin. The list of categories, dysfunctions and the remedial interventions carried out in the environmental pillar is presented in Table 3.

The highest environmental sustainability, as the result of the activities carried out, was achieved in Leszno (69.0%) and Słupsk (63.3%), the lowest in Gorzów Wielkopolski (28.6%) and Koszalin (12.5%). Compared to other pillars, it is worth noting that the implemented environmental interventions are, in general, characterised by a higher degree of sustainability. Except for Gorzów Wielkopolski and Koszalin, all other cities achieved at least 50%. Figure 3 shows the degree of achieving a balance in the environmental dimension of the examined cities.

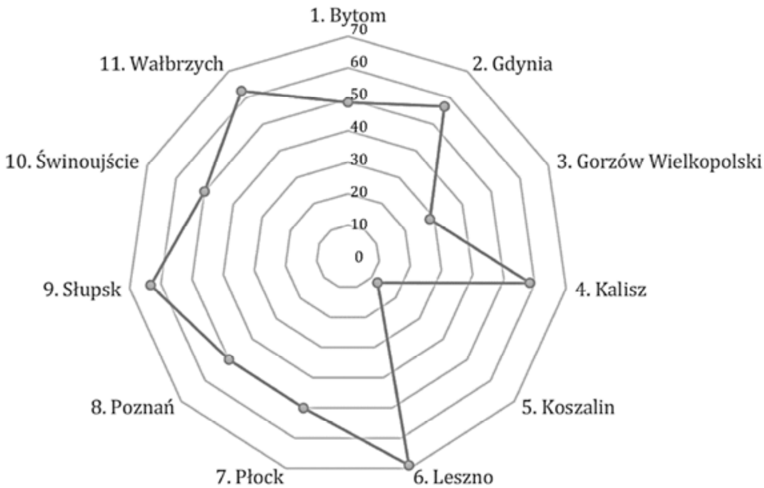

Figure 3. Degree of achieving a balance in the environmental dimension as the result of the implemented revitalisation activities in the examined cities

Source: author's work.

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By the adopted methodology, the sustainable nature of the revitalisation process is demonstrated by: (1) properly planned intervention, i.e. planning a remedial action for the diagnosed development deficits; (2) implementation of the planned projects. The study shows that the revitalisation process is the most sustainable in Gdynia (63.2%), Słupsk (62.7%) and Wałbrzych (57.2%). On the other hand, the least balanced results are noticed in Świnoujście (13.7%), Koszalin (26.2%) and Bytom (27.0%). In general, it can be concluded that even the most advanced cities are not yet close to achieving full sustainability. The degree of achieving the SD as the result of the revitalisation activities carried out in the examined cities is presented in Figure 4.

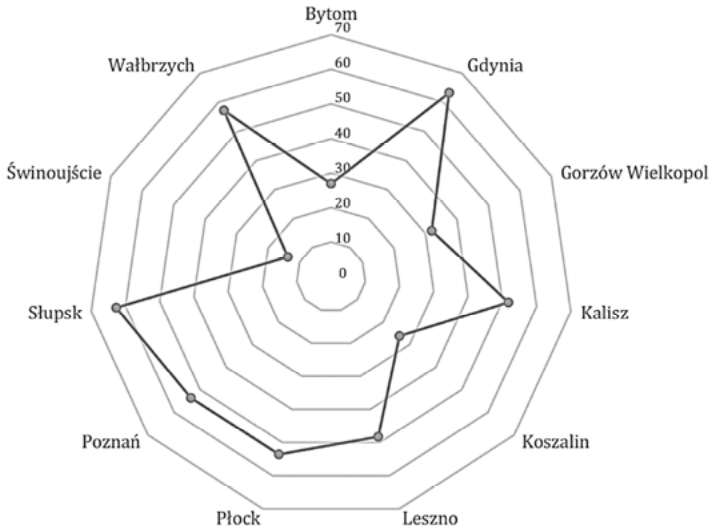

Figure 4. Degree of sustainable development achieved as the result of the implemented revitalisation activities in the examined cities

Source: author's work.

Conclusions

Despite the methodological limitations, it seems that the proposed methodology is appropriate for a preliminary assessment of trends in conducting urban regeneration processes in Poland in the context of sustainable development, proving the research hypothesis. The study also allowed us to draw some general conclusions regarding the diagnosis, planning and implementation of revitalisation activities under the current legal (Ustawa, 2015) and financial conditions, which are:

- the provisions of the Act (Ibid) indirectly imply that the planned process should be carried out in accordance with the principles of sustainable development;
- the actual planning of the process by the cities, however, is not entirely consistent, as the activities to counteract the diagnosed dysfunctions within the respective SD dimensions are not always planned;
- the existing financial conditions (lack of funding at central and regional levels) are an obstacle to the sustainability of the intervention;
- due to economic conditions, even assuming that the research covered a relatively short period, it can be argued that cities will not be able to implement all planned activities;
- even a high degree of the projects' implementation in a given category does not translate into achieving a sustainable character of the intervention (example of Poznań);
- due to the above, the intervention carried out by the cities will not be fully comprehensive and integrated, as it stands in the Act on Revitalisation (Ibid). Thus the regeneration processes will not be fully sustainable and in line with the SD paradigm.

In the context of the undisputed importance of the SD and the results of the study, the following solutions might be proposed: (1) development of an integrated sustainable development strategy at the national level and link it to the Act on Revitalisation (Ibid), or (2) inclusion in the latter a direct requirement of planning a coherent intervention respecting the SD principles. It seems that the current legal conditions do not fully ensure such intervention. The planning and implementation of the process depend on the cities themselves, their authorities' awareness, institutional capacities, human capital, and financial possibilities. On the other hand, under the existing financing conditions, the planned intervention must be thoughtfully tailored. Hence it seems that more sustainable actions are possible only in smaller than currently designated revitalisation areas, which will feature fewer needs.

A more detailed picture of what causes cities to carry out revitalisation activities in a more or less sustainable manner could be provided by qualitative research based on the analysis of case studies with in-depth interviews with people responsible for urban regeneration processes and assessment of the changes during field research.

The contribution of the authors

Paulina Basińska (review of the literature, desk research, data collection and analysis, interpretation of the results) 50% of the involvement.

Edyta Tomczyk (review of the literature, desk research, data collection and analysis, interpretation of the results) 50% of the involvement.

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METHODS OF SUSTAINABLE SPACE MANAGEMENT IN REVITALISATION PROCESSES – COMPARATIVE ANALYSIS OF URBAN OPERATING TOOLS USED IN THE POLISH CITIES

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ABSTRACT: The paper attempts to analyse the instruments of urban operating tools used for spatial management in the urban regeneration processes. A comparative analysis of planning documents prepared for the implementation of revitalisation policy, i.e. spatial development concepts and Local Revitalisation Plans, was carried out. These instruments were juxtaposed with master plans, commonly used in the revitalisation practice by German cities but by some Polish cities as well. The article presents mechanisms of the impact of urban operating tools on the scope and nature of the urban regeneration processes. The scale of the impact understood as the pace of the implementation of the sustainable development goals in degraded urban areas was also assessed.

KEYWORDS: sustainable development, planning models, planning policy

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Introduction

As Ziobrowski et al. (2010) points out, a notion of a city includes a system of functions, institutions and corresponding permanent material devices created as a result of the efforts to achieve a balanced state at a specific level of selectivity of needs and an established system of mutual spatial accessibility. In this approach, the "natural" target state of a city is sustainable development, which enables modification of the need patterns, availability and quantitative features of individual elements (Ibid, p. 41). Urban planning is responsible for steering the cities' development and building structures that support urban life (Zuziak, 2008, p. 32). Spatial policy, on the other hand, is the activity of public authorities aimed at transforming or maintaining the spatial development of these structures. Urban operating planning serves to implement effective plans and concepts regarding the creation of space (Ossowicz, 2019, p. 5).

The International Guidelines on Urban and Territorial Planning (2015), the 2030 Agenda for Sustainable Development (Agenda, 2017), and the New Urban Agenda (2016) emphasise the importance for including sustainable urban development goals in city planning processes. Whereas C40 Cities Integrating Climate Adaptation (2020) additionally assumes that spatial planning should include instruments aimed at counteracting climate change.

The New Leipzig Charter (2020) formulates general principles for urban development policy, including in particular those concerning sustainable spatial development. The quality of public spaces, urban cultural landscapes and architecture play an important role in creating good living conditions. Therefore, their integration in development policy should be strengthened in order to create attractive public spaces and to achieve a high standard of a "building culture". This concept is understood as the sum of cultural, economic, technical, social and ecological factors influencing the quality, planning and construction processes (Majda, 2017, p. 118).

Postulates on a "building culture" are formulated at the stage of implementing spatial policy in the form of an urban development, most often undertaken by public authorities. According to the typology developed by Lang (2006), 4 types of urban projects can be distinguished, depending on the way they are implemented:

- Total urban development – carried out by one team of stakeholders (Total Urban Design),
- Urban development – controlled by a detailed master plan which defines the guidelines for many independent participants: developers and architects (All-of-a-piece Urban Design),

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- Urban development – with an implementation tool in the form of a Local Spatial Development Plan (miejscowy plan zagospodarowania przestrzennego) and a system of incentives to encourage and discourage certain types of investments (Piece-by-piece Urban Design),
- Urban development, where the construction of a new infrastructure element or system is treated as a stimulus for the development (Plug-in Urban Design).

Urban developments implemented in degraded urban areas, covered by urban regeneration processes, take a special form. Revitalisation, defined as a comprehensive process consisting of integrated actions for the local community, space and economy, territorially concentrated (Act on Revitalisation, 2015), fully implements the idea of balancing key development factors specified in the Environmental Protection Law (Environmental Protection Law, 2001, Art. 3, Par. 50), i.e. society, economy, nature, infrastructure. The definition of the urban regeneration process implies the necessity to strive for greater city sustainability. Revitalisation is a very complex process including elements such as historical evolution, functional and spatial structure, transport, environment, and economic and social structure (Rey, Laprise, & Lufkin, 2022). In Poland, the aim of the urban regeneration process is to reverse the negative trends of social, economic and material degradation (Jarczewski, 2009, p. 26) as well as, indirectly, to increase the attractiveness of the city, carried out with urban operating tools. The latest postulates dedicated to crisis areas include the need to take into account the mechanisms of counteracting gentrification and ensuring the residents' equal access to green areas, taking into account their needs (Oscilowicz et al., 2021). In degraded urban areas, however, the most common problem is non-functional space equipped with inefficient infrastructure, striking with debris and ugliness from the aesthetic point of view (Ossowicz, 2019, p. 92).

In such cases, urban developments are needed to improve urban space as a place to live, conduct business and use services. The following types of space improvement developments can de distinguished: 1) improvement of the mobility system, 2) improvement of technical infrastructure, 3) improvement of social infrastructure, 4) creation and improvement of public space, 5) enhancement of the beauty and uniqueness of the place (improvement of spatial composition) (Lynch, 1981), 6) improvement of the functional and spatial structure understood as a way of arranging and joining respective elements of the city (Ossowicz, 2003, 2004, 2013, 2016; Kochanowski & Ossowicz, 2009; Lerner, 2006; Suchorzewski, 2010). Their use in revitalisation processes are conditioned by the needs of degraded areas and the determination of public authorities, whose support (organisational and financial) is a key success factor. Although authorities may not always engage in a close financial cooperation with private entities, support for large investments almost always involves a political decision and risk. This is especially true due to the scale and external effects of urban developments, which still require the involvement of public funds, for example, the implementation of supporting infrastructure (Pancewicz, 2012, p. 135).

Purpose of the article and research methods

The article attempts to analyse the impact of urban operating instruments used for space management in urban regeneration processes. The study included Polish municipalities implementing revitalisation policy based on the municipal revitalisation programmes (gminny program rewitalizacji, GPR), for which the Act on Revitalisation (Act on Revitalisation, 2015) provides support in the form of specific legal and urban instruments accelerating the process of the assumed changes. The study was based on the desk research method, which includes the analysis of scientific reports about urban regeneration, legal acts and strategic documents forming the revitalisation system in Poland, as well as expert opinions and papers on urban operating planning. The desk research analysis was supplemented with the statistical method, consisting in drawing conclusions from "Rewitalizacja w gminie" (CSO, 2018). The data study was used to identify Polish municipalities with the municipal revitalisation programmes that pursue revitalisation policy with the use of the above-mentioned special solutions. The relevant revitalisation programmes were identified thanks to the lists of the positively verified GPRs, which are carried out by all voivodeship self-governments in Poland. Then, the main forms of managing spatial changes in the processes of the degraded areas' restoration planned in the GPRs, were selected. The research objectives included determining the impact of urban operating tools on the efficiency of the urban regeneration processes.

The size of the impact was assessed, taking into account the pace of the implementation of the sustainable development goals in the degraded areas. The assessment was made with the comparative analysis method, which is a technique of recognising the individual features of a given whole and the assessment of its functional efficiency (Penc, 1997, pp. 23-24). The use of this method allows the assessment of complex instruments which differ significantly by their essential features, the formulation procedure and the scope of the findings. For a comparative analysis, spatial development concepts, Local Revitalisation Plans (miejscowy plan rewitalizacji, MPR) and master plans, are most often used by the Polish cities while implementing revitalisation policy. They were ordered according to the typology of urban developments by Lang (2006). In the process of analysis, their basic features were distinguished and their relationships with the municipal revitalisation programmes

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established, assuming that their scale is directly responsible for the pace of achieving the sustainable development goals in the degraded urban areas. At this stage, the features of the respective tools were analysed, which allowed their assessment in terms of the impact on balancing the goals in the revitalisation processes. In the next step, the assessment of the impact was effectuated by assigning points from 0 to 2 to the respective features of the tool, where 0 means no or little influence of the analysed feature on balancing the goals, 1 – intermediate influence, and 2 – a decisive one. The sum of points indicated the instrument's potential to influence reaching the sustainable development goals in the revitalisation processes.

Municipalities' practice in the field of urban operating tools

The framework for revitalisation policy in Poland was defined in the Act on Revitalisation (Act on Revitalisation, 2015). According to its assumptions, the municipal revitalisation programme is the basic document defining the directions of activities in the process of the degraded area restoration. The Act assigns special opportunities to such a programme, resulting from its temporary superiority over other planning documents in force Art. 20, par. 1 (Act on Revitalisation, 2015). In the case of a contradiction between the revitalisation projects and the provisions of the Study of Conditions and Directions of Spatial Development (Studium uwarunkowań i kierunków zagospodarowania przestrzennego, the Study), it is possible to correct the latter in a shortened manner. Consequently, if a contradiction also concerns the Local Spatial Development Plan, its change can be carried out simultaneously with the change of the Study (Jadach-Sepioło et al., 2018, p. 117).

In the area covered by the revitalisation process, The Act enables municipalities to establish the Special Revitalisation Zones (Specjalna Strefa Rewitalizacji, SSR)[1], as well as to adopt the Local Revitalisation Plans, which strengthens the efficiency of the authorities and the effectiveness of their intervention (Szlachetko, 2017). The Act does not introduce the requirement to implement urban developments in the urban regeneration processes, allowing municipalities to make their own decisions on revitalisation policy. However, the use of the Local Revitalisation Plan, which is an optional tool, depends on the local conditions of the revitalisation area and the authorities'

1 Special Revitalisation Zone, foreseen in Art. 25 of the Act on Revitalisation, is a special area established in the revitalisation area for a maximum period of 10 years in order to ensure the efficient implementation of the revitalisation projects. In Poland there are 15 Special Regeneration Zones, in Łódź, Płock, Opole Lubelskie, Bytom, Kalisz, Ośno Lubuskie, Polkowice, Włocławek, Świnoujście, Waganiec, Malczyce, Rumia, Słupsk, Gorlice and Jarocin.

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decision to apply it. Apart from the features and regulations shared with the Local Spatial Development Plans, the Local Revitalisation Plans can, additionally, prohibit commercial or service activities on a given property or allow a commercial investment on an undeveloped property conditionally, making it dependent on a prior implementation of an investment significant for the municipality. The bans include activities harmful to the goals of the revitalisation process. During the study of the municipal revitalisation programmes, 15 Special Revitalisation Zones and one Local Revitalisation Plan, adopted by Kalisz (Miejscowy Plan Rewitalizacji Jabłkowskiego-Podgórze, 2021), were identified. The Polish revitalisation model was based on the German cities' renewal experience, which uses specific urban concepts, the so-called master plans, i.e. long-term planning documents, to control the districts' development. Master plans, most often, cover the analysis and conception for the population, economy, housing, transport, utilities and land development. The concept of the master plan is to create relationships between buildings and their surroundings in order to build social bonds[2].

During the study of the municipal revitalisation programmes, examples of master plans and spatial development concepts used in Polish revitalisation policy were identified. For the comparative analysis, the bellowed-presented documents were selected.

1. The Local Revitalisation Plan (MPR) was prepared by Kalisz. The Kalisz revitalisation area is situated in a historic district in the city centre (Miasto Kalisz, 2017). In order to increase the efficiency of the process, the Special Revitalisation Zone was established on the whole area. It was supplemented with the MPR for the Jabłkowski-Podgórze district, which introduced the principles for a new building complex adapted to the existing land development plan, introduced regulations regarding the facade of buildings, the layout and equipment of public spaces, commercial activities, technical and social infrastructure, including the desired functions of the investments, urban layout and spatial structure;
2. The spatial development concept – is chosen by large cities to manage complex spatial structures. For example, in Wałbrzych, such concepts were developed for 6 revitalisation sub-areas in order to improve the efficiency of the revitalisation process (Miasto Wałbrzych, 2020, p. 197). The concepts indicated the directions of the districts' transformations, new development of public spaces, protection of cultural resources, proposals for the transport system, and real estate management. They also included guidelines for the preparation of the Local Spatial Development Plans. The districts' inhabitants were involved in the process of their cre-

[2] Examples of master plans are documents prepared for the Potsdam Drewitz housing estate: Masterplan Gartenstadt Drewitz (2011) and the Garden City Drewitz (2014), or the Masterplan for the Oberbillwerder district in Hamburg (2019).

ation in order to "develop socially acceptable models of a new, but culturally sensitive, urban order, dedicated to the sub-areas of revitalisation" (Ibid, p. 200). The concepts were prepared at the stage of the implementation of the Wałbrzych GPR for the years 2016-2025. They became the basis, among others, for the change in the Study. In Radomsko, on the other hand, the concept was used at the stage of the GPR programming. The city got advisory support under the project "New model of urbanisation in Poland – practical implementation of the responsible urbanisation and a compact city principles (NewUrbPact)". As a result of the support, the diagnostic stage helping to determine the revitalisation needs was extended to include an urban inventory to determine the conditions of the area's spatial development. For this purpose, an intervention tailored to the area's needs, in the form of a spatial development concept including urban development solutions, was designed. In this case, the concept was performed at the early stage of the GPR programming, which enabled to raise the rank of spatial planning in the revitalisation process, giving it priority over the other fields of intervention.

3. The master plan was introduced into the practice of some Polish cities on the basis of the German revitalisation model. Wrocław, which has been carrying out revitalisation processes since 2004 (Miasto Wrocław, 2005, 2009, 2016), has a special experience in this field. In order to comprehensively control urban processes in the revitalisation area, planning documents for Przedmieście Odrzańskie and Przedmieście Oławskie were developed. The studies were based on the German integrated neighbourhood renewal strategies. The Wrocław master plans aimed at integrating planning activities, as well as investment and non-investment activities in the revitalisation process.
4. The studies presented the historical, regional and local context and took into account formal and legal regulations, such as relationships with local planning documents. Based on the diagnoses, the scope of the studies was determined. The urban layout, utility functions, ownership structure and the condition of historical housing estates were analysed, as well as the communication system, the districts' spatial structure, greenery, technical infrastructure and cultural issues. The quarter housing, building quarters and the entire architectural fabric were also examined. The economic, environmental and social conditions of the areas were also discussed. A map of the technical and social infrastructure objectives was created. In the conceptual part, strategic and operational goals and concepts for individual fields of activity were designed, and their implementation in the long-term perspective was described. The master plans initiated the revitalisation projects and identified participants in the urban regeneration process. Based on the adopted schedule, the projects were

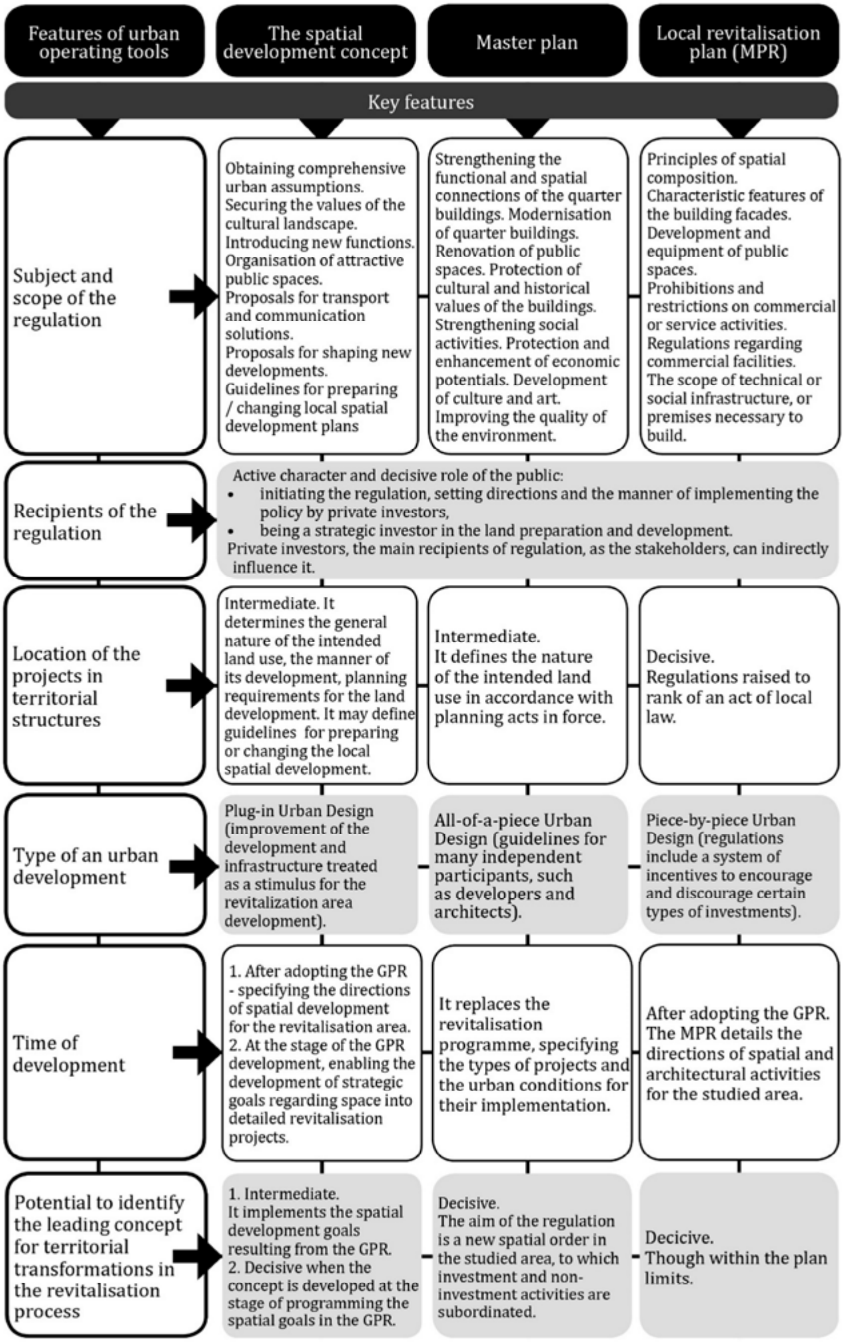

Figure 1. Key features of urban operating tools for the analysis of their impact on the implementation of the sustainable development goals in the revitalisation processes, Part 1

Source: authors' work.

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Features of urban operating tools	The spatial development concept	Master plan	Local Revitalisation Plan (MPR)
Key features responsible for balancing the development goals in the revitalisation processes			
Success factor	Responsibility of the public entity for providing the key initiative and long-term commitment in the implementation of the revitalisation projects.		Responsibility of the public entity for balancing regulations facilitating the implementation of investment procedures and restraining investment processes.
Level of integration of various entities' and sectors' activities	Intermediate. Integration of the stakeholders (public and private) around the spatial goals resulting from the GPR.	Decisive. The integration of activities in the urban, technical, environmental, social and economic fields. The regulations applies to all stakeholder groups, i.e. residents, developers, entrepreneurs, real estate owners, NGOs.	Intermediate. Integration of the stakeholders (public and private) around the spatial goals resulting from the GPR. Weakening of integration when applying the regulations introducing restrictions on undesirable commercial and service activities.
Impact on the achievement of the sustainable goals of the revitalisation process	1. Intermediate. It is limited to the spatial development goals defined in the GPR. 2. Decisive. When the concept is developed at the stage of the GPR goals' programming enabling to raise rank of spatial planning in the revitalisation process (space as a priority of the changes, causing influencing the directions of activities in other fields).	Decisive. Due to the high integration of the spatial goals with the social, economic, environmental and technical ones.	Intermediate. Restricted to the spatial development goals defined in the GPR for the chosen area.
Impact on the real estate market in the revitalisation area	Decisive. Market-friendly regulations conducive to the growth of its value.	Decisive. Market-friendly regulations conducive to the growth of its value.	Decisive within the litmist of the plan: 1. Market-friendly due to the legibility of detailed investment procedures, minimising necessary arrangements (e.g. regarding features of building facades). 2. Restraining investment processes due to possible restrictions on commercial, service and investment activities (urban development contrat).
Impact on the economic conditions of the revitalisation area	Intermediate. No direct mechanisms to support the location of economic activities. The impact on the economic conditions consists only in improving the conditions for conducting service and commercial activities.	Intermediate. No direct mechanisms to support the location of economic activities. Impact on economic conditions possible (cooperation of the public entity with entrepreneurs, projects related to the improvement of service and commercial activities conditions).	Decisive within the limits of the plan, which enables, inter alia, introducing bans and restrictions for undesirable commercial and service activities as well as large-area facilities. It also establishes the rules for conducting business activities on the ground floors of the buildings.
Influence on the environmental conditions of the revitalisation area	Decisive. Environment-friendly regulations. Among the desired goals of the intervention are: activities related to the creation and maintenance of green leisure areas, improvement of urban mobility, development of ecological transport systems.		Intermediate, within the limits of the plan (regulations regarding the arrangement and placement of green areas among the principles of public space development).
Stakeholder participation in programming the regulations	The decisive role of the external stakeholders in the process of preparing the regulations (optional consultation, social inclusion mainly at the stage of the GPR development and implementation).	The decisive role of the external stakeholders in the process of prepring the regulations (optional consultation mechanism, social inclusion mainly at the stage of the GPR development and implementation).	The decisive role of the external stakeholders in the process of prepring the regulations (obligatory consultation mechanism).

Figure 2. Key features of urban operating tools for analysing their impact on the implementation of the sustainable development goals in the revitalisation processes, Part 2.

Source: authors' work.

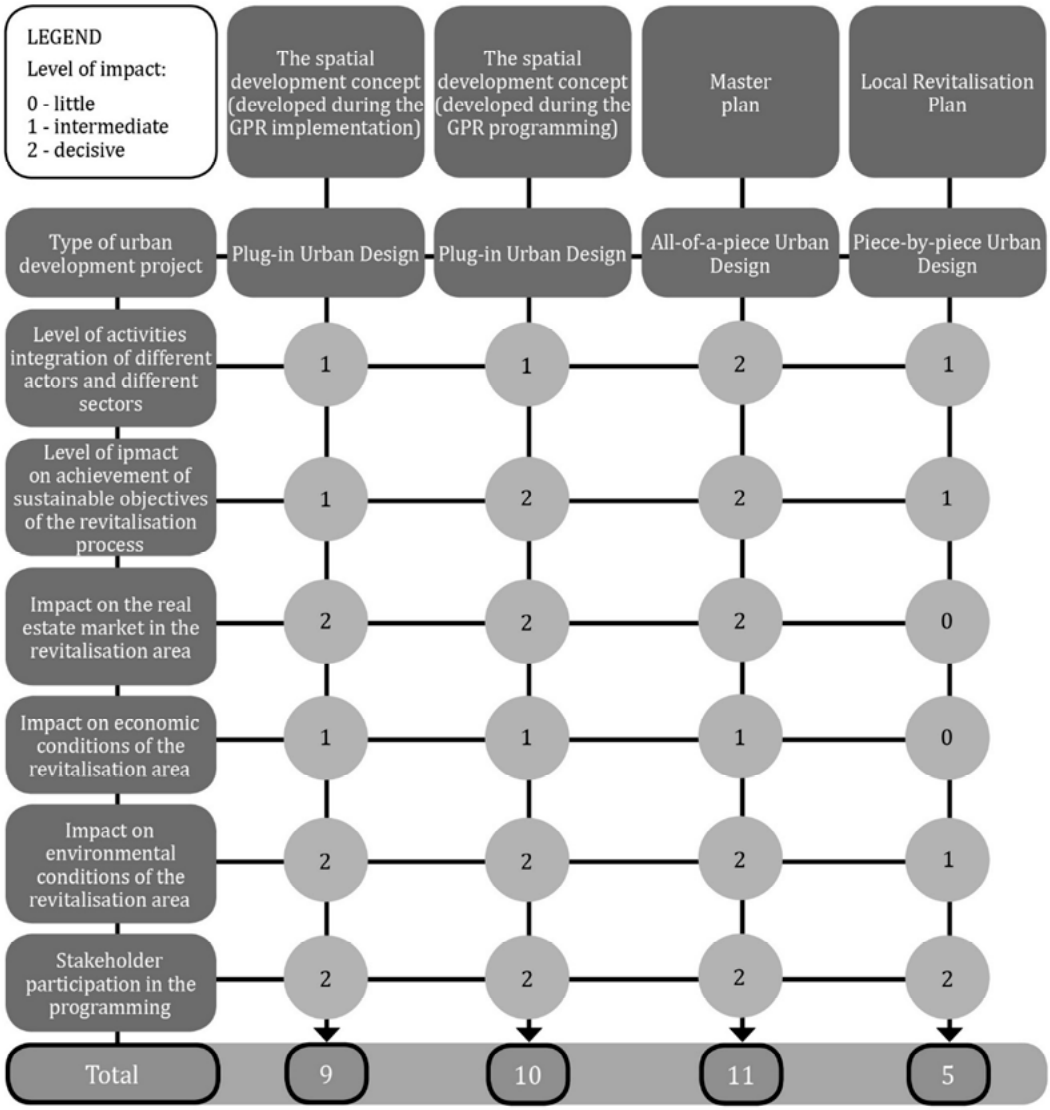

Figure 3. Assessment of the urban operational tools for balancing the development goals in revitalisation processes

Source: authors' work.

implemented in a long-term perspective, in accordance with the municipal investment plan, so that they complemented each other. The master plans served as a knowledge basis on the crisis areas and were used to develop the Local Revitalisation Programme for 2016-2018[3]. The shape of the concept was greatly influenced by numerous public consultations, which made it possible to adjust the regulation to the needs of the residents.

The Figures 1 and 2 show the effects of the comparative analysis of the above-mentioned urban operating tools. For the purposes of the study, the features of individual instruments were distinguished, taking into account their differences in relation to the revitalisation process. Their potential to implement the directions of sustainable development resulting from urban regeneration processes was also assessed.

In the further part of the study, an assessment of the impact of the key features of the tools responsible for balancing the development goals in the revitalisation processes was performed. For this purpose, points from 0 to 2 were assigned to the respective features, where 0 meant no or little impact of the feature on balancing the development goals, 1 – an intermediate influence, and 2 – a decisive one. The sum of the points indicated the impact of the instruments' potential to influence the sustainable development goals in the revitalisation processes. Additionally, the type of concept developed at the stage of revitalisation programming was selected as a separate item, due to the different achieved effects related to the strength of the impact on the revitalisation process. The results of the study are presented in Figure 3.

The study shows that the master plan, being a competitive document in relation to the revitalisation programme, implemented the best goals of sustainable development. Similar potential characterises the spatial development concept introduced at the early stage of revitalisation programming. Thanks to this approach, it was possible to visualise all objectives of the revitalisation process in the idea, as well as to ensure complementarity of the spatial changes. The study shows that the impact of the concept on the goals of sustainable development weakens when it is used at a later stage of the process, i.e. the GPR implementation. The analysis assessed the Local Revitalisation Plan as the least balancing tool for the development of the revitalisation area due to the regulations limiting the equal development of the economic sector, under which activities desired for the revitalisation process are supported at the expense of undesirable activities.

3 The necessity to have a revitalisation programme to coordinate urban regeneration activities resulted from the document "Wytyczne w zakresie rewitalizacji w programach operacyjnych na lata 2014-2020", developed by the Minister of Development in 2016 (Ministry of Development, 2016).

Conclusions

The principle of sustainable development in revitalisation policy is implemented at the stage of its programming and implementation, primarily through the problem complementarity required by the Polish revitalisation system, and translated into an equal treatment of social, economic, environmental, and technical and spatial issues. The strength of public participation is also of key importance, as it enables the high accuracy of interventions and social control of the process.

Urban developments play a unique role in the revitalisation process, as they have the potential not only to improve urban space but also to contribute to social and economic development, improvement of living conditions and the quality of the environment. The analysed urban tools are responsible for creating a vision of the development of degraded areas and are also responsible for generating the development processes there. Revitalisation processes include all types of urban developments: those that improve space, favour the improvement of communication systems, technical and social infrastructure, public spaces and spatial composition.

The conducted comparative analysis of urban operational tools showed their high potential for achieving the goals of sustainable development in the degraded areas. The study proved the existence of numerous relationships that these instruments form with the revitalisation process, significantly increasing the importance of spatial planning within this policy. The results indicated the instruments which guarantee greater effectiveness in balancing the development goals. Particularly noteworthy are comprehensive master plans and spatial development concepts used at the early stage of the revitalisation programming, as they both enable achieving very detailed visions of the changes in degraded areas, possible to be included in the GPRs. The use of urban tools strengthens not only the balance of the objectives of revitalisation policy but also promotes social inclusion, enabling the visualisation of the process assumptions for the purposes of public participation and facilitating a better perception of the programme by stakeholders.

The contribution of the authors

Katarzyna Spadło (review of the literature, desk research, data collection and analysis, interpretation of the results) 50% of the involvement.

Emilia Grotowska (review of the literature, desk research, data collection and analysis, interpretation of the results) 50% of the involvement.

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ARE EU ENVIRONMENTAL REGULATIONS CONSISTENT WITH THE CONCEPT OF INTERNALISATION OF EXTERNALITIES – THE CASE OF THE POLISH ELECTRICITY SECTOR

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ABSTRACT: The article's goal is to examine whether the existing EU environmental regulations implemented in the Polish electricity sector are consistent with the concept of internalisation of external costs. The tool used in the research is the partial equilibrium model of the mid-term development of the Polish power sector. There are two scenarios. The first 'base' scenario assumes gradual decarbonisation of the Polish energy sector. In the 'int' scenario, the structure of energy production results from the full internalisation of external costs. The structural changes in the 'base' scenario are a significant challenge. All coal-based technologies are being drastically phased out and will be replaced by RES and nuclear technologies. The climate policy leading to a gradual reduction of CO_2 emissions in Poland makes sense, assuming much higher external costs of CO_2 emissions (€65/Mg CO_2) than those assumed in this study.

KEYWORDS: electricity sector, externalities, energy mix, model

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Introduction

Negative externalities provide a sufficient ground to justify government intervention to eliminate market distortions. The aim of this intervention should be to set a price for environmental use that allows getting the social optimum. The theoretical basis for this type of intervention was presented and developed by Pigou (1932). There are a number of classical works dealing with this issue (Baumol et al., 1988; Dales, 2002; Pearce et al., 1990). It has been proven there that the inclusion of external costs in the decision-making process is necessary to achieve a social optimum. This theoretical consequences of market failure are particularly evident in the case of energy sectors, where environmental impact is noticeable. The energy markets are typical examples of market failures in terms of negative externalities. Hence, the long-term development of energy sectors for increasingly stringent environmental constraints is intensively studied.

The aim of the article is to examine whether the existing EU environmental regulations implemented in the Polish electricity sector are consistent with the concept of internalisation of external costs, and whether their implementation is efficient. In the case of Poland, this applies in particular to coal-based technologies, which are a major source of environmental threats. In the case of PM, SO_2 or NO_x emissions, the domestic power plants deals with them in a highly effective manner. Power plants are equipped with flue-gas desulfurization (FGD) and selective catalitical reduction (SCR) technologies. What is more, these methods are efficient as well, as their abatement costs are significantly lower than external costs due to the deposition of air pollutants (Dimitrijevic et al., 2012; Wu, 2001; Devitt et al., 2012; Marano et al., 2006). Here, the EU regulations such as emissions standards for individual power plants (for example the Industrial Emissions Directive (IED) or Best Available Technology (BAT) directive) are effective and efficient instruments of environmental policy. On the other hand, the current EU climate policy focuses on the complete reduction of CO_2 emissions. This raises the question of whether a full decarbonisation policy is sensible and economically justified? Are the costs of structural changes in electricity generation justified by the environmental benefits of CO_2 reduction. The author intends to analyse this issue based on his own mid-term development model of the Polish electricity sector.

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An overview of the literature

Studies concerning the external costs of the energy sectors focuses on the methods of their valuation and potential internalisation through a set of economic instruments. The first group of studies tries to assess the negative impact arising from fossil fuel-fired power plant's air emissions and the damages related to global warming effects, human health, ecosystems, crops, materials and forests (Bickel et al., 2005; *New Energy…,* 2009; Jori et al., 2018; Hall, 2004). They also provide theoretical and methodological backgrounds of their assessment (Samadi, 2017; Kim, 2007). The results are used by policy makers to take measures to avoid additional costs and to apply newer and cleaner energy sources, which is directly linked to the issue of the internalisation of external costs.

There are numerous studies that examine the impact of internalisation of externalities on the structure of energy production, which can be found in (Rentizelas et al., 2014; Klaassen et al., 2007; Fahlén et al., 2010; Rafaj et al., 2007). All of them illustrate the same effect: faster retirement of fossil fuel-fired power plants and an increase of RES share. These studies are ongoing for the energy sectors of several countries, including Greece (Georgakellos, 2010), Croatia (Borozan et al., 2015), China (Chen et al., 2016) and Iran (Ghoddousi et al., 2021). They prove that if production costs reflect all the negative effects, the structure of energy production changes significantly. Other studies concern the effectiveness of environmental policy tools. They indicate that market-based instruments are not effective in internalizing of external costs (Maca et al., 2012). Research on the impact of internalization of external costs on the structure of electricity production in Poland can be found as well in Kudełko (2006) and Juroszek et al. (2016).

Mathematical modelling is a standard method used in the mid- and long-term development of energy sectors. Different types of energy models have been developed for various policy and planning concerns. The so-called "bottom-up" modelling approach is focused mainly on micro-level technological issues and does not capture important macroeconomic inter-links within the economy. These models are mainly concentrated on least-cost energy planning with reference to environmental constraints. They are limited to policy goals since they do not analyse the effects of price changes on other markets. Examples are PRIMES, LEAP, POLES, MARKAL/TIMES, MILP, MESSAGE, EFOM-ENV and other models. Description and specification of these models, including classification schemes used for bottom-up energy system modelling, their resolution in time, in space, in techno-economic detail and in sector-coupling are provided in (Prina et al., 2020).

A model-based approach is also commonly used for the long-term development of the Polish energy sector (Departament Analiz Strategicznych, 2015; Wierzbowski et al., 2017). The growing challenges related to decarbonisation impose a new perspective for new energy technologies. This issue is reflected in recent papers such as (*Risk associated…,* 2018; Gajowiecki, 2019; Engel et al., 2020; Wyrwa et al., 2022). Some of the works concerns the rationality and costs of full decarbonisation of energy sectors (Hübler et al., 2013; Capros et al., 2012), also in Poland (Kiuila, 2018). Part of them provide a strong support for the implementation of decarbonisation scenario (Sofia et al., 2020), however, there are other surveys as well (Tol, 2021). The author reviews the targets set by the European Union, discusses the costs and benefits of greenhouse gas emission reduction and concludes that the benefits of the European Union's climate policy do not outweigh its costs.

Research methods

The concept of negative external effects and the economic consequences for an electricity market is presented on Figure 1. MPC (marginal private costs) represents individual electricity producers using different energy technologies with different generation costs. MSC (marginal social costs) is a function that includes the additional external cost of electricity production. The demand function represents energy consumers, i.e. economic sectors and households. If there are negative externalities, marginal social cost (MSC) is higher than the private cost of production (MPC) at the size of external costs (MEC). If producers do not include external costs in their cost calculations, the market supply function reflects only private costs (MPC). Market equilibrium is achieved at the price of P_1 and the production volume of Q_1. However, if a producer paid for the negative effects, the equilibrium point would be different – P^* and Q^*. Consequently, the negative externalities causes an overproduction of $Q_1 - Q^*$.

The economic consequences for producers (producers surplus), consumers (consumers surplus), and the environment (external costs) of both cases are as follows. Net social welfare is the sum of consumer and producer surpluses minus external costs. If the volume of production is Q^*, and the product is sold at a market price P^*, net social welfare would increase by field M. Of course, it creates serious distribution effects. Consumers would suffer losses in the sum of fields B, G, K, whereas the situation of producers would improve by the total of fields B+G–N. Environmental costs would decrease by the sum of fields M+N+K. This type of price regulation limits the level of production to a socially optimal volume. Of course, energy producers can take other adaptation measures, such as using abatement technologies to reduce

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emissions. In this case, price intervention will reduce the negative impact to an optimal level without reducing energy production. Which strategy is chosen depends on which is more cost-effective for them.

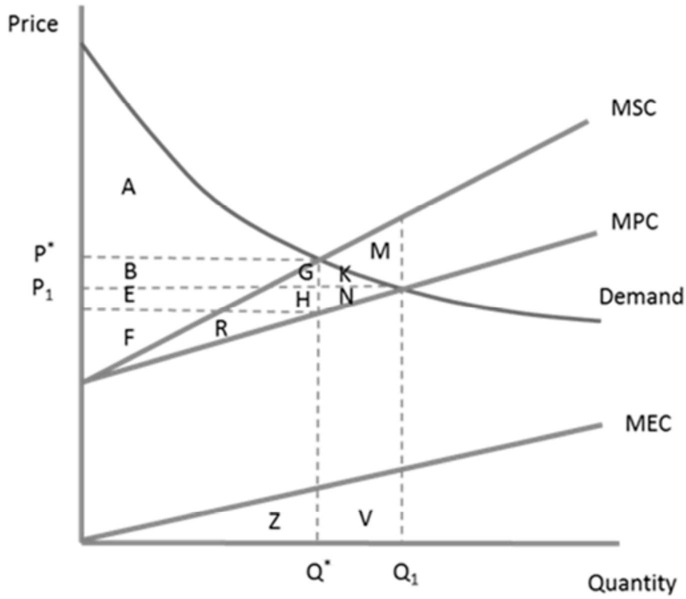

Figure 1. Negative externalities

Source: author's work.

The EU environmental policy, for various reasons, tends to avoid the use of price instruments (environmental taxation) in the energy sectors. It primarily uses direct tools (quotas – e.g. RES share; limits – CO_2 level; emissions standards – IED directive). However, the question is whether both types of regulation are coherent and whether they guarantee to meet the same environmental goals. This question is explored below.

The tool used is the partial equilibrium model of the mid-term development of the Polish electricity sector. It is a tool that allows analysing different scenarios of the electricity sector development. The model can apply both mentioned environmental adaptation strategies. The first one is reducing electricity production due to the increase in energy prices (demand reaction). The second one enables the use of abatement technologies or switching generation technologies. Both strategies allow compliance with imposed direct or indirect environmental regulations.

Table 1. Energy technologies characteristics

Technology	net efficiency electr., effG [%]	load factor, lfG [h]	cogeneration factor, cogfG	capacity installed, cbM [MW]	investment costs, icG,t [€/kW]	fixed costs – electr., fcG,t [€/kW]	fixed costs –heat, fcG,t [€/kW]	variable costs – electr., vcG,t [€/GJ]	variable costs – heat, vcG,t [€/GJ]	emissions coefficient PM, efG [g/GJ]	emissions coefficient SO_2, efG [g/GJ]	emissions coefficient NOx, efG [g/GJ]	emissions coefficient CO_2, efG [kg/GJ]
System power plants:													
Hard coal-fired power plants – life extension	40	3565	0.92	10000	0	37	37	0.8	0.9	40	241	223	188
Hard coal public power plants – simple modern.	40	3565	0.92	0	160	37	37	0.8	0.9	40	241	223	188
Hard coal public power plants – simple modern. + gas turbine	40	3565	0.92	0	280	37	37	0.8	0.9	32	195	180	162
Hard coal public power plants – FBC	45	3565	0.92	0	950	37	37	0.8	0.9	40	24	76	188
Hard coal-fired power plants – simple modern. with biomass co-firing	38	3565	0.92	0	160	37	37	0.8	0.9	40	241	223	169
Hard coal-fired power plants – biomass co-firing	38	3565	0.92	8036	0	47	37	0.8	0.9	40	241	223	169
Lignite-fired power plants – life extension	38	5607	0.97	5500	0	47	37	0.9	0.9	43	256	224	197
Lignite-fired power plants – simple modern.	39	5607	0.97	0	160	47	37	0.9	0.9	43	256	224	197
Lignite-fired power plants – simple modern. + gas turbine	39	5607	0.97	0	280	47	37	0.9	0.9	35	207	180	169
Lignite-fired power plants – FBC	45	5607	0.97	0	950	47	37	0.9	0.9	43	26	76	197
Lignite-fired power plants – simple modern. with biomass co-firing	37	5607	0.97	0	160	47	37	0.9	0.9	43	256	224	177
Lignite-fired power plants – biomass co-firing	35	5607	0.97	3252	0	58	37	0.9	0.9	43	256	224	177
Hydropower plants – life extension	70	938	1	2341	0	65	0	0.5	0.0	0	0	0	0
Wind turbines power plants – life extension	40	1806	1	6621	0	30	0	0.1	0.0	0	0	0	0
New coal-fired power plants	46	6200	0.97	0	1400	37	37	0.9	0.9	40	40	74	188
New lignite-fired power plants	46	6200	0.97	0	1380	47	37	0.9	0.9	43	40	75	197
New IGCC power plants	47	6200	0.96	0	1860	37	37	0.4	0.4	36	2	74	169

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New gas turbines power plants	40	4100	0.96	0	470	19	19	0.2	0.2	39	3	75	58
New CCGT power plants	60	4100	0.96	0	770	19	19	0.2	0.2	0	10	6	58
New biomass power plants	36	6200	0.97	0	1440	70	37	0.5	0.5	0	10	6	100
New biogas power plants	40	4100	0.97	0	1440	93	0	0.5	0.0	20	80	80	58
New PV power plants	14	2000	1	0	1700	19	0	0.1	0.0	0	10	6	0
New nuclear power plants	36	6200	1	0	4400	93	0	0.5	0.0	0	0	0	0
New hydropower power plants	70	2000	1	0	2300	58	0	0.5	0.0	0	0	0	0
New wind turbines power plants – offshore	40	2100	1	0	1600	26	0	0.1	0.0	0	0	0	0
New wind turbines power plants – onshore	40	4000	1	0	3000	93	0	0.1	0.0	0	0	0	0
District CHP plants:													
Hard coal-fired CHP plants – life extension	55	3495	0.33	4000	0	37	37	0.8	0.9	40	241	223	188
Hard coal-fired CHP plants – biomass co-firing	55	3495	0.33	1179	0	58	37	0.8	0.9	40	241	223	169
Gas turbine CHP plants – life extension	62	4100	0.71	2330	0	65	19	0.2	0.2	0	10	6	58
Hard coal-fired CHP plants – simple modern.	57	3495	0.33	0	160	37	37	0.8	0.9	40	241	223	188
Hard coal-fired CHP plants – simple modern. + gas turbine	55	3495	0.33	0	280	37	37	0.8	0.9	32	195	180	162
Hard coal-fired CHP plants – FBC	61	3495	0.33	0	950	37	37	0.8	0.9	40	24	76	188
Hard coal-fired CHP plants – simple modern. with biomass co-firing	55	3495	0.33	0	160	37	37	0.8	0.9	40	241	223	169
New coal-fired CHP plants	56	4200	0.33	0	1400	37	37	0.8	0.9	40	40	74	188
New gas turbines CHP plants	40	4100	0.33	0	470	19	19	0.2	0.2	0	10	6	58
New CCGT CHP plants	60	4100	0.33	0	770	19	19	0.2	0.2	0	10	6	58
New oil CHP plants	60	4100	0.33	0	770	19	19	0.2	0.2	54	70	63	149

Note: Industry CHP plants and municipal heat plants are not presented here. The net efficiency, load factor, cogeneration factor, capacity installed, and emissions coefficients for the existing energy technologies were estimated based on public energy statistics (The Energy Market Agency, 2019; 2019a; 2019b; 2019c; Polish Statistics, 2019).

Source: author's work.

The demand side is represented by the leading electricity and heat consumers, i.e. industry and construction, transport, agriculture, trade and services, and individual consumers. The goal of the model is to find the structure of energy production that will be optimal from traditionally perceived production costs or in a broader social context. So, the first approach assumes to achieve the cost-efficiency condition, i.e., satisfying the exogenously final energy demand at a minimal cost. The second approach is based on maximising social welfare, which is defined as the sum of consumer and producer surplus, less negative externalities produced by energy technologies. The last one was applied here. Table 1 presents the most important technical, economic and emissions parameters of all energy technologies implemented in the model.

The equations and the structure of the model are described in (Kudełko, 2020). The model is being upgraded to cover new environmental policy targets (new regulations), economic conditions (e.g. electricity demand, fuel prices) or technological changes (new technologies, investment costs decrease, conversion efficiencies, etc.). This version of the model is recalibrated to the latest production, economic and environmental data of the Polish energy sector. The module for sensitivity analysis has been introduced to recalculate risk parameters, such as CO_2 reduction targets, the price of CO_2 allowances and the costs of nuclear and RES technologies. Furthermore, the rate of implementation of new investments in RES and nuclear sources were updated, which allowed for a more detailed calculation of the optimal structure of energy generation. This made it possible to look at the RES structure again and examine these technologies, which did not work in the previous version.

The external costs estimates of air pollutants are based on (Kudełko, 2009) and (*New Energy…*., 2009). The Polish statistics are very incomplete, and an extreme effort is needed to calibrate the model to actual economic and production parameters. Therefore, own estimations were required to calculate the production, cost and emission parameters for the existing energy technologies. Generally, the model assumptions (i.e. demand forecasts, fuel prices, investment and operating costs of energy technologies, energy fuel supply data, etc.) correspond to the deductions taken from the official Polish documents (Ministry of Energy, 2021), domestic and foreign literature (Mrowiec, 2019; European Commission, 2020; Agencja Rynku Energii, 2016) and data published in the Polish energy statistics (see the Table 1 references).

Very few countries have set clear targets for the use of in power generation. Hydrogen also plays a minor role in the Polish electricity sector. Hence, due to the insufficient potential and lack of commercial applications – so far – in Poland, hydrogen has not been considered a competitive source of energy.

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The first 'base' scenario assumes that all environmental regulations are met (i.e., limits on production from RES – the target is 30% RES in the electricity-generation structure, the Industrial Emissions Directive (IED) standards for individual power plants, and the EU emissions trading system (EU ETS) for CO_2 emissions). This scenario is generally consistent with the assumptions of the Polish Energy Policy (Energy policy..., 2021). Furthermore, a CO_2 reduction target of 35% in 2035 is set. The intention was to illustrate a much deeper CO_2 reduction and thus a policy of gradual decarbonisation of the energy sector. It can be said that in this scenario, external costs are internalised by environmental regulation, which is not necessarily optimal in terms of efficiency.

In the 'int' scenario, the structure of energy production is a result of the internalisation of external costs suggested by economic theory (Pigou, 1932; Coase, 1960; Pearce et al., 1990). Using the ExternE methodology (Bickel et al., 2005) and own study for Poland (Kudełko, 2009), external costs were assigned to particular types of pollutants (€11,000/Mg for PM10, €6,000/Mg for NOX, €7,000/Mg for SO_2, and €25/Mg for CO_2). There are no environmental regulations here at all; the reduction of emissions and volume of energy production from RES technologies results from optimisation. In this way, the environmental rules implemented in the 'base' scenario are verified from the point of view of their efficiency. The model was run on the GAMS software package using the SIPLEX solver. Model statistics are presented in Table 2.

Table 2. Model statistics

Specification	Number
Block of equations	26
Single equations	66 457
Block of variables	17
Single variables	1 221 505
Non zero elements	2 941 101

Source: author's work.

Results of the research

Figure 2 presents the results of the computer simulations. In the 'base' scenario, existing hard coal-based and lignite-fired power plants are being drastically phased out. New coal-fired unitsare not built but are being replaced by new CCGT power plants. New biomass, biogas, and PV power plants (on a small scale), and mostly wind turbines (both offshore and onshore), fulfil the RES and CO_2 limits. The latter is to be the primary source of 'green' energy to meet the growing demand for electricity after 2030. Nuclear power is an efficient source of electricity after 2030, and it assures meet the required reduction of CO_2 emissions. Generally, the results correspond pretty well to the forecasts given in the official governmental documents (Energy policy…, 2021). The structure of electricity production from coal, RES and gas power plants is very similar in both studies. Nuclear power is being developed on a slightly larger scale due to a faster decarbonisation rate. These results are also comparable to (Departament Analiz Strategicznych, 2015) and (*Risk*…, 20018), which assumes a similar CO_2 reduction path.

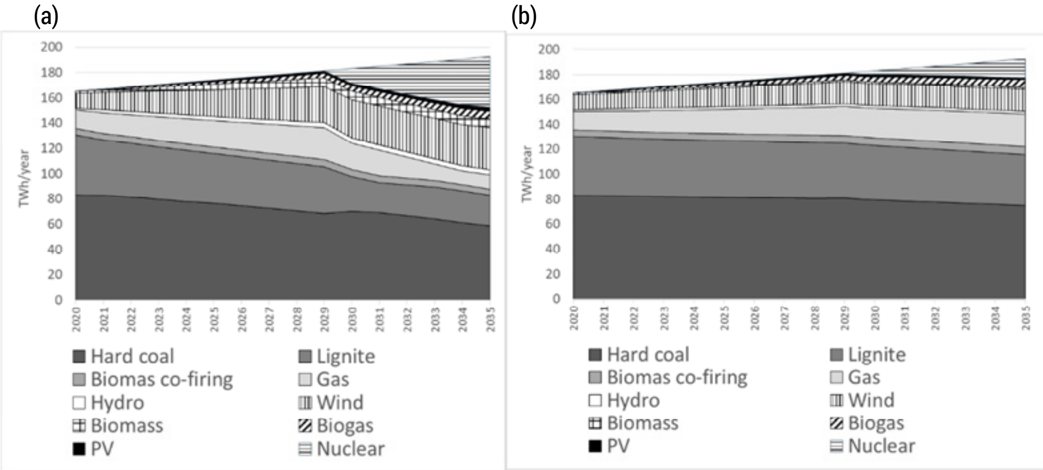

Figure 2. The structure of electricity production, TWh/year; (a) – 'base' scenario, (b) – 'int' scenario

Source: author's work.

In the 'int' scenario, the share of coal-based technologies in electricity production is falling much more slowly than in the 'base' scenario (Figure 2b). Carbon technologies account for about 60% of the energy mix in 2035 (43% in the 'base' scenario). The share of electricity production from RES sources is about 19% in 2035 (30% in the 'base' scenario). Nuclear power is growing on a smaller scale (8% of the total share, compared to 21% in the 'base' scenario). Consequently, CO_2 emissions do not decrease between 2020 and 2035 and remain at the same level of 119 million Mg. This suggests that either the climate policy objectives are too ambitious, or the marginal external cost of CO_2 is underestimated in the 'int' scenario. It will be discussed below.

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Table 3 shows the cost estimates of both scenarios. The social cost is the sum of generation costs (i.e., the sum of the investment, fuel, variable, fixed and abatement costs of energy technologies, excluding the costs of purchasing CO_2 allowances – as a financial transfer between power plants and the government) and external charges caused by the emission of air pollutants. The social costs in the 'int' scenario are 0.7% higher than in the 'base' (€187 billion compared to €185 billion) in discounted terms. This is the vast differences in the structure of electricity generation and significant different CO_2 emissions levels. Consequently, in the 'int' scenario, discounted generation costs are lower (€141 billion compared to €142 billion), while external costs are higher (€45 billion compared to €43 billion).

Table 3. The social costs of electricity production in system power plants, district and industry CHP plants (€ million)

Cost	2021-2025	2026-2030	2031-2035	Total – not discounted	Total – discounted
'base' scenario					
Generation costs	63 636	70 328	74 881	208 845	142 381
External costs	22 675	20 570	18 560	61 804	43 539
Total	86 310	90 898	93 441	270 649	185 920
'int' scenario					
Generation costs	63 706	68 874	74 863	207 442	141 469
External costs	22 207	22 009	21 674	65 890	45 694
Total	85 913	90 883	96 537	273 332	187 163

Source: author's work.

As noted, for the marginal external cost at a level of €25/Mg CO_2 in the 'int' scenario, CO_2 emissions remain virtually unchanged, and the structural changes in energy generation are relatively small compared to the 'base' scenario. This, in turn, suggests that either CO_2 emissions reduction targets and RES limits in the 'base' scenario seems to be too ambitious (which is somewhat questionable) or the marginal external cost assumed in this study is underestimated. A sensitivity analysis was made to verify this issue. It examined whether and to what extent the higher external cost of CO_2 would affect structural changes in the domestic electricity sector. The CO_2 allowance prices in the 'base' scenario were accordingly adjusted as well in order to maintain the assumptions comparable.

Table 4 presents the sensitivity analysis results for three levels of the marginal external cost of CO_2: €25, €50 and €65/Mg CO_2. An aggregate pic-

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ture of these simulations is the electricity production structure in 2035 and the social costs in 2020-2035. The general conclusion is that the higher the marginal external cost of CO_2 emissions, the greater the structural changes. At a €65/Mg CO_2, the energy generation structure and CO_2 reductions are pretty similar to the 'base' scenario (except for coal and gas technologies). It means that the climate policy leading to a gradual reduction of CO_2 emissions in Poland makes sense, assuming much higher external costs of CO_2 emissions (€65/Mg CO_2) than adopted in this study. The same conclusion can be drawn by analysing the level of CO_2 abatement costs in the 'base' scenario. These costs result from the structural changes in the Polish electricity sector. The average abatement costs of CO_2 in 2020-2035 is around €70/Mg CO_2, which is pretty consistent with the results presented above. Thus, all measures aiming to meet climate policy goals in the Polish electricity sector are reasonable if the abatement costs of CO_2 are lower than the external costs of CO_2.

Table 4. Sensitivity analysis

Parameters	RES,%	Coal,%	Nuclear,%	Gas,%	CO_2 reduction in 2035*, %	Generation costs increase, %	External costs increase, %	Total costs increase, %
'base' scenario	30	43	21	6	35	-	-	-
'int' scenario	€25/Mg CO_2							
	19	60	8	13	0	-0.6	5.0	0.7
	€50/Mg CO_2							
	26	43	19	12	23	-1.5	-2.4	-1.9
	€65/Mg CO_2							
	29	37	21	13	34	-3.9	-0.6	-2.5

*Comparing to 2020

Source: author's work.

Conclusions

The Polish electricity sector's scope and rate of structural changes strongly depend on the model assumptions, mainly the optimisation criteria. The optimisation procedure does not guarantee that such challenging changes will be implemented in the real economic policy. The decarbonisation of the Polish energy sector is a massive challenge for the entire economy, and there is no certainty that it will succeed.

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The 'base' scenario assumes gradual decarbonisation of the Polish electricity sector. A CO_2 reduction rate of 2.3% per year has been taken in 2020-2035, ensuring a 35% reduction by 2035. But even for this relatively short period, the projected structural changes are a tremendous effort. The results show that investments in new electricity generation capacities – mostly RES – over 2020-2035 are within a range of 2,500-4,000 MW/year, and investment costs are estimated at around €2.3 billion/year on average. In addition, the cost of purchasing CO_2 allowances is approximately €2-3 billion/year. However, to achieve zero-carbon electricity production in 2050, the rate of CO_2 emissions reduction would have to increase even further – to more than 4% per year after 2035.

Consequently, the RES investment plan would have to accelerate, which seems to be a complicated process, both from a technical and financial point of view. It also means that the Polish coal mines will have to be phased out by 2050. The Polish Government has signed an agreement with the miners' trade unions, which seems to guarantee the success of this process. However, it does not apply to the Polish coal-based power plants. Here, for several reasons, it is unclear whether and at what rate these plants will be closed. We know that investors do not plan to finance new coal capacities, and the government announced the early closure of the existing plants.

The decarbonisation pathway set out in the model assumes electricity generation from the nuclear power plant. The fundamental question is whether and when this investment will be made. This decision is up to the government, which must also consider a social resistance. Recent government declarations suggest that nuclear energy is gaining support among political decision-makers. It appears almost certain that a decarbonisation policy can not take place without nuclear energy, which also reflects this study's results. The investment was initially planned in 2030, which was assumed in this study. However, this deadline is already out of date, and the investment has been delayed for several years. Shifting this investment beyond 2030 makes decarbonisation policy impossible to implement.

Interesting findings come from the analysis of effectiveness of both scenarios. In the case of system power plants, EU environmental instruments like IED standards and RES limits are both effective and efficient. This is evident for SO_2, NO_X, and PM emissions, where abatement technologies are cheaper than negative environmental effects. However, this is not the case for CO_2. The climate policy leading to a gradual reduction of CO_2 emissions makes sense assuming much higher external costs of CO_2 emissions than reported until recently as the most likely values (see Bickel et al., 2005 and *New Energy...,* 2009).

The high uncertainty concerning the energy sector and the EU environmental policy programmes stimulates further modelling experiments. Firstly,

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it is necessary to extend the research period to 2050. Only then will it be possible to fully assess the potential structural changes and economic costs of the Polish energy sector decarbonisation. Secondly, there is growing concern about new hydrogen technologies and energy storage issues. So far, there are no reliable technological and cost details to include these technologies in the model as an effective measure to mitigate CO_2 emissions. Moreover, if we assume an extensive expansion of hydrogen, the volume of electricity production must be strongly revised as well (*Neutralna emisyjnie Polska…,* 2020). Thirdly, the potential and costs of RES and nuclear energy need to be continuously updated, which can significantly improve their competitiveness.

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ENVIRONMENTAL INSURANCE AND ISO 14001 ENVIRONMENTAL MANAGEMENT SYSTEMS – ANALYSIS OF THE WILLINGNESS TO IMPLEMENT SYSTEMIC SOLUTIONS RELEVANT TO INSURANCE

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ABSTRACT: The first purpose of the research was to assess the dependence between the organisational decision-makers willingness to implement systemic solutions relevant to insurance (RSSs) and the attributes (systemic, awareness-related and organisational) of an organisation managed in accordance with ISO 14001. Another purpose was to identify the motivators that drive entities to implement additional system elements.
Earlier studies suggest that the structures of currently implemented ISO 14001 EMSs should be modified in order to increase their utility for the process of insurance provision.
The research problem was solved based on data obtained through an online survey among organisations implementing and certified ISO 14001 EMSs in Poland. Depending on the type of variables, the independence chi-square test, U-Mann-Whitney test, and the test of Spearman's rank correlation, among others, were used for analysis.
The results of the study may help build integrated environmental risk management tools. They indicate the legitimacy of using non-insurance motivators (e.g. reduction of environmental fees) to achieve the desired EMS structure in the organisation from the insurers' point of view. At the same time, they emphasise the need to build environmental risk awareness (including, among other things, the risk of liability for environmental damage and its severity) to achieve the above.

KEYWORDS: environmental insurance, environmental management system ISO 14001

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Introduction

For over five decades, mankind has been dynamically engaged in building up the tools for managing environmental risk, unfortunately being somewhat uncoordinated and inharmonious in their actions (Lisowska, 2014). As a result, it is often impossible to benefit from the full potential of the proposed instruments. The article refers to the potential integration of two tools for environmental risk management: environmental insurance and environmental management systems according to the ISO 14001 standard (ISO 14001 EMSs).

In 2004, the EU implemented the directive on the environmental liability with regard to the prevention and remedying of environmental damage (ELD) (Directive 2004/35/CE). Article 14 of the Act urges the member states to encourage the development of financial security instruments to enable operators to use financial guarantees to cover their responsibilities under this Directive. The regular reviews of the Directive identify the ongoing problems relating to environmental insurance market development and indicate their potential solutions. In the most recent documents pertaining to this area, the European Commission has tackled the issue of the importance of the voluntary environmental risk management systems for the development of the financial security instruments market (European Commission, 2016; European Commission, 2017). The above assertion is the prime justification for the commencement of research devoted to the relation between environmental insurance and ISO 14001 EMSs.

ISO management standards (including the ISO 14001:2015 standard) are just a flexible framework for organisations' systems whose structures are contingent on decision-makers (Yin & Schmeidler, 2009). Consequently, ISO systems can be implemented in a way which takes into account the interests of environmental insurers. The decisions referring to this aspect are solely within the authority of the organisation's decision-makers.

The purpose of the research is the assessment of the dependence between the organisational decision-makers willingness to implement systemic solutions relevant to insurance (RSSs) and the attributes (systemic, awareness-related and organisational) of an organisation managed in accordance with ISO 14001:2015. Another purpose is the identification of the motivators (potential benefits that are recognised as motivating) for implementing the additional system elements.

The analysis was based on data obtained through an online survey among organisations that have implemented and certified ISO 14001 EMSs in Poland. Depending on the type of variables, the independence chi-square test, U-Mann-Whitney test, and the test of Spearman's rank correlation, among others, were used for analysis.

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Literature review

The relation between environmental insurance and environmental management systems in compliance with ISO 14001 standard has been analysed by scholars for over two decades. Soon after the publication of the ISO 14001 standard, its potential utility for the process of insurance provision was detected (Swiss Re, 1998; Environmental Protection Agency, 2006), and scientists initiated studies of the possible applications of ISO 14001 EMSs in the course of providing insurance services (Minoli & Bell, 2002a; Minoli & Bell, 2002b; Minoli & Bell, 2003). Nevertheless, despite the initially strong interest in the integration of the analysed environmental risk management tools, it was never completed in practice. According to the insurance sector representatives, a lack of uniform interpretations of the standard and divergent and unsatisfactory implementations of the systemic solutions in organisations constitute the essential barriers to applying ISO 14001 EMSs in the process of insurance provision (Lemkowska, 2020b).

Parallel to the insurance-related scientific approach to the systems managed according to the ISO 14001 standard, analysis was undertaken of the motivators of systems implementation in organisations, pointing to those involving expectations of reduced insurance premium (Sorooshian, Qi, & Fei, 2018; Zutshi, & Sohal, 2004; Jovanovic & Janjiz, 2018; Hajduk-Stelmachowicz, 2013; Matuszak-Flejszman, 2010). The research, however, was only limited to identifying the motivators for system implementation. The decision-making process was neither examined in the context of the factors determining such decisions nor in the light of economic theories concerning decision-making. The causative relations were only analysed in the context of the already reached outcomes of systemic management.

It is tough to anchor a decision-making process to implement an ISO 14001-based system within decision-making economic theories. The variety of motivators (extrinsic/intrinsic; economic/environmental), flexibility in the construction of the system framework, and the simultaneous difficulty in predicting the outcome of system implementation – all the above elements make the decision-making process barely susceptible to formalisation or modelling.

Limiting the analysed objects to the motivators for implementing only the selected system elements (as opposed to a decision to implement the system itself) may partly reduce the research difficulties. The flexibility of the structure of ISO 14001 – compliant systems enables them to perform a wide range of functions. The selected system elements can be therefore connected with a limited set of expectations because of which they have been implemented. The statement above explains the choice of the research subject area.

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The research to date proves that ISO 14001 EMSs implementation in any form does not by itself contribute to its utility for the insurance provision process. At the same time, however, a modification of the already implemented system (by complementing it with additional structural elements) may increase this utility (Lemkowska, 2020c). Therefore, the subject of this study is the willingness of decision-makers to implement the additional system elements.

However, within the present economic circumstances, the decision-making process that results in implementing these elements is burdened with various limitations (Hansson, 1994). Decision-makers do not know whether any desirable consequences will be brought about by the modification of ISO 14001 EMSs and what their nature will be; they have no guidelines as for how the environmental management system should be modified, and, finally, they are faced with a conflict of interests of the organisation's internal clients who pursue various goals due to ISO 14001 EMSs implementation. The above state of affairs renders the neo-classical theories of choice useless for the examined decision-making process. Expected utility rules were introduced as early as in the 18th century by D. Bernoulli (Makuch, 2012) and elaborated on in the mid-twentieth century by J. von Neumann and O. Morgenstern within the so-called normative theory of choice (Solek, 2010), propose an array of assumptions (Kotlarek, 2014) which are inadequate with regard to the situation in which the decision-makers have to make their choices in an ISO 14001 standard-managed organisation.

However, studies of the willingness to implement ISO 14001 EMS solutions relevant to the insurance process merge with behavioural theories of decision-making. They assume the existence of a rich, heterogeneous, individualised bundle of decision-making factors. Behavioural theories question the assumptions referring to decision-makers access to complete information and their full capability to interpret it, their unchangeable preferences[1], or sufficient numeracy to select the best option (Simon, 1955). Behaviourists also reject the assumption of the decision-makers substantive rationality, which means the assumption that subjects always have a pre-defined goal (e.g. maximisation of utility or profit) and pursue it rationally. Conversely, in behaviourists' opinion, a decision stems from complex thought algorithms which reflect the elaborate bundle of preferences instead of a limited set of mathematical decision axioms, the application of which guarantees maximisation of the expected utility (Simon, 1976)[2]. It is also counterfactual – according to behavioural theories – to claim that a decision-maker always

1 Assumption invalidated by Maurice Allais in 1953 in his experiment (Zaleśkiewicz, 2011).

2 Neoclassicists assume the rationality of market entities, whereas the market does not have the tools to generate the rationality of its entities (Mullainathan & Thaler, 2000).

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aims to maximise numerically designated benefits. Observations lead to a conclusion that entities make satisfying decisions which do not necessarily maximise benefits (so-called satisficing theory) (Hansson, 1994).

The neo-classical theories treated making non-optimum decisions as a marginal phenomenon; they are diversions from the model, but within the market *en masse,* they cancel one another out (Fama, 1998). The neo-classicists did not research the premises for making non-optimum decisions. Nevertheless, they constitute the prime area of interest of behavioural economics. According to assumptions of behavioural economics, among other factors, are the cognitive capabilities, emotions, thinking patterns, habits, timing, situational context and social mechanisms (Śliwowski, & Wincewicz-Price, 2019), which create a broadly understood decision-making environment (decision-making architecture) (Thaler, Sunstein, & Balz, 2013).

Mullainathan and Thaler (2000) point to three essential traits of a decision-maker in the behavioural approach: bounded rationality, bounded willpower (the entities make decisions which are not suitable for them in the long term) and bounded self-interest (the entities take decisions that benefit others). The bounded rationality concept was created in 1955 by Simon (1955), although the term itself was only used explicitly two years later (Barros, 2010). It means that the entities pursue rationality, but they are limited by cognitive, emotional and situational capabilities (e.g. attempting to achieve contradictory goals). Thaler (1994) uses the term "mental accounting" to refer to complex mental acts attempted by decision-makers which lead to arrangements, assessment and analysis of the decision-making situation. In the course of the evolution of behavioural theories, a range of heuristics was identified (simplified mental rules) (Kaczała, 2019), which led to the occurrence of cognitive bias (Makuch, 2012; Solek, 2010) and caused diversions from optimum choices derived from the neo-classical approach (Cossette, 2014).

The catalogue of heuristics and the resulting cognitive biases is not complete. In its primary form, Tversky and Kahneman (1974) identified three heuristics (representativeness heuristic, availability heuristic, anchoring-and-adjustment heuristic) to which they matched thirteen cognitive biases (Tversky, & Kahneman, 1974). The following studies within behavioural economics have led and are still leading to the extension of the above catalogue[3].

The assumptions of behavioural economics are used in the analyses of the risk management process. Heuristics and cognitive biases, which are derived from the attributes of the risk subject, are indicated in numerous

3 Selection of the most often analysed heuristics (Kaczała, 2019); overview of studies on that area (Cossette, 2014); a record-breaking number of researched heuristics may be attributed to Manimal's work (1992). He studied more than 600 heuristics, which he next reduced to 186 grouped into 57 sets.

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studies as a determinant of risk perception and risk control decisions (e.g. Slovic, Fischhoff & Lichtenstein, 1980; Janmaimool & Watanabe, 2014; Kaczała, 2019; Lemkowska, 2021) (Figure 1).

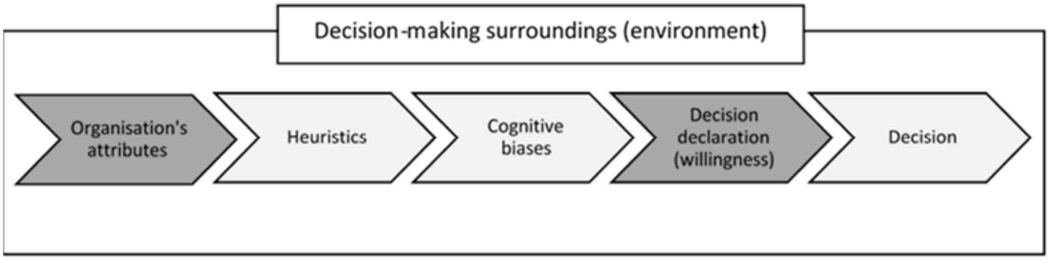

Figure 1. Elements of the decision-making process
Source: authors' work.

Behavioural economics helps explain anomalies which have remained beyond neo-classicists analysis (Solek, 2010) and have defied the mathematical tools which are unsuitable for a description of the full array of decision-makers' behaviours (Beed, & Kane, 1991). Behaviourists increase the realism of assumptions made for the sake of economic theories (Solek, 2010). Their assumptions are the fruit of observations of reality, and they do not result from the attempts to create simple mathematical models. Thanks to them, it is possible to break through the neo-classicists narrowness, rigidity and mechanical character (Tomer, 2007) and broaden the horizons of the analysis through the integration of economists' works with the accomplishments of psychologists[4], sociologists, anthropologists, cognitive scientists or even neurobiologists (Mruk, 2018). Another reason for the continuation of studies in the area of behavioural economics and compounding them with the analysis of the relationship between environmental insurance and ISO 14001 EMSs is that assumptions of behavioural economics were not created by the 20th-century economists. Their sources should be found amongst the classics of economics, i.e. in Smith's Theory of moral sentiments, in Bentham's works where the term of homo oeconomicus was created, or in Mill's paradigm of *homo economics* (Bogdanowicz, 2014; Solek, 2010; Camerer, & Loewenstein, 2004)[5]. Mathematisation has been dominating economics over the past decades, especially in the wake of V. Pareto's and his successors' accom-

4 The founders of behavioural economics are believed to be the psychology professors: Daniel Kahneman and Amos Tversky.

5 Some detect the sources of behavioural economics as early as in Xenophon's works (5th – 4th century BC), where he uses the term 'economics' while integrating within it the elements which today are attributed to psychological sciences (Bogdanowicz, 2014).

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plishments (e.g. J.R. Hicks', R.G.D. Allen's, P.A. Samuelson's), has to be accepted as one of the many in the history of economic thought, albeit neither the dominating nor the only correct way of explaining economic phenomena.

Research methods

To denote the objective scope of the research and identify the barriers to the decision-making process, it is essential to demarcate the stages of taking the decisions in the organisation.

The process studied here refers to the form of environmental management system in accordance with the ISO 14001 standard. The standard itself determines the form. However, due to its flexibility, it remains individualised depending on the organisation's boundary conditions (e.g. the applied technologies, identified relations with the elements of the environment), as well as implementation motivators[6]. The catalogue of systemic solutions (the form of ISO 14001 EMSs) is not circumscribed. The limitations in attempting to demarcate the studied decision-making problem amount to, among other things, an undefined list of alternatives in the decision-making process (there is no catalogue of systemic solutions which would be considered by the insurance sector to be helpful for the decision-making process), an undefined record of motivators (the decision-maker does not know what effect will be derived from the implementation of particular systemic solutions), an undefined decision time horizon (which changes, in particular in the area of the environment, along with the changing regulatory conditions about sustainable development).

Research to date has shown that the structure of the currently implemented ISO 14001 systems in Poland only scarcely reflects the insurer's requirements (Lemkowska, 2020a). Hence, insurance companies hardly ever consider systemic management when assessing the potential insured's risks. At the same time, theoretical analyses imply quite a large potential utility of these systems for insurance purposes and their relatively straightforward

[6] Research shows that the impact of EMSs implementation remains significantly dependent on the system implementation motivators. Environmental impact is inferior when obligatory extrinsic motivators dominate (Gavronski, Paiva, Teixeira, & de Andrade, 2013; Castka & Prajogo, 2013; Prajogo, Tang, & Lai, 2012). The obligation can be classified according to various criteria: according to the factual condition that it refers to, according to its origin, as well as the consequences of the lack of its realisation. The obligation can be realised concerning two factual conditions: ISO 14001 EMS implementation and certification itself or implementation of particular system elements. It may have an economic or legal dimension. In the first case, the source of obligation is legal regulations which provide for the consequences of the lack of ISO 14001 EMS implementation (e.g. more frequent inspections, obligation to obtain insurance for more significant sums of money). In the other case, the debt is created by the relations conceived within the economy. Modification of these relations is the sanction for failure to comply with this obligation (e.g. lack of permission to participate in a tender, potential lack of or inferior terms of insurance cover).

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adaptability to the insurance sector expectations. There are hardly any incentives for such an adaptation in the present situation.

The choice of systemic solutions is part of the environmental risk management process. The research assumes a particular decision-making scheme in the risk management process (Figure 1). The subject analysed is merely a fragment of the elements which build up this scheme. The present study encompasses the analysis of the correlation between the organisation's attributes, the types of motivators (incentives, potential benefits) and willingness to implementation of additional system elements. The set of motivators drives the decision-making environment of the organisation.

There are seventeen variables describing the organisation's attributes, divided into systemic, awareness-related and organisational variables (Table 1). The index of independent variables was created based on research results regarding the identity of the factors which lead to a positive environmental impact (such as reducing harmful emissions and lowering consumption of natural resources). Although the past twenty years of the history of ISO 14001 environmental management systems have seen numerous studies of their functioning in the economic reality (Lemkowska & Wiśniewska, 2021), the subject of the relation between the positive environmental impact and the attributes of an organisation managed according to ISO 14001 standards has hardly been analysed.

The limited number of studies which concerned the above were devoted to the assessment of the relation between positive environmental impact and the attributes such as the size of the organisation, its ownership (private/public), sector (manufacturing/service), stability/changeability of the applied technologies, amount of time for which the system has been in operation in a given organisation, possession of quality management system in conformity with ISO 9001, or finally, the external/internal motivation for the system implementation (Matuszak-Flejszman, 2010; Prajogo, Tang & Lai, 2012; Boiral & Henri, 2012; Christmann & Taylor, 2006; Fura, 2013; Castka & Prajogo, 2013; Gavronski et al., 2013).

Based on the above, a catalogue of features and independent variables was divided into systemic features, awareness-related features, and organisational features. The independent variables are presented in Table 1.

Table 1. The catalogue of independent variables

Vari-ables		Description	Measurement method/ categories
Systemic features			
I		Time span of systemic management	Qualitative variable, in ordinal scale Categories: 1) shorter than 5 years 2) 6-10 years 3) over 10 years
II	 a b c d	Motivator for implementation of EMS Linked to environmental insurance risk Linked to other environmental aspects Financial Extrinsic	Four binary variables, meaning that a given motivator has been indicated (1 – if indicated; 0 – if not indicated)
Awareness-related features			
III		Subjective evaluation of organisation's exposure to environmental risk	Ranked variable, in the 5-level Likert scale, where: 1 – definitely not exposed to risk 5 – definitely exposed to risk
IV	a b c d e f	Subjective evaluation of the likelihood of damage occurrence Loss catalogue: Group A in surface waters, in groundwater in land in protected species Group B emissions of substances into the air energy emissions	Six ranked variables, in the 7-level Likert scale, where: 1 – causing this damage is entirely unlikely 4 – it is hard to say 7 – causing this damage is extremely likely
V	a b c d e f	Loss experience (particular damage was caused in the past) Loss catalogue: as above	Six qualitative variables, in nominal scale. Categories: No, such damage was never caused I do not know if a given damage was caused in the past Yes, such damage was caused in the past
VI	a … f	Loss experience (payment of compensations to third parties experienced in the past as a result of causing particular damage) Loss catalogue: as above	Six binary variables, where: 1 – compensation was paid, 0 – compensation was not paid
VII	a … f	Loss experience (environmental damage remediation costs incurred in the past) Loss catalogue: as above	Binary variables, where: 1 – costs were incurred; 0 – costs were not incurred

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Variables		Description	Measurement method/ categories
VIII	 a b c d e f	Subjective evaluation of likelihood of bearing the particular consequences resulting from damage occurrence Catalogue of consequences: Claims due to damage to property caused by emission Claims due to damage to person caused by emission Environmental organisations claiming infringement of the environment as a common good Obligation to remedy environmental damage in water according to ELA (…) Obligation to remedy land damage according to ELA (…) Obligation to remedy environmental damage in protected species and habitats according to ELA (…)	Ranked variables, in the 7-level Likert scale, where: 1 – entirely unlikely 4 – it is hard to say 7 – extremely likely
IX	a b c d e f g h i j	Subjective evaluation of severity of the particular consequences resulting from damage occurrence Catalogue of consequences: Cost of conducting remediation (cr) in water Costs of cr in land Costs of cr in protected species (…) Volume of compensations paid on account of damaged property due to emissions Volume of compensations paid on account of damage done to person due to emissions Volume of compensations paid in response to environmental organisations' claims Loss of revenue due to breaks in operations Loss of reputation Legal costs Loss of permissions to conduct operations Loss of competitive advantage Loss of customers	Ranked variables, in the 7-level Likert scale, where: 1 – Minor and entirely not severe 4 – it is hard to say 7 – Major and extremely severe
X	a … j	Impact of legal acts on operations Catalogue of legal acts included 10 items	Ranked variables, in the 7-level Likert scale, where: 1 – entirely no impact 4 – it is hard to say 7 – extreme impact
XI	a b c d e	Impact of regulations on operations Catalogue of regulations: Regulations on environmental permits Regulations on emission caps Regulations on civil liability for consequences of environmental damage (…) Regulations on obligation to remediate environmental damage Regulations on disclosure of environmental information	Ranked variables, in the 7-level Likert scale, where: 1 – entirely no impact 4 – it is hard to say 7 – extreme impact

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Vari-ables	Description	Measurement method/ categories
XII	Insurance against environmental risk	Qualitative variable, in nominal scale Categories: Organisation has civil liability insurance with an environ-mental clause or another specialised contract Respondent does not know if the organisation has this type of insurance Organisation does not have this type of insurance
Organisational features		
XIII	Number of employees	Qualitative variable, in ordinal scale Categories: Fewer than 10 workers 11-50 workers 51-250 workers 251-1000 workers More than 1000 workers
XIV	Type of operations	Qualitative variable, in nominal scale Categories: Operations in a single location Operations in several particular locations Services provided in various locations
XV	EPL classification (the organisation has been classified as prone to large or increased risk of a serious industrial failure)	Binary variable (1 – yes, 0 – no)
XVI	ELA classification (the organisation has been classified as a user of the environment, running operations which create a risk of environmental damage)	Binary variable (1 – yes, 0 – no)
XVII A/B	Environmental permits	Two measurement methods: Binary variable, meaning: organisation requires at least one environmental permit (1 – yes, 0 – no) Quantitative variable – the number of required permits

Source: authors' work.

Because of the barriers to decision-making identified above, the respondents[7] were asked about their willingness to implement "additional system elements" without their further specification. However, the motivators for the elements' implementation were indeed specified. Therefore, the respondents were asked if the organisation was willing to introduce an additional system element to achieve a particular goal. The willingness referred to seven types of motivators[8]:

7 Persons responsible for ISO 14001 EMS in an organisation.

8 Respondent also had the opportunity to indicate additional motivators which would persuade them to modify EMS. There were the following indications: "meeting the contractors' expectations" (1 response) and "obtaining state support" (1 response).

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- group A consists of four non-insurance-related motivators (improvement of the organisation's image; reduction in environmental fees; obtaining tax reliefs; lowering other operating costs);
- group B consists of three insurance-related motivators (reduced insurance premium; increasing the scope of insurance cover; obtaining insurance premium subsidy).

First of all, the analysis was conducted about the correlation between the willingness to implement additional system elements and the organisation's attributes. To that end, willingness was described by two variables: (1) qualitative binary variable, denoting indication of at least one benefit from groups A or B, which encourages implementation of an additional EMS element – in brief, „WILLINGNESS"; (2) quantitative variable meaning the number of indicated motivators from groups A or B, further on denoted as "NUMBER OF MOTIVATORS".

The literature divides the motives for implementing EMS ISO 14001 into internal and external (Matuszak-Flejszman, 2007; Prajogo, Tang, & Lai, 2012; Boiral & Henri, 2012; Christmann & Taylor, 2006). Internal motives result from the organisation's own need to manage environmental aspects derived from environmental awareness, including awareness of environmental risks. External motives are, in turn, generated by various forms of coercion. Studies have shown that internal motives for implementing the ISO 14001 EMS were the most important determinant of achieving beneficial environmental effects (Gavronski, Paiva, Teixeira, & de Andrade, 2013; Prajogo, Tang, & Lai, 2012). Thus, they were the basis for the actual (material) rather than the formal implementation of the ISO 14001 EMS. The above leads us to assume that also internal (awareness) factors will be the main motivators for the implementation of additional system elements.

This hypothesis is also supported by studies from the area of risk perception determinants (not only the environmental one) and their influence on taking control actions in the risk management process (Slovic, Fischhoff & Lichtenstein, 1980; Breweret al., 2007; Kaczała, 2019; Toma & Mathijs, 2007).

Both research areas indicated above justify the formulation of the following hypothesis:

H1: Higher awareness of environmental risk (operationalised by awareness attributes of the organisation) increases the propensity to implement additional elements of the ISO 14001 EMS

Amongst the motives for implementing an ISO 14001 EMS, the literature identifies economic factors (e.g. reduction in environmental charges, taxes, waste management costs), contractual factors (e.g. ensuring the ability to deliver services/goods to the contractor) or legal factors (e.g. exemption from compulsory insurance, reduced frequency of inspections). The cata-

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logue of motives is also fed by insurance factors (i.e. reduction of the insurance premium or increased coverage). The order of their indication in the motives' studies is significantly later, and their frequency substantially lower than other factors (Environmental Protection Agency, 2006; Sorooshian & Fei, 2018; Zutshi & Sohal, 2004; Jovanovic & Janjiz, 2018; Hajduk-Stelmachowicz, 2013; Santos et al., 2016). At the same time, studies conducted on the Polish market show that insurance is still of little importance in environmental risk management (Hęćka, 2017). The above leads us to assume that also the propensity to implement additional elements of the ISO 14001 EMS will be more often motivated by non-insurance factors, which justifies the formulation of hypothesis 2.

H2: Non-insurance motivators are more likely to positively determine an organisation's propensity to implement additional elements of an ISO 14001 EMS

The type of statistical features, the number of observations and the distribution of responses became the significant criteria of choice for statistical tests and inference methods about the dependence (or correlation) between them. Therefore, in the case of a binary and qualitative dependent variable, "WILLINGNESS":

- the independence chi-squared test was applied whenever the independent variable was also qualitative and nominal scaled or was an ordinal variable but with a relatively low number of possible variants;
- U-Mann-Whitney test was applied in the case of qualitative but ranked independent variables with a relatively high number of variants (e.g. 1-entirely unlikely, ... 7 – very likely), as it was impossible to conduct an independence chi-squared test because of too small expected frequencies in some cells of a cross table.

In the case of quantitative dependent variable "NUMBER OF MOTIVATORS":

- U-Mann-Whitney test was used for dichotomous independent variables and the Kruskal-Wallis test if the qualitative organisation attribute had more than two variants. The choice of the nonparametric test was caused by a distinct asymmetry of the quantitative variable distribution;
- the test of Spearman's rank correlation was applied in the case when the independent variable was quantitative or qualitative but ordinal one (with a relatively high number of variants); this choice was determined by the rank character of organisation attributes and also by the distribution of the variables (it wasn't normal).

What is more, whenever drawing conclusions concerning the features' correlation required multiple testing in pairs, the Bonferroni correction was applied. In all the cases, the correlation (or dependence) was considered significant when the p-value of a given test did not exceed the statistical significance level of 0.05.

The other stage of the analysis was focused on particular types of motivators. At this point, it was investigated which potential benefits turned out to be motivating enough for an organisation to declare willingness to implement additional elements of EMS. Significantly, the frequency of indication of particular motivators was examined. Establishing sub-groups in the sample made it possible to verify whether the proportion of respondents willing to implement additional EMS features depends on the motivator type (therefore, the test of equality of proportions was carried out for each pair of motivators). Due to multiple pair comparisons, Bonferroni's correction was applied.

The analysis of the indicated motivators also let to find out how many of the motivators were selected by particular organisations and which motivators were connected to each other. The connection between motivators was reflected by the fact that they were chosen simultaneously as motivating to implement additional EMS elements. In order to evaluate the dependence between the motivating factors, for all the possible pairs of „potential motivators", values of conditional probability were estimated, i.e. a chance that a given „benefit" would be considered to be motivating to implement an additional EMS element on condition that the respondent thought another "benefit" as inspiring. The probabilities were estimated as fractions inappropriately defined sub-samples.

The data for the analysis was obtained using an online survey (October 2018 – May 2019). The invitations to participate in the survey were sent to 1612 organisations which had been certified for ISO 14001:2015 EMSs in Poland. 121 complete responses were returned. Enterprises employing from 251 to 1000 employees (33.06%) and from 51 to 250 employees (28.1%) were the most numerous groups in the sample. Only 7.5% of the surveyed organisations belonged to the category of "prone to large or increased risk of a serious industrial failure" (classification according to Environmental Protection Law), and 15.7% constituted an organisation classified as a "user of the environment, running operations which create a risk of environmental damage" (classification of the Environmental Liability Act).

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Results

The results of tests regarding dependence between the willingness and organisation's attributes have been presented in Table 2; detailed findings (including the p-value given in brackets) were only mentioned if the dependence (correlation) could be considered statistically significant. The analysis discovered only a few statistically significant dependences between the organisation's attributes and the „WILLINGNESS" variable. The scarcity of these dependencies may result from the fact that most respondents (79.2%) declared thus measured willingness to implement additional system elements for at least one motivator.

Far more statistical dependencies (and correlations) were found when the research pertained to the correlation between "NUMBER OF MOTIVATORS" and the organisation's attributes. The detailed findings (Table 2) show that the correlation coefficients are positive. This means that the higher the rank attributed to the likelihood of loss occurrence as well as the level of the particular impact and loss severity, along with the highly ranked influence of legal acts and regulations concerning environmental liability, the more frequently the organisations declared willingness to implement additional system elements in order to obtain a given benefit (the number of motivators increases). At the same time, the values of correlation coefficients are not very high, which means that even though the correlations are statistically significant, they are not strong.

It should be added here that although being insured against environmental risk did not affect either the „WILLINGNESS" or „NUMBER OF MOTIVATORS", organisations which have acquired this kind of insurance declared with significantly greater frequency than others that they were willing to implement an additional EMS element to obtain an insurance benefit (73% cases vs 27% cases). Organisations in possession of environmental insurance, at the same time, indicated a more significant number of insurance-related motivators (on average, 2 out of 3 motivators in group B) than organisations which did not have this kind of insurance (the average amounted to 0.6).

It also turned out that the "NUMBER OF MOTIVATORS" was additionally contingent on the motivators which drove the implementation of the system. The increase in the value of this variable was affected by the fact that EMS was introduced for reasons related to environmental insurance risk, other environmental aspects as well as financial issues. Moreover, the number of indicated motivators was significantly higher when the organisation needed to obtain a permit to conduct its activities. However, the number of tickets itself did not affect the number of motivators.

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Table 2. Dependences between willingness to implement additional system elements and organisation's attributes (the table omits the variables for which no statistically significant correlations were detected)

		Are they willing (indication of at least one motivator)? *	For how many motivators are they willing?*
I		Lack of dependence (l/d)	Lack of correlation(l/c)
II	a	(l/d)	Significant dependence (0.028)
	b	(l/d)	Significant dependence (0.048)
	c	(l/d)	Significant dependence (0.048)
	d	(l/d)	(l/c)
III		(l/d)	rS: -0.2 (0.025)
IV	a	(l/d)	rS: 0.197 (0.031)
	b	(l/d)	(l/c)
	c	(l/d)	(l/c)
	d	(l/d)	rS: 0.185 (0.043)
	e	(l/d)	(l/c)
	f	(l/d)	rS: 0.237 (0.009)
VIII	a	(l/d)	rS: 0.242 (0.008)
	b	(l/d)	rS:: 0.269 (0.003)
	c	(l/d)	rS: 0.192 (0.035)
	d	(l/d)	rS: 0.247 (0.007)
	e	(l/d)	rS: 0.228 (0.018)
	f	(l/d)	(l/c)
IX	a	(l/d)	rS: 0.208 (0.023)
	b	(l/d)	(l/c)
	c	(l/d)	(l/c)
	d	(l/d)	rS: 0.244 (0.008)
	e	(l/d)	rS: 0.191 (0.037)
	f	(l/d)	rS: 0.192 (0.036)
	g	Significant dependence (0.001)	rS: 0.360 (0.000)
	h	Significant dependence (0.002)	rS: 0.328 (0.000)
	i	Significant dependence (0.012)	rS: 0.353 (0.000)
	j	Significant dependence (0.029)	rS: 0.305 (0.001)
	k	Significant dependence (0.001)	rS: 0.362 (0.000)
	l	Significant dependence (0.002)	rS: 0.357 (0.000)
X	a	(l/d)	(l/c)
	b	(l/d)	rS: 0.183 (0.046)
	c	(l/d)	(l/c)
	d	(l/d)	rS: 0.193 (0.035)
	e	(l/d)	rS: 0.202 (0.027)
	f	Significant dependence (0.036)	rS: 0.181 (0.048)
	g	(l/d)	(l/c)
	h	(l/d)	rS: 0.19 (0.038)
	i	(l/d)	(l/c)
	j	(l/d)	(l/c)
XI	a	(l/d)	(l/c)
	b	(l/d)	(l/c)
	c	(l/d)	rS: 0.206 (0.024)
	d	(l/d)	(l/c)
	e	(l/d)	rS: 0.196 (0.033)

		Are they willing (indication of at least one motivator)? *	For how many motivators are they willing?*
XII		(l/d) Significant dependence in group B (0.010)**	(l/c) Significant dependence in group B (0.005)**
XIII		(l/d) (not enough observations)	Significant dependence (0.027) – the largest numbers of motivators were indicated by organisations 51 – 250 and 250 – 1000
XVII	A	(l/d)	A: Significant dependence (0.019)
	B	(l/d)	B: Lack of correlation between the number of permits and the number of motivators.

*in brackets the p-values are given unless they exceed 0.05; r_S – the values of Spearman's rank correlation coefficient (displayed if significant)
** the analysis limited to group B motivators
Source: authors' work.

Further analyses proved that seven potential motivators were relatively frequently considered to be convincing to implement an additional EMS element (24.2% cases). Such a situation was more common than when no motivator was indicated (Figure 2).

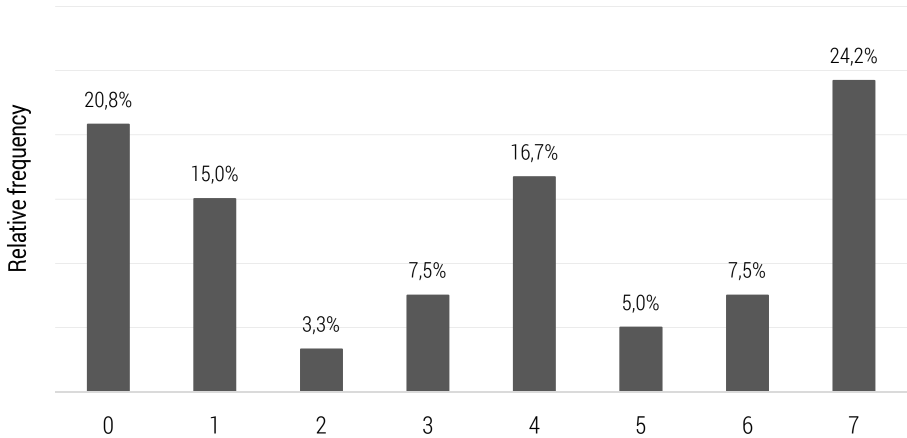

Figure 2. Distribution of the number of indicated motivators for implementation of additional system elements

Source: authors' work.

It should be emphasised that the overall percentage of indications for a particular motivator was not always similar (Table 3). The largest group – as many as 68.5% of the respondents were willing to implement an additional EMS element in order to enhance the organisation's image. Many organisations (65.8%) would like to reduce operating costs in this way. It is meaningful that insurance-related motivators (group B) were indicated relatively more seldom; in this group, the most frequently selected motivator was the reduced insurance premium.

Differences in frequency of indications of particular motivators suggest a hypothesis that the declared willingness to implement an additional EMS element is contingent on the given motivator. This hypothesis concerning the correlation between willingness and the motivator type was corroborated by means of the equality of two proportion test. In Table 3, the highlighted boxes mark the cases where the proportions of those willing to implement additional EMS elements are significantly different. The results once more point to the disparity between group A (motivators unrelated to insurance) and group B (insurance-related motivators).

Table 3. The percentage frequencies of particular motivator indications and p-values for the equality of two proportion test

Motivators	non-insurance motivators				B – insurance motivators			Sample proportions
	a	b	c	d	e	f	g	
a	1.0000	0.0460	0.0178	0.6816	0.0001	0.0000	0.0000	68.3%
b	0.0460	1.0000	0.6985	0.1142	0.0402	0.0001	0.0005	55.8%
c	0.0178	0.6985	1.0000	0.0050	0.0968	0.0005	0.0019	53.3%
d	0.6816	0.1142	0.0050	1.0000	0.0004	0.0000	0.0000	65.8%
e	0.0001	0.0402	0.0968	0.0004	1.0000	0.0622	0.1452	42.5%
f	0.0000	0.0001	0.0005	0.0000	0.0622	1.0000	0.6907	30.8%
g	0.0000	0.0005	0.0019	0.0000	0.1452	0.6907	1.0000	33.3%

Source: authors' work.

As it has already been said, organisations often indicate a few potential motivators. The estimated conditional probabilities that particular motivators were indicated, presented in Table 4, show that there are correlations between the motivators: if one of the potential benefits appears to motivate the organisation, it increases the likelihood of another benefit also becoming a motivator for implementation of an additional EMS element. The strength of this correlation, once again, depends on the motivator type. The lowest conditional probability values were obtained in the case of benefits marked e, f and g (group B of motivators). Consequently, if the organisation was willing to implement an additional element for reasons unrelated to "insurance" (e.g. in order to gain a tax relief or to enhance the company image), it does not imply a substantial likelihood of recognising the insurance-related motivator (e, f or g) as convincing. Hence, group A of motivators (a-d) does not remarkably affect group B motivators' choice. There is, however, an inverse correlation: the selection of a motivator in group B implies that all the other potential benefits (both from group A and B) are highly probable to be recognised as motivating.

Particularly high values of conditional probability for group B motivators were obtained in columns f and g, which means that there are strong correlations in the group of insurance-related motivators; e.g. if it is known that benefits f and g are motivating for the organisation (i.e. an increase in the scope of insurance or obtaining an insurance premium subsidy), it is practically certain that a reduced premium will also turn out to be motivating. (Table 4).

Table 4. Estimates of conditional probability values for pairs of potential motivators

Estimate of the conditional probability that the motivator will turn out to be:	if it is known that the motivator is also…							Overall fraction of cases when a benefit was recognized as motivating
	a	b	c	d	e	f	g	
a – enhancement of company image	1.00	0.91	0.91	0.86	0.90	0.95	0.93	0.68333
b – reduced environmental fees	0.74	1.00	0.89	0.84	0.86	0.89	0.85	0.55833
c – obtaining a tax relief	0.71	0.85	1.00	0.80	0.92	0.92	0.90	0.53333
d – reduced operating costs	0.83	0.99	0.98	1.00	0.98	0.97	0.98	0.65833
e – reduced insurance premium	0.56	0.66	0.73	0.63	1.00	1.00	0.98	0.42500
f – increased scope of insurance	0.43	0.49	0.53	0.46	0.73	1.00	0.88	0.30833
g – obtaining an insurance premium subsidy	0.45	0.51	0.56	0.49	0.76	0.95	1.00	0.33333

Source: authors' work.

A similar situation can be seen in the case of group A motivators (a-d). Suppose it is known that any of the group A motivators was considered convincing. In that case, the likelihood of another group A motivator being convincing is very high – it often reaches beyond 0.9. The weakest influence on the selection of other motivators can be noticed in the case of motivator a, which refers to the enhancement of the company image.

Conclusions

Information about the willingness to implement additional elements of ISO 14001 EMS and its determinants make it possible to model the decision-making process in organisations managed in compliance with ISO 14001 standard. Planned system restructuring can directly facilitate the increase in ISO 14001 EMS utility for the process of providing insurance cover (i.a., through the supply of the indispensable information for risk assessment or through physical control of risk). On the other hand, it may indirectly translate into the fulfilment of the demand relating to article 14 of ELD, which urges the EU member states to create the conditions for the development of financial instruments which may constitute a safety mechanism for remediation commitments, implied by the directive, concerning the damaged elements of the environment. In this context, restructuring the EMS according to ISO 14001 facilitates environmental risk management, which is one of the duties on the agenda for sustainable development within the EU.

The interested parties in the studied decision-making process may become its architects. The identified correlations point to the areas which are particularly relevant to the opportunity for deliberate modification of ISO 14001 EMS. The results of the study confirmed both previously stated hypotheses.

Firstly, a more frequent impact of non-insurance motivators was discovered on the declared willingness to implement additional elements of EMS. This means that the direction of change in the structure of environmental management, even if it is aimed at an increase in system utility for the process of insurance provision, should be stimulated not only by insurance-related motivators but also by motivators which appear to be more discernible for the organisation decision-makers (e.g. tax reliefs, reduced environmental fees or other factors which lower the costs and enhance the organisation's image at the same time). Insurance-related motivators present themselves as relevant, but it is true only for the group of organisations which have already signed environmental insurance contracts. They constitute a meagre percentage of the studied entities (15.3%). The survey did not produce results which would imply that the lack of insurance can stem from the lack of exposure to environmental risk or it is related to limited legal and insurance awareness. Nevertheless, considering the conclusions of previous studies, which point to the low understanding of the demand side as the prime barrier to the development of the insurance market (European Commission, 2016; Hęćka, 2017), one can assume that some of the researched organisations most probably did not sign an insurance contract despite the exposure to environmental risk. Exclusive use of insurance-related motivators for planned restructuring of ISO 14001 EMS might, in fact, preserve the "lack of awareness" trap, as it would be effective only with regard to entities which have – thanks to signing the insurance contract – actually proved such awareness. On the other hand, creating a system of non-insurance incentives is rather complex, as it requires commitment not only from the insurance sector but also from the owners of the motivating instruments (including the state in particular, but also environmental organisations which support the company image).

The research findings clearly suggest that except for the development of an effective motivator system, what strengthens the willingness for ISO 14001 EMS transformation of the organisation is the awareness-related attributes of the organisation. Organisations which ranked highly the subjective evaluation of the likelihood of damage occurrence (a, d, f), subjective evaluation of the likelihood of bearing particular consequences of the damage (a-e) or those which ranked highly the subjective evaluation of the severity of these consequences indicated more motivators which potentially could persuade them to implement additional ISO 14001 EMS elements. Also, more motivators were indicated by organisations which highly ranked the impact of most of the environmental legal acts on their operations, the impact of the regulations pertaining to civil liability for the consequences of environmental damage, as well as the legislation referring to obligatory disclosure of environmental information.

It is worth stating that the rare significant statistical correlations for the variable (1) describing the willingness to implement additional EMS elements (indication of at least one motivator) were identified in the area of variables describing awareness-related attributes of organisations. The sentence above refers to variants g-l of the variable "subjective evaluation of the severity of the particular consequences resulting from damage occurrence" and the variant f (act on environmental damage prevention and remediation) of the "impact of legal acts on operations" variable. Out of all the legal actions mentioned in the research, it is the latter that most remarkably determines the scope of insurance cover. High evaluation of its effect on the organisation's activities coupled with greater willingness to implement additional system elements emphasises how important it is for the process of integration between environmental insurance and ISO 14001 EMSs to develop legal awareness.

What is quite astonishing, though, is the outcome of the analysis of the correlations in the area of the "subjective evaluation of the severity of the particular consequences" variable. Significant correlations with the variable (1) of willingness were mainly discovered in those of its variants which do not pertain to the scope of insurance in the currently offered environmental insurance products (i.e. loss of reputation, loss of permissions to conduct operations, loss of competitive advantage or loss of customers). The variants „loss of revenue due to breaks in operations" and "legal costs" are the only ones which are found within the scope of insurance and, at the same time, in significant statistical correlation with the variable (1) of willingness. Focussing on the development of awareness regarding these two types of consequences of environmental damage may therefore lead to an increase in

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organisations' flexibility towards adapting their systems for insurance protection purposes.

The range of correlations described above leads to a multifaceted perception of the issue concerning the integration of the studied environmental risk management instruments. On the one hand, the addition of the insurance-related motivators to the array of incentives will be possible if the ecological awareness increases and leads to a greater frequency of finalising environmental insurance contracts. On the other hand, emphasis placed on the consequences of ecological damage not directly covered by insurance results in organisations' greater willingness to implement additional ISO 14001 EMS elements. Therefore it seems to make perfect sense – in the process of awareness development – to point at the indirect importance of insurance for minimisation of such consequences of damage as loss of customers, loss of competitive advantage, reputation or permissions to conduct operations.

As both the current study and previous analyses show, integration of ISO 14001 EMSs and environmental insurance seems to only be attainable in the long-term perspective (Lemkowska, 2020a; Lemkowska, 2020b) once multiple groups of stakeholders (insurance companies, the state, environmental organisations) have been involved in the process. Their commitment should be aimed at fostering organisations' insurance awareness and making the conditions of the decision-making process that will take place there increasingly accurate and precise. It is essential both to indicate the expected systemic solutions which will facilitate providing insurance cover and to build up a catalogue of motivators for implementing thereof. In view of the very meagre interest expressed by insurers themselves (Lemkowska, 2020b) due to i.e. the relatively small size of the environmental insurance market in Poland, the dominant role should be played by the public institutions. The fact that the EU agenda mentions environmental damage issues within the realm of sustainable development makes one anticipate an increase in the activism of various stakeholder groups in this area in the near future. The research findings suggest, at the same time, the validity of initiating integration measures in companies employing between 50 and 1000 workers in the first place. It was these organisations that indicated the largest numbers of motivators for which they were willing to implement the additional ISO 14001 EMS elements. The same is true for the entities which named among the incentives for system implementation the motivators connected with environmental insurance risk.

Further research should first of all be aimed at a precise description of the environment of the decision-making process studied here (the systemic elements applicable in the course of providing insurance cover; the willingness of the stakeholders to generate motivators for the decision-making process). The subjective scope of such studies should encompass the architects

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of decision-making, i.e. stakeholder groups which represent the insurance sector as well as public institutions. Secondly, the economic efficiency and environmental effectiveness of the suggested ISO 14001 EMSs modifications should also be subject to analysis.

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The contribution of the authors

Lemkowska M. developed the concept and assumptions of the research and conducted the online survey, which was the source of data analysed.

Wiśniewska D. worked out the statistical methods used to analyse the data.

Both authors prepared the conclusions part of the article.

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STUDIES AND MATERIALS

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HOW VIEWING A FOREST AFFECTS WILLINGNESS TO PAY OF USERS AND NON-USERS IN CONTINGENT VALUATION METHOD?

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ABSTRACT: In Contingent Valuation studies, users generally declare willingness to pay (WTP) higher than non-users. This study attempts to investigate if viewing the good during CV survey has a different impact on users' and non-users' WTPs. A framed field experiment was conducted in which users and non-users were surveyed in two locations – one with a view of the forest and the other without it. Our study showed that the WTPs of users were significantly higher than those of non-users only when respondents did not see forest during the survey. However, when the experiment was conducted in a location where the respondents could see the forest – the difference disappeared. Our results also show that the relationship between declared WTP and both the respondents' socio-demographic status and their environmental attitudes were weaker among respondents surveyed in a location with a forest view. We believe that the increase in WTP of non-users is temporary and represents a kind of bias. This in turn may be relevant in the design of CVM studies.

KEYWORDS: contingent valuation method, forest valuation, willingness to pay, user status, view of a good

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Introduction

The growing scale of the environmental and climate crisis has made the economic value of environment the subject of numerous scientific studies but also of growing interest to policy makers. For this reason, economic accounts for the environment, including forests, have been developed and systematically expanded: at the international level within the System of Environmental-Economic Accounting (2014) and in the European Union as the European Framework for Integrated Environmental and Economic Accounting for Forests (Eurostat, 2002). Legislative work is currently underway to extend the European Environmental Economic Accounts by adding some new modules, including forests. While these environmental accounts currently focus on market transactions, there is a strong possibility of adding non-market environmental services as well. However, this would require more knowledge about the monetary valuation of these goods and services. The methodological issues related to the valuation of the environment have therefore become not only scientific matter, but also a matter of practical importance.

The Contingent Valuation Method (CVM) is a method used to value environmental goods based on stated preferences. One feature of the CVM is that the set of information possessed by the respondents affects their declared WTP. It is known that users generally declare higher WTP than non-users. First, users express both use and non-use value. Second, for users, the experience or familiarity with a good is generally higher than that of non-users. This has lead us to the question if non-users who become familiar with the good under valuation (meaning they can see the good while taking the survey) still declare WTP lower than users. The environmental good in our study is a protected forest located in north-eastern Poland – the Knyszyn Forest. The following research questions have been formulated:

1. Is there a difference in the willingness to pay for the protection of the considered forest among users and non-users?
2. Does the user-status affect the WTP equally when the survey is conducted in a location with and without a view of the forest?
3. Does the level of WTP sensitivity to the socio-demographic profile of respondents change when the survey is conducted in a location with and without a view of the forest?

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Literature review

The Contingent Valuation Method (CVM) is one of the stated preference methods that has been widely applied for the assessment of social preferences of goods in cases where market valuation is difficult or impossible. This often occurs with environmental goods. In the CVM a hypothetical scenario is constructed to show the respondents what they will receive in exchange for payment. The survey results are then usually generalized to generate estimates for WTP in general population.

In a CVM survey respondents declare their willingness to pay (WTP) for valued goods based on some set of information that may be endogenous or exogenous. Endogenous information comes from past experiences, like familiarity and personal behaviours while exogenous information is provided through the survey design (Cameron & Englin, 1997; Berrens et al., 2004). One feature of the CVM is that the set of information possessed by the respondents affects their declared WTP (Arrow et al., 1993; Bateman et al., 1993). Having direct experience with a good usually results in higher WTPs (Gilbert, 1992; Blomquist & Whitehead, 1998; MacMillan et al., 2006; LaRiviere et al., 2014).

Exogenous information (usually objective information) also has a proven impact on WTP (Blomquist & Whitehead, 1998; Bergstrom et al., 1990; Napolitano et al., 2008; Toma et al., 2012; De Steur et al., 2013; Lusk, 2004). But some authors, including Cameron and Englin (1997) claim that information in the questionnaire is not equivalent to previously acquired information especially for goods with a large component of use value. A similar conclusion can be drawn from the work of Whitehead et al. (1995) where respondents who had not initial information declared the lowest WTP and users declared the highest WTP, with people who possessed theoretical knowledge of the good in between.

The view of a good (or some of its characteristics) raises the WTP declared by respondents, which is often analyzed in the context of valuations in the real estate market (Xiao et al., 2016; Mittal et al., 2019; Lifang et al., 2020) or tourism (Weber et al., 2002), landscape preferences (Mittal et al., 2019; Bishop & Rohrmann, 2003; Campbell et al., 2009; Sayadi et al., 2009). As a rule, in these studies respondents were provided with various visual materials (photographs, films, virtual tours) depicting the good in question in different versions. Providing such information increased respondents' valuations and the increment was even larger when those images were more attractive or were more realistic (Bishop & Rohrmann, 2003; Shi et al., 2020), e.g. computer simulations and virtual reality presentations have a greater impact than photos (Kroh & Gimblett, 1992; Sevenant & Antrop, 2011; Xiang et al., 2021).

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Physical proximity to a good is also a way of providing view of a good. According to literature (Sutherland & Walsh, 1985; Jørgensen et al., 2013; De Valck et al., 2018) it also increases the declared WTP. The impact of the physical proximity to a good on respondents' answers can be seen in studies that compare the answers of participants questioned at a good's location (on-site surveys) and those questioned in different locations (off-site surveys) (Bishop & Rohrmann, 2003; Shi et al., 2020; Xiang et al., 2021; Brown et al., 1989; Gyllin & Grahn, 2015). For example, in a study carried out by Xiang et al. (2021), the WTP of on-site respondents was higher than those of off-site participants. Studies comparing the preferences of on and off-site respondents were only carried out among users of goods (Xiang et al., 2021) or their status (user or non-user) was not taken into consideration (Bishop et al., 2003; Shi et al., 2020; Gyllin & Grahn, 2015). According to our knowledge, there have been no studies using CVM that consider how being able to see the good affects valuations of users and non-users.

Users usually include people who have had a direct experience with a good in question (Cameron & Englin, 1997; Sutherland & Walsh, 1985; Schaafsma, 2012; Jørgensen et al., 2013; Kniivilä, 2006). The user status may also be analyzed as a multidimensional continuum that considers a varying scale of experiences connected to a given good, for example, the number of years for which it had been used (Cameron & Englin, 1997) or way of using the good (Whitehead et al., 1995). Whitehead et al. (1995) assumed that the limited validity of assessments is the result of incomplete information and thus defined non-users as people who have no information about the good other than that obtained as part of the CVM study. Significantly, they found that non-users did not answer WTP questions in a theoretically predictable way. For example, they did not consider budget constraints. Therefore, WTP declared by on-site users was both more reliable and higher than WTP stated by off-site users and non-users. Next, Schaafsma et al. (2012) found that, compared to users, non-users' preferences are less sensitive towards the distance to the good. The demand of users declines faster the farther away they are from the good which can be explained by the greater impact of distance on the use value as compared to the non-use value.

Surprisingly, Kniivilä found no significant difference between users and non-users in their likelihood to support continued conservation in Finland (Kniivilä et al., 2006). This could have been caused by a change in the way the WTP questions were asked. Respondents were presented with two forms of WTP questions, one referring to personal utility and the other emphasizing the social benefits. Responses to the second version of the question showed that user and non-user responses could be similar.

Research methods

Our study investigates the impact of two sources of information in a CV survey: the user status and the view of a good in question during the survey. A framed field experiment (Harrison and List, 2004) was conducted. The study was carried out in two towns: Supraśl (experimental group) and Tykocin (control group). Supraśl is located on the edge of the Knyszyn Forest and the survey was conducted in a location where this forest was visible. Tykocin is approximately 50 kilometers from the Knyszyn Forest and the survey was conducted in a location where respondents could not see this nor any other forest. We have chosen these towns as they are similar in terms of size, socio-economic profile and role in the regional economy, including tourism. As the basic method of our study was an experiment, we used a simplified form of CVM. As a result, we do not estimate the value of the forest based of the survey results but analyze the differences between the experimental group and the control group assuming that possible bias affect both groups in a similar way.

Our basic control variable was user status. We defined a user as a person who had made use of the given object in the past and, therefore, had directly experienced the good (similarly to Sutherland & Walsh, 1985; Schaafsma et al., 2012; Jørgensen et al., 2013; Kniivilä, 2006). In order to obtain a similar proportion of users and non-users and keep the relative homogeneity of the study groups we interviewed only tourists defined as people declaring a place of residence other than the town in which the survey was conducted.

Table 1. Composition of the research sample for implemented treatment options (including protesting respondents)

Types of respondents	Treatment options		Total
	with a view of the forest (experimental group)	without a view of the forest (control group)	
Users	123	120	243
Non-users	120	121	241
Total	243	241	484

Source: authors' work.

The empirical CVM application dealt with the Knyszyn Forest – a vast forest complex (about 1050 km^2) located in the Białystok Upland within the Podlaskie Voivodship (North-Eastern Poland). The forest covers areas of the terminal moraine with the Supraśl River as well as its tributary, the Sokołda River flowing through them. Dominant species of trees include pine, spruce,

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birch, alder, and oak. Since 1974 it has been a refuge to European bison. In 1988 the Knyszyn Forest Landscape Park, which includes 19 nature reserves, was established.

Data for the study was collected through paper and pencil interview (PAPI). The questionnaire consisted of 16 questions concerning (a) user status, (b) WTP, (c) control question of „protest zeros", (d) environmental attitudes and (e) the respondents' socio-economic background. The first part of the questionnaire (a-c) was filled in by interviewers and part d-e, i.e. sensitive questions by respondents themselves.

We attempted to limit the scenario to 500 characters to balance the amount of information provided and the respondents' involvement and cognitive burden (Schaafsma et al., 2012; Rolfe et al., 2002). Respondents received general information about the Knyszyn Forest and were familiarized with threats to the functioning of the forest's ecosystems caused by the lowering of groundwater tables. Moreover, a general map of the Knyszyn Forest was shown.

The payment vehicle took the form of a one-time fee that would be added to the water bill. We decided that, considering the compelling arguments for the use of periodic instead of lump sum payments (Johnston et al., 2017); such a payment method would be more clear and acceptable to respondents. The fee would be transferred to a program that would preserve the natural qualities of the Knyszyn Forest.

We used a double-bounded dichotomous choice (DBDC) elicitation format (Hanemann et al., 1991; Johnston et al., 2017). The initial bid was set at 50 PLN (~11 €) with the bid vector of 50-100-200 PLN established per household. In cases where the respondent stated that 50 PLN was too high a vector of 50-20-10 PLN was used. The initial bid was selected based on a pre-survey.

The survey was carried out between September 19 and October 10, 2020. The total sample consisted of 484 people. Among them, 13.8% (68 interviews) were determined to be „protest zeros" (following e.g. Lo & Jim, 2015; Halstead et al., 1992). This reduced the total sample to 416 questionnaires.

Data analysis was conducted using statistical tests and multinomial regression models, aiming to compare each category of a dependent variable with a reference category. The general multinomial logistic regression model is shown in the equation below (Greene & Hensher, 2010; Long & Freese, 2014):

$$Log\ [Pr(Y=j)/Pr(Y=j')]=\alpha + \beta_k X_k, \tag{1}$$

where: j – the identified class, j' – the reference class, X – the asset of independent variables (or an independent variable).

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The structural parameters of the models were estimated using the maximum likelihood method.

In the models, coefficients, standard errors and average marginal effects (AMEs) were presented (Williams et al., 2012). The structural parameters of the models were estimated using STATA 16 (StataCorp LLC).

Respondents characteristics

Information on socio-demographic profile of the respondents was shown in Table 2. The experimental and control group had similar socio-demographic profile, which is a key issue in research conducted using the experimental method.

Table 2. Socio-demographic profile of respondents (including protesting respondents)

[redacted]			
Location (%):			
– Supraśl	50.20	100	-
– Tykocin	49.80	-	100
Age – mean (SD)	42.68 (14.36)	42.56 (14.42)	42.80 (14.32)
Gender (% of females)	53.70	55.1	52.3
Education:			
– lower*	14.30	10.70	17.80
– upper secondary school	30.00	28.80	31.10
– higher education	55.80	60.50	51.00
Financial situation (%)			
– bad	14.30	11.10	17.50
– rather good	59.20	64.60	53.80
– very good	26.50	24.30	23.70
Parental status (% having children)	57.60	60.90	54.40
Sample size	484	243	241

* lower secondary/basic vocational school or lower

Source: authors' work.

Additionally, Environmental Attitude Index (EAI) based on 6 questions (Table 3) was constructed (as recommended inter alia by the NOAA panel, Arrow et al., 1993). Respondents answered questions concerning their environmental behaviours as well as attitudes.

To verify the internal consistency of the scale, Cronbach's alpha was used. This measure is a function of the number of test items and the average inter-correlation among the items (Cronbach 1951). Cronbach's alpha for the entire sample was 0.754 and exceeded the minimum required reliability coefficient of 0.7 as recommended by Nunnally and Bernstein (1994).

Table 3. Percentage of responses to Likert scale questions describing respondents' environmental attitudes

Statement	Percentage of responses to Likert scale					Descriptive statistics	
	1	2	3	4	5	Mean	SD
I reuse one-side printed sheets of paper	10.3	12.7	24.8	24.5	27.6	3.46	1.31
I use single-use plastic shopping bags[2]	11.1	26.7	31.3	27.0	3.9	2.86	1.06
I reprimand a person who litters in a public place	15.9	22.6	32.7	14.9	13.9	2.88	1.26
I worry about the climate change	4.3	20.7	27.4	26.2	21.4	3.39	1.17
I talk with people about topics related to environmental protection	8.4	21.6	33.2	23.3	13.5	3.11	1.16
I read information/watch programs connected to the state of the environment	4.3	20.2	35.4	24.8	15.2	3.26	1.09

[1] Likert scale: 1 – never, 2 – sometimes 3 – quite often, 4 – very often, 5 – always/constantly
[2] an inverted Likert scale was used: 5 – never, 4 – sometimes, 3 – quite often, 2 – very often, 1 – always/constantly
N=416 (protesting responders were excluded)

Source: authors' work.

Results

WTP of users and non-users

To address the first research question, the arithmetic mean WTP of respondents by user status was compared (Table 5).

In the first step, WTP was treated as a quantitative variable. The study indicated that users of the Knyszyn Forest declared a significantly higher WTP for its protection (on average 62.06 PLN, about 14€) compared to non-users (45.86 PLN, about 10.3€).

Next, due to its discrete character that is characteristic of DBDC studies, the WTP answers were grouped into three categories, where a respondent declared: 1 – less than the initial bid, 2 – the initial bid (no more and no less), 3 – more than the initial bid. According to the test for a difference in proportions, a significantly higher fraction of non-users ($p<0.01$) declared their WTP at a level lower than the initial bid (non-users – 47.76%, users – 30.23%. The difference results from the percentage of people declaring the lowest WTP (less than PLN 10). At the same time, the difference in the percentage of

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respondents who agreed to pay the initial bid was not statistically significant. Generally, we observed that users of the forest declared higher WTP than non-users, which is the answer to our first research question. This result does not bring new knowledge, but confirms that participants responded as predicted by theory.

Table 5. WTP by user status

Definition	Unit	Distribution of answers			Differences between users and non-users (significance)
		Total sample	Users	Non-users	
WTP arithmetic mean (SD)	PLN	54.31 (2.77)	62.06 (4.27)	45.86 (3.36)	U-Mann Whitney1 ***
Original bid vector:					In proportions:
10 PLN or less	%	26.87	13.95	20.19	***
20 PLN	%	20.90	16.28	18.51	-
50 PLN	%	34.83	42.33	38.70	-
100 PLN	%	11.94	21.40	16.83	***
200 PLN or more	%	5.47	6.05	5.77	-
Grouped answers					In proportions:
1 – less than the initial bid	%	38.70	30.23	47.76	***
2 – initial bid	%	38.70	42.33	34.83	-
3 – more than the initial bid	%	22.60	27.44	17.41	**
N – sample size	persons	416	215	201	

[1] The results of the Kolmogorov-Smirnov test showed that the variable does not meet the criteria of normal distribution
significance code: ***p<.01;**p<.05;*p<.10

Source: author's work.

Factors influencing respondents' WTP

To understand which factors influence the WTP level a multinomial regression technique was employed (Table 6). We made the decision to distinguish three levels of WTP in order to meet the minimum sample size criterion in the models. User status as well as a view of the forest were considered as exogenous variables.

The analysis indicated that the probability of respondents declaring WTP below the initial bid depended on their user status, EAI, and financial situation. Specifically, an increase in EAI by one caused a 15% decrease in the probability that a respondent's WTP is below the initial bid. The probability

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of users declaring their WTP below the initial bid fell by 10.6%. At the same time, the probability that people who declared a very good financial situation would not agree to pay the initial bid fell by 8.3%. This may suggest that people in bad or rather good financial situation accounted for their budgetary limits (Loomis et al., 1994; Choi & Fielding, 2013). It was also noted that the probability of $WTP>WTP_{initial}$ was impacted only by EAI and this influence was lower than the probability of declaring a low WTP.

Table 6. Multinomial regression models of WTP for both locations (alternative base – initial bid)

Variable	WTP less than the initial bid			WTP more than the initial bid		
	Coef.	SE	AME	Coef.	SE	AME
User status	-.461*	.238	-.106**	.156	.281	.055
Location (a view of the forest)	-.251	.238	-.036	-.235	.275	-.020
Age	-.007	.011	-.001	.001	.012	.001
Gender	.201	.253	.047	-.081	.273	-.026
Parental status	-.237	.305	-.013	-.542	.350	-.068
Education: 1 – lower secondary/ basic vocational school or lower (base)						
2 – upper secondary school	.437	.390	.085	.092	.532	-.014
3 – higher education	.231	.400	.033	.227	.513	.021
Financial situation: 1 – bad (base)						
2 – rather good	-.614*	.364	-.129*	-.090	.511	.031
3 – very good	-.817*	.430	-.083**	.091	.554	.075
EAI	-.496***	.177	-.150***	.692***	.212	.141***
Cons.	2.471***	.639		-2.711***	.914	
N (in the model)	411					
McFadden's R2	.0844					
AIC	2.149					
BIC	-1433.833					

Coef. – coefficient, SE – standard error, AME – average marginal effect, AIC – Akaike Information Criterion, BIC – Bayesian Information Criterion.
Significance code: ***p<.01;**p<.05;*p<.10.

Source: author's work.

Generally, for the entire sample we observed that declared WTP was dependent on the EAI, the user status and the financial situation, as predicted and confirmed in the literature. We confirmed that the WTP sensitivity to the demographic characteristics and socio-economic status of respondents was different when the survey was conducted in a location with and without a view of the forest (third research question).

Table 7. Multinomial regression models of WTP (alternative base – initial bid)

Variable	Survey location with a view of the forest (Supraśl)						Survey location without a view of the forest (Tykocin)					
	WTP less than the initial bid			WTP more than the initial bid			WTP less than the initial bid			WTP more than the initial bid		
	Coef.	SE.	AME	Coef.	SE.	AME	Coef.	SE	AME	Coef.	SE	AME
User status	-.016	.349	-.007	.055	.390	.010	-.776**	.343	-.178***	.423	.426	.106**
Age	-.004	.015	-.001	-.003	.017	-.000	-.008	.015	-.003	.019	.020	.003
Gender	.358	.371	.076	.144	.414	-.006	.215	.362	.063	-.346	.448	-.061
Parental status	-.362	.428	-.039	-.547	.469	-.064	-.234	.454	.003	-.813	.565	-.099
Education: 1 – low (base)												
2 – upper	-.489	.605	-.106	-.076	.807	.028	.940*	.528	.185**	-.191	.754	-.073
3 – higher	-.880	.614	-.183	-.221	.789	.034	.963*	.564	.162*	.258	.728	-.015
Financial situation: 1 – bad (base)												
2 – rather good	-.171	.571	-.044	.170	.758	.034	-.848*	.511	-.167*	-.071	.733	.052
3 – very good	.024	.684	-.053	.836	.841	.137	-1.431**	.588	-.261**	-.478	.784	.028
EAI	-.641**	.266	-.153**	.246	.309	.085*	-.523**	.257	-.172***	1.144***	.326	.191***
Cons.	2.818***	1.014		-1.315	1.348		2.486***	.897		-4.649***	1.423	
N	205						206					
McFadden's R2	.0545						.150					
AIC	2.365						2.144					
BIC	-486.664						-531.534					

Coef. – coefficient, SE – standard error, AME – average marginal effect, AIC – Akaike Information Criterion, BIC – Bayesian Information Criterion.
Significance code: ***p<.01;**p<.05;*p<.10.

Source: author's work.

In the next phase, we verified whether the impact of seeing the forest during the survey was the same for users and non-users. We used multinomial regression models instead of interactions for this purpose because we also wanted to investigate whether or not it changed the impact of respondents' socio-economic characteristics on their WTP. We suspected that a view of the forest may affect the sensitivity of users and non-users differently in regards to other factors influencing their declarations (the third research question). The models are shown in Table 7.

Declaring WTP below the initial bid is more sensitive to respondents' socio-economic status when they do not see the forest (a statistically significant impact was noted with respect to user status, education, financial situation, and EAI). In cases when the respondents did see the forest while being surveyed, their declarations were considerably less dependent on the individual characteristics with only a week influence of EAI noted. As a result, we see a significantly lower model fit (R^2) in the forest view survey group. It shows that the WTP of respondents who could see the forest during the survey did not depend on those factors that usually influence respondents' declarations.

Secondly, when the respondents were able to see the forest while being surveyed, the difference between users and non-users became insignificant. In the group of respondents who were questioned with the forest not visible, the probability of WTP declarations below the initial bid was lower among users by 17.8%. This shows that viewing a good eradicates differences in the declared WTP between users and non-users. This effect also existed in the probability of WTP declarations that were higher than the initial bid, although it was less pronounced. On the other hand, when the survey was conducted in a location where respondents could not see the forest it was significant whether or not a person was a user of the forest, a factor that did not matter among people questioned while looking at the forest. So we concluded that the user status does not affect the WTP equally in these two situations (second research question).

Discussion and conclusion

In the whole sample WTPs declared by users were significantly higher than that of non-users. These results correspond with the results of numerous studies e.g. Jørgensen et al., (2013), Choi (2013), or Tabi & del Saz-Salazar (2015). This is also consistent with the theoretical explanations and it likely is a result of the fact that users hold both use and non-use values (Smith, 1987; Shechter& Freeman, 1994).

Our research also confirmed the relationship between the strength of environmental attitudes and the willingness to pay for environmental programmes, which is consistent with the results obtained by, among others, Bartczak (2015) and Choi & Fiending (2013). A relationship between

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respondents' self-assessed financial situation and declared WTP may suggest that people in a bad or rather good financial situation did account for their budgetary limits (Loomis et al., 1994).

However, the next stage of the survey showed that the relationship between respondents' characteristics and declared WTP differed when the survey was conducted with and without a view of the forest. Generally, when the respondents saw the forest, their answers were less dependent on the individual characteristics. They did not consider their budgetary constraints when stating their WTP. A similar reaction was recorded by Whitehead et al. (1995) who concluded that the WTP of non-users was less reliable. What is interesting, also user status did not matter among those who saw the forest during the survey. This shows that viewing a good eradicates differences in the declared WTP between users and non-users. We find this fact surprising, as users should assign the good an additional value resulting from its use. The view of the forest may compensate for a lack of familiarity for non-users. It is, in some way, an equivalent of its use.

From yet another perspective, a certain rise in the WTP of non-users surveyed in the location with a view of the forest is justified. First of all, the view of the forest provides a certain value in terms of aesthetic or mental experience. Familiarity is considered to be an important determinant of declared preferences (Tabi & del Saz-Salazar, 2015; Brouwer, 2012). A view of the good is a form of familiarity and this, in and of itself, generates a rise in WTP. It should be underlined that within the present study non-users are defined as people who have never before visited the considered forest. Comparing this with the methodology proposed by Whitehead et al. (1995) providing a view of the forest causes a person to become, in a way, a type of user, which is defined by these authors as an off-site user. It can also be argued that the experimental group (respondents who saw the forest during the survey) received more information (in a form of a view) about the good than the control group. It is, however, puzzling as to how the rise in the WTP of non-users was high enough to match that of users. This issue requires further study, however, we see two possible explanations for this phenomenon.

The first one assumes that when the survey was conducted in the location near the forest, non-users may have gained a potential use value of the forest because they could imagine its probable use (for walks, for example) as more likely. A basic use value of a protected forest is its recreational value. Being near a forest causes non-users to hold a potential use value that might be close to its 'real' use value. This explanation is in line with the results of the study by Kniivilä (2006) who revealed a significant difference between respondents who intended to visit areas in question in the near future and those who did not have such intentions. Moreover, an increase in the distance

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from the good in question is associated with an increase in the number of available substitutes (Pate & Loomis, 1997). This, in turn, reduces the WTP of respondents (e.g. Hanley et al., 2003). Our results, in a way, provide a response to the questions raised in the conclusions of the paper by Liu et. al. (2021), who underline the importance of exploring whether there is a difference in the value of WTP between ‘nature-based’ tourists and ‘general’ tourists.

The second possible explanation is that the rise in the WTP of non-users who see the good in question is temporary and is the result of heuristics and cognitive errors. Non-users surveyed in a location where they could see the forest may be influenced by a heuristic effect which makes first assessment an emotional one. This in turn may be seen as the reason for ignoring the budgetary constraints which, according to Whitehead et al. (1995), may mean that their WTP is less reliable (Loomis et al., 1994). Another possible cognitive effect that may occur in this situation is availability heuristic – people who do not see a forest have to exert a greater cognitive effort to visualize the good in question and possible benefits from its use (Mitchell & Carson, 1988; Frör et al., 2008; Jia et al., 2017; Parsons et al., 2021).

This explanation may be supported by two observations. First, differences become apparent for respondents who declare their WTP at a level lower than the initial bid. Taking into account the structure of a DBDC survey the differences concern how the first question about WTP was answered. Studies conducted by Matel and Poskrobko (2019) indicate that in survey studies, especially in direct interviews, the first question is more susceptible to cognitive errors. This problem in CVM studies was addressed by Dupont (2003) who concluded that potentially active users are affected by question order to a greater extent than active users. This would explain the increase in WTP of non-users who saw the forest during the survey.

The second observation concerns a change in the sensitivity of non-users to their socioeconomic status, including budgetary constraints, when viewing the forest. Factors influencing the probability of agreeing to particular WTP values among people seeing and not seeing the forest while being surveyed were assessed separately. Generally, we anticipated a relatively low impact of respondent’s characteristics on valuations in both groups since the forest is considered to be a good that is of large scale importance (according to Barrick and Beazley, 1990). Nevertheless, the study showed that the declarations of respondents, especially their refusals to pay the initial bid, were much more sensitive to a respondents’ socio-economic status when they did not see the good in question. This may be an indication that higher assessments of non-users were mainly emotional in character.

Determining which of these two basic explanations remains valid is important from the perspective of CV studies involving forest services valuation, CV methodology in general and, more broadly, stated preference-based

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research. This, however, requires further study. Moreover, forest is a specific subject of valuation, especially in the context of valuation of use and non-use values, which creates certain limitations in generalization of research results (Riera et al., 2012).

Further research would also be needed to assess to what extent our results are site and country specific, as the frequency of visits to forests in Poland is quite high compared to Western European countries (Bartczak et al., 2008; Giergiczny et al., 2021). The fact that forests are much more important for the economic welfare in Poland than in many other countries is important for the generalisation of our findings. We do not know whether the difference between WTP of users and non-users will be the same in other countries. Similar studies in other countries would be needed.

Other limitations relating to the generalisability of the results are due to the lack of control for hypothesis bias (Riera et al., 2012) which resulted from the assumption that this bias occurs to the same extent among users and non-users. Another limitation stems from the use of DBDC while several elicitation question formats are available. In DBDC investigators ask multiple valuation questions of each subject, which, according to e.g. Johnston (2017), may involve some bias. However, there is no reason to suspect that this impact differs between users and non-users (due to homogeneity of the groups compared). As a result, we believe that using DBDC format does not undermine the research findings. Nevertheless, it is reasonable to carry out further studies based on other question formats, such as single-binary choice question or payment card.

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The contribution of the authors

Edyta Sidorczuk-Pietraszko – conceptualization, methodology, data acquisition and validation, analysis and interpretation of data, project administration, funding acquisition – 30%.

Anna Matel – conceptualization, methodology, data acquisition and validation, investigation, analysis and interpretation of data, funding acquisition – 30%.

Tomasz Poskrobko – conceptualization, methodology, analysis and interpretation of data, funding acquisition – 30%.

Dariusz Andrejuk – data analysis and interpretation, original draft preparation – 10%.

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PERSPECTIVES OF POLISH ORGANIC FARMING DEVELOPMENT IN THE ASPECT OF THE EUROPEAN GREEN DEAL

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ABSTRACT: The paper aims to examine the determinants for the development of organic farming in Poland under the present conditions associated with membership in the European Union (EU). The study is based on analyses of secondary sources and a nationwide survey among organic farmers. Organic farming in the EU is a subject to development under the influence of the strategies related to the European Green Deal. Polish organic agriculture developed dynamically after the EU accession. However, the process reversed from 2013 due to the unstable domestic support policy. The barriers are poor connections between farmers and distributors, bureaucratic procedures and low profitability. A significant chance for the development is the expected demand growth. The most important factors encouraging farmers were associated with environmental aspects and the use of labour. The further growth is conditioned by the better organized policy of Polish organisations involved in agricultural policy.

KEYWORDS: sustainable agriculture; organic farming; ecological products markets

No. 2(81) 2022 • pages: 154-167 DOI: 10.34659/eis.2022.81.2.461 JEL: O130, Q15, Q180, Q570

Introduction

According to the UE, A Farm to Fork Strategy adopted in 2020, 25% of the EU's agricultural land is expected to be under organic farming by 2030 (European Commission, 2020a). Together with the EU Biodiversity Strategy for 2030 (European Commission, 2020c), the strategy is one of crucial parts of the European Green Deal (EGD), which sets out how to make Europe the first climate-neutral continent by 2050 with a fair and prosperous society, as well as a modern, resource-efficient and competitive economy. The strategies are connected with a need to rethink crucial UE policies, including food and agriculture, so as to reduce the use and risk of pesticides, the use of antibiotics and fertilisers in agriculture, increase the share of organic farming and enhance the percentage of landscape elements (European Commission, 2020b).

This paper aims to examine the determinants for the development of organic farming in Poland under the present conditions associated with membership in the European Union (EU). To indicate these determinants, the problem of motivation of farmers to convert into organic farming was analysed on the example of Poland in the aspect of plans of development of organic agriculture connected with the EGD. The results obtained in the course of such examination would provide valuable information on the relative impact of each of the studied spheres upon the availability of income sources for producers, with good potential to explain some of the reasons behind the observed decline in the number of Polish organic farms (and the associated acreage). The recognition of the conditions and prospects for the development of the organic food market and production potential could contribute to the better policy of public institutional and financial support for organic farming.

An overview of the literature

Organic farming contributes to sustainable development in its three main dimensions (environmental, economic and social), which are essential for the green economy, and the EGD. In organic farming, the negative environmental consequences of agricultural activities are minimised (Cattell Noll et al., 2020), while their positive side effects are increased compared to conventional agriculture (Zaher et al., 2016). Most of the studies that compared biodiversity in both types of farming demonstrated lower negative environmental impacts from organic than from conventional farming (Tuomisto et al., 2012). Organic fields have around 30% more biodiversity, and organically farmed animals enjoy a higher degree of animal welfare and take fewer anti-

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biotics. Water and air pollution, as well as soil contamination, are minimized. These external effects are significant both for people living in the countryside (internal environmental sustainability) and those living outside rural areas (external environmental sustainability).

Organic farming is important for the social pillar of sustainable development (MacRae, Frick, & Martin, 2007). It is the source of the provision of high-quality food products to consumers, which contributes to the well-being of the population living outside of rural areas (external social sustainability). It can also stimulate the use of labour surplus in the countryside (internal social sustainability). Torres et al. (2014) found that restructuring the citrus sector towards organic farming in one of the regions in Spain resulted in a significant improvement of employment both at the farm level and the municipality level.

In the economic dimension, organic farming falls into a special category. Its efficiency is lower than conventional farming (Seufert et al., 2012). It was also indicated in the study of Krause & Machek (2018). Organic farms have a lower operational efficiency; to achieve their sales, they spend more than double the operating costs of conventional farms. Consequently, an interesting scientific problem is to investigate factors influencing the profitability of Polish organic farms compared to conventional ones. Many elaborations showed that demand is an essential factor affecting the possibilities of organic production (Tzouramani et al., 2014). That is why ecological consumption patterns determine the market's capacity and capability. It was confirmed by the study of McCullough et al. (2008), which showed global shifts in consumption, marketing, production and trade and their consequences on organisational changes along the food chain. Growing demand could enable the price of organic products, which would be a premium for farmers, as powerful motivation for conversion to organic methods (Siepmann & Nicholas, 2018). Serra et al. (2008) estimated that 37% of farms would start organic production as a result of a 40% increase in the price, while a 90% premium may trigger the conversion of 70% of farms. An increased price should cover lower yields and labour cost bigger than in conventional agriculture, which could be a barrier to the further development of organic farming. Another one is a financial risk during the conversion period (Siepmann & Nicholas, 2018), which is confusing because of producer cost (Veldstra et al., 2014). It is not only associated with a financial burden but also with administrative procedures. Bravo et al. (2012) found that certification-related bureaucracy negatively affected farmers' expectations. All these factors influencing Polish farmers' decisions to convert were examined in the study presented in this paper.

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Research methods

The first part of the paper presents the comparison of the development of organic farming in the EU and Poland. The next part includes the latest solutions of the EU's policy related to the development of organic agriculture in the context of documents of the EGD. These parts of the study were based on the descriptive and comparative analyses of secondary sources from Statistics Poland, Agricultural and Food Quality Inspection (IJHARS – Inspekcja Jakości Handlowej Artykułów Rolno-Spożywczych), international organic agriculture organisations, the EU databases, scientific papers referring to the conditions of organic farming development in years 2004-2019. These parts of elaboration include law analysis referring to current issues of the EU policy connected with support for the development of organic farming for the years 2021-2027 and was based on regulations of the Common Agricultural Policy (CAP) and the EU strategic documents.

The results of the surveys on factors influencing Polish organic farms are in the further section. The empirical study among farmers was conducted using questionnaires prepared by the author. The nationwide surveys were performed in 2019 by a professional research institute, using CATI (Computer Assisted Telephone Interviews) and CAWI (Computer Assisted Web Interviews) methodology. The nation-representative sample in Poland involved 65 certified organic farms. The questions concerned their experiences connected with participation in the market and were focused on four groups of factors: those influencing the economic performance of farm (price, income, cost, demand, subsidies), environmental aspects (care for the environment, ecological standards, clean environment in farm area), the social ones (prestige in society, job satisfaction care for health) and the institutional conditions (administrative procedures). The results enabled us to explain existing barriers and stimulants for organic production in Poland in the aspect of the future perspectives for that process. The discussion involves remarks on investigated conditions of development of organic farming in the light of the UE policy with special consideration of CAP for the years 2021-2027 under the influence of the EGD.

Results of the research

Development of organic farming market in the European Union and in Poland

In 2020 9.2% of the total Utilized Agricultural Areas (UAA) in the EU were certified organic (Trávníček et al., 2022). In Austria, organic farming was carried out at 26.5% UAA, in Italy at 16% UAA, in Germany at 10.2%

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UAA, in Spain at 10% UAA, and in France at 8.8% UAA. In Poland, it was only 3.5% UAA which was less than the new member states (UE 13) average – 5.95% UAA. According to the author's calculations based on IJHARS data (2007, 2011, 2019a, 2019b), in Poland, in the years 2004-2013, thanks to the implementation of the CAP subsidies, the organic area has increased by 737% (to 0.67 million hectares UAA) and the number of farms by 608% (to 26.6 thousand). The trend of development of Polish organic farming reversed in 2013. Between 2013 and 2020, the number of organic farms fell by 24% (to 19.2 thousand, which represented 1.3% of all farms), and the area of crops fell by 27% (to 50.9 million hectares UAA). In the EU, the number of farms increased by 61%, and the crop area increased by 47.5% over the same period. The decrease in the number of organic farms and areas in Poland was due to how government agricultural organisations distributed CAP subsidies. When irregularities in the application for these funds occurred between 2008 and 2013, the Ministry of Agriculture and Rural Development (MARD) streamlined and tightened procedures[1]. The errors in the support system have been partly reduced but have discouraged some farm owners from taking organic production. Moreover, the policies pursued by the MARD and the Agency for Restructuring and Modernization of Agriculture (ARMA) were inconsistent. It applied to frequent and chaotic changes in the procedures and delays in the payments. Bureaucratic obstacles have become an important barrier to the development of Polish organic farming. Finally, the MARD cut the CAP support for organic farming in 2014-020 by EUR 178 million compared to the original plan.

The largest global organic food markets are in the United States (EUR 49.5 billion in sales in 2020) and the EU (EUR 44.8 billion) (Trávníček et al., 2022). In 2020, Germany had the largest market in the EU– EUR 15billion (33.5% of the EU market value). The highest share of organic products sales value in the national food markets has been recorded in Denmark (13%), Austria (11.3%), Luxembourg (9.1%), Sweden (8.7%), and Germany (6.4%). In Poland, sales value was one of the lowest in the EU. In 2019, it amounted to EUR 314.1 million. Organic food expenditures accounted for 0.6% of the value of total food sales in Poland and 1.5% in the Czech Republic – a country with a similar level of economic development. Polish consumers spent only EUR 8.3 per person on organic food, which is 43.5% of the value in the Czech Republic (EUR 19.1 per person) and twelve times less than the average in the EU as a whole (EUR 101.8). In the most developed European markets, the expenditures are much higher than the EU average: in Denmark, EUR 383 per

1 An ineffective system of control and attestation of production was not able to prevent from granting subsidies for farm holders without providing environmental services, without supplying products to the market, or even without real crops (sometimes they were carried out ostensibly).

person, in Sweden, EUR 212.3 per person, in Germany, EUR 180.3 per person. The problem with the functioning of the Polish organic market is the poor connection of producers with the distribution system (NIK, 2019). Retail sales are dominated by imported final products, which account for about 50-60% of their value. Consequently, the market does not effectively absorb production potential. It could be another reason why the organic area and the number of farms decreased from 2013 until now.

The latest solutions of the European Union's Policy are related to developing organic farming

According to A Farm to Fork Strategy, at least 40% of the total budget of the CAP will be intended for combating climate change. According to the strategy, agricultural holdings should be rewarded more than ever for achieving environmental and climate goals. It influenced the shape of the CAP for the years 2021-2027 (adopted in 2021 and planned to be implemented from 2023) aligned with the EGD objectives. The total allocation for the CAP in 2021-2027 amounts to EUR 386.6 billion at current prices (European Commission, 2022). The value is reduced by 5% in comparison to the years 2014-2020. Its share in the EU's multiannual financial framework is less too (32% form EUR 1.21 trillion). However, the division of the CAP funds is more favourable for the Pillar II (25.4%) than for Pillar I (74.6%) in comparison to the previous period when they had respectively 21.5% and 78.5%. The Pillar II includes more measures aimed at organic farming support than the Pillar I. The new CAP includes new elements contributing to the EGD (with the target of a 25% organic area in the EU by 2030). From 2023 at least 25% of the Pillar, I (direct payments and market interventions) will be allocated to eco-schemes (Regulation 2021/2115). This is the new tool supporting organic farming, precision farming, agro-ecology and agro-forestry, which is mandatory for the Member States but designed on their own in a 'bottom-up' approach. At least 35% of the Pillar II (rural development measures) should be devoted to actions that benefit the environment, climate and animal welfare (agri-environment programmes, Natura2000 and Water Framework Directive payments). The EU Member States will implement the new CAP with National Strategic Plans addressing their specific needs and delivering tangible results in relation to the EU objectives, including those laid out in the EGD, Farm to Fork and biodiversity strategies. The plans should display a higher ambition for the environment and climate action compared to the previous programming period.

In 2021 the Commission presented the Action Plan for the Development of Organic Production (European Commission, 2021a), which is another document in line with the EGD. It is designed to provide the organic sector with

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the right tools to achieve the 25% target. The growth in the sector must be more dynamic because the trends show that with the present growth rate, the EU will reach 15-18% UAA by 2030 (European Commission, 2021b). It will be stimulated by supporting demand through green public procurement (for example, a greater use of organics in public canteens) and promotion of the consumption of organic food, maintaining consumer trust and bringing products closer to citizens. Furthermore, the supply-side will be granted by increased funds from the CAP – mainly thanks to the implementation of the eco-schemes, which will be backed by a budget of EUR 38-58 billion for the period 2023-2027 (European Commission, 2022). That kind of financial support for sustainable agriculture will have a 25% share in total Pillar I expenditures in these years. Currently, around 1.8% of CAP is used to support organic farming (EUR 7.5 billion from the Pillar II).

The results of the surveys on organic farmers' experiences connected with their participation in the market

Surveyed farmers declared that mostly the environmental factors influenced their decisions to switch farms to organic methods: care for an environment and a clean environment in the farm area (Table 1).

Table 1. Factors that influenced the decision to switch the farm into organic methods

Rank	Factor	(% responses)
1	a care for the environment	64.6
2	clean environment in the farm area	53.8
3	the ability to increase the use of labor resources	43.1
4	growing sales opportunities	35.4
5	job satisfaction	30.8
6	prestige in society	16.9
7	high prices for organic products	6.2
8	increased profitability	4.6
9	care for health (of my family and mine)	3.1
10	use of extensive production methods on the farm	0.0

Source: author's work.

In the third place (in terms of the number of indications) was the socio-economic factor – the possibility of using labour resources. Slightly more than one-third of respondents expected increasing sales opportunities, which came in fourth place. This was reflected in the assessment of opportunities and barriers to the development of organic production (Table 3). The strictly economic incentives were less important – high prices for organic products were ranked seventh, and increased profitability ranked eighth place in terms of frequency of indications.

Most farmers replied that after the conversion, there was no change in the economic conditions for their operation (Figure 1). Among those, who have identified changes in their economic situation, the most significant number of producers declared the simultaneous decrease in yields, the increase in production costs and the increase in income after the conversion. In terms of response frequency, the most critical category of inputs associated with an increase in production cost were expenditures associated with the fulfilment of environmental standards. They are necessary to deliver agricultural public goods (rural amenities), so it is justified. The second one was bureaucracy (administrative procedures) connected with documentation and other requirements associated with certification.

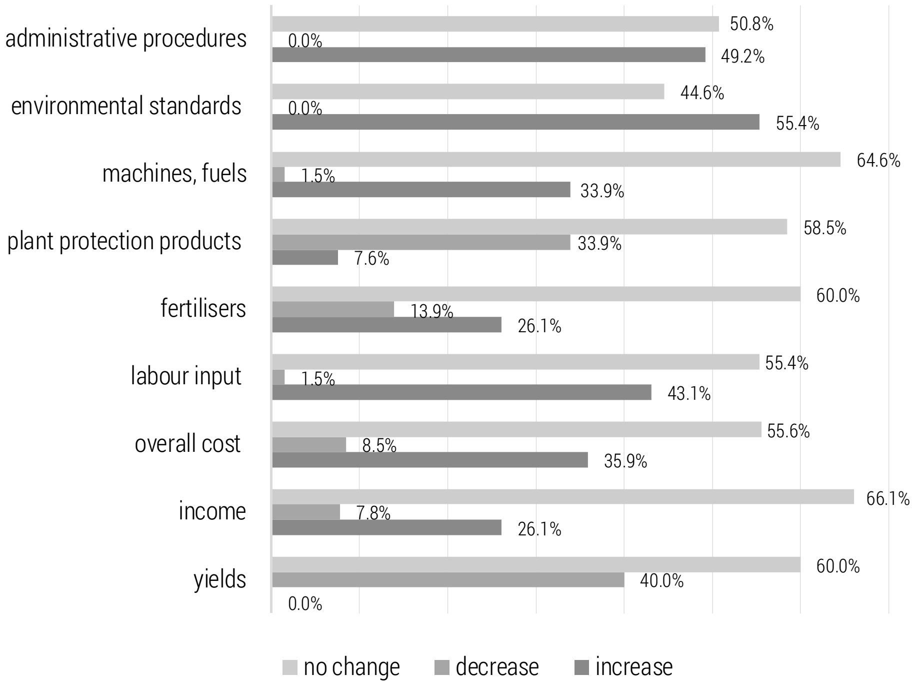

Figure 1. Change of yield, income and different cost categories after conversion into organic farming (% response)

Source: author's work.

Labor input was the third most frequent answer indicating the increase of a production cost (43.1%). 34.9% of respondents saw a decrease in expenditures for plant protection products after conversion.

75.38% of farmers assessed the subsidy rate and the level of support offered to farmers during conversion into organic farming as too low (Table 2). According to 69.2% of respondents, the prices of organic products were too low. Most of them accepted the level of retail margins taken by distributors.

Table 2. Assessment of factors influencing income of organic farming (% responses)

Specification	should be higher	could be lower	it is at the appropriate level
price	69.2	0.0	30.8
retail margins	10.7	15.4	83.9
rate of subsidy per hectare of organic farming	75.4	1.5	23.1
the subsidy for farms in conversion into organic farming	75.4	6.1	18.5

Source: author's work.

Only 18.5% of respondents identified subsidies as the opportunity –the fourth one in terms of response frequency (Table 3). Many more farmers saw opportunities in demand factors: growing environmental awareness of consumers (the first place), increasing demand (the second place) and popularity of ecological consumption patterns (the third place).

Table. 3. The opportunities and barriers to the development of organic production

Rank	Opportunities	% responses	Barriers	% responses
1	growing environmental awareness of consumers	67.7	a weak system of distribution and promotion	46.2
2	growing demand	52.3	too much bureaucracy	46.2
3	popularity of ecological consumption patterns	52.3	low profitability	44.6
4	EU subsidies	18.5	small sales opportunities	33.9
5	better distribution	15.4	too difficult procedures	27.7
6	favorable policy of Polish authorities	12.3	too high production costs	27.7
7	any of these factors	9.2	low yields	24.6

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8	-	-	the difficulty of applying organic farming methods	13.9
9	-	-	limited access to fertilizers, pesticides and feed additives	7.6

Source: author's work.

The most important barriers were a weak distribution system, bureaucratic procedures and low profitability.

Discussion and conclusion

Organic farming is well developed in the EU and is a subject of further development. Polish organic agriculture is at a low level of growth compared to most old Member States (EU15) but also to the Czech Republic and other EU 13 countries. It developed dynamically after its accession to the EU (in years 2004-2013); however, from 2013, it is a subject to regressive trends. Years 2013-2020 saw a decrease in the number of farms by 24% and a reduction in organically farmed areas by 27%. Consequently, organic agriculture constituted 3.5% of the UAA in Poland – much less than across the EU (9.2% of the UAA). Among the factors which contributed to the reduced willingness of farmers to take up organic production, attention should be paid to the policy pursued by the Polish authorities and organisations concerned with organic farming support. It was inconsistent and disorganised. Unless the regressive trends were reversed, Polish organic agriculture would not reduce the development gap.

Considering the EGD and A Farm to Fork Strategy, organic farming will grow in importance in European agriculture and the food market. Its supply side will be supported by increased spending and new tools from Pilar I and Pillar II of the CAP. However, the definition of new eco–schemes has been left in the hands of Member States and, in some countries, could be not ambitious enough to favour organic farming. It depends on the effectiveness of their domestic policies and procedures. Activities of the EU member states will foster the demand according to the new Action Plan for the Development of Organic Production. These measures contribute to sustainable agriculture development.

The empirical surveys showed that the most critical factors encouraging farmers to take up production were associated with environmental aspects and the possibility of using labour resources (Table 1). It could confirm findings from previously considered studies related to ecological elaborated by Cattell Noll et al. (2020), Zaher et al. (2016) and Tuomisto et al. (2012). This also refers to the aspects of social sustainability indicated by MacRae et al.

(2007) and Torres et al. (2016). It may also confirm that organic farming is based more on human capital than on external factors of production. It can contribute not only to ecological benefits but also to employment and thus to improving the social situation in rural areas. It is also visible infrequent answers indicating the increase in labour cost after conversion (Figure 1). It is worth underlining that the CAP 2023-2027 beneficiaries will have to respect elements of European social and labour law to receive subsidies (social conditionality). The other social factors, such as job satisfaction and prestige in society, were less critical to farmers' decisions.

Farm owners did not expect a significant improvement in their economic situation when deciding to convert to ecological methods. A small number of respondents were under the influence of high prices for organic products and increased profitability (Figure 1). It confirms the findings showing relatively low efficiency of organic farming (Seufert et al., 2012; Krause & Machek, 2018). Many farm holders did not notice any change in their economic performance after conversion. It may confirm that – as indicated in the section on the development of organic farming in Poland – they had no significant links with the distributors on the organic market. Active market participants can be found among those who have identified changes. Most registered a simultaneous decrease in yields and an increase in production costs and income (Figure 1). It may mean that one of the reasons for increased revenue is the support from the subsidies under Pillar II of the CAP. However, most farmers declared that they should be higher (Table 2). This may explain the previously presented decrease in the number of farms and the organic area in the years 2013-2018. This is also evident in the result, in which a small number of farms identified subsidies as the opportunity for organic production (Table 2). Currently, they do not function as sufficiently strong incentives for further development of organic farming.

The result showing decreased expenditures for plant protection products may suggest that farm holders were required to limit their negative impact on biodiversity. Some of them declared an increased cost of fertilisers. They had to spend more money on specific, expensive products approved under the organic farming regime. Both changes contribute to lower external environmental costs than conventional agriculture, as presented in the introduction (Tuomisto et al., 2012).

A significant opportunity for developing organic production is the expected demand growth. Its role in that process was explained by Tzouramani et al. (2014), McCullough et al. (2008), Siepmann & Nicholas (2018) and Serra et al. (2008). According to the study results, it is mainly related to the increasing environmental awareness and environmental change in consumption patterns (Table 3). However, as explained in the section presenting data on organic farming development, it is not a sufficient factor in ensuring the economic conditions for increasing production in Poland.

The most important barriers to organic farming development are poor connections between farmers and the distribution system, bureaucratic procedures and low profitability. These results confirm that the Polish organic food market requires improving the links between farmers and wholesalers, processors, retailers and consumers. A bureaucratic burden is necessary in many cases due to the certification process requirements. It was visible in the studies taken into consideration in the introduction (Veldstra et al., 2014; Bravo et al., 2012). On the other hand, administrative procedures could be unstable, chaotic and overcomplicated – as was the case in Poland in the years 2013-2018. The domestic system of the CAP subsidies needs to be streamlined and formed in a stable manner such that it could stop being a barrier to enhanced production potential. There are important factors for developing organic agriculture coming from the demand side of the market. Still, its further growth is conditioned by increased rates of subsidies and better-organised policy of Polish government agendas and organisations involved in agricultural policy. Otherwise, they will not seize opportunities from the EGD and related documents creating new enforced policies supporting organic farming as an important element of agriculture transformation towards sustainability.

Consequently, Polish organic farming would not reach the 25% share in total UAA until 2030. IFOAM Organics Europe (2021) showed that the level of ambition to develop and support organic farming is not high enough in CAP national Strategic Plans of many EU Member States. They need significant changes in the measures and budgets to reach the Farm to Fork Strategy's target.

The research was carried out before the Covid 19 pandemic, which could change the situation of consumers and manufacturers. Therefore, it is worthwhile to undertake further research on the conditions of market development, in particular concerning the experience of organic farmers and the expectations of conventional farmers after the pandemic. There is also a need to investigate conditions and relationships between actors involved in the organic food chain, which is crucial for further market development.

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SMALL-SCALE FARMS IN THE ENVIRONMENTAL SUSTAINABILITY OF RURAL AREAS. OPINIONS OF FARMERS FROM POLAND, ROMANIA AND LITHUANIA

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ABSTRACT: The aim of the article is to assess the environmental sustainability of small-scale farming. The authors tried to reach the farmers' subjective opinions, their way of thinking, attitudes and determinants affecting environmental performance. The use of in-depth interviews gave a chance to draw reliable and accurate conclusions on the analysed topic and register many elements that could be omitted using quantitative methods. Thus, the work forms a complementary part of research on the sustainability of small-scale farms, which is its main added value. Furthermore, the use of data from three EU member states – Poland, Romania and Lithuania – provided a basis for comparative analysis. Conclusions proved that small farms perform important environmental functions in rural areas. It results from the very essence of this type of farm, based on the cultivation of traditions and experience passed down from generation to generation, as well as from the family nature of these units.

KEYWORDS: small-scale farms, environment, sustainability, interviews, producers' opinions

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Introduction

The common agricultural policy (CAP) of the EU supports the European model of agriculture, which exposes the duality of its functions – apart from food production, it contributes to the broadly understood development of rural areas and provides public goods (Committee, 1999; Fischler, 1999). This model is based on family farms, a large part of which have a small-scale of production. What is more, the observation of subsequent periods leads to a claim that a response to the policy designed in the 1960s was to change the CAP's objectives and adjust new solutions. After the first 30 years of its functioning, this was the case when it changed from a market and price policy to an income and structural policy, and then also to an environmental policy. The construction of the most important instrument of aid, i.e. direct payments, also changed – the dependence of financing on the type and volume of production was almost entirely abandoned, and the so-called decoupling was introduced, along with minimum environmental and animal protection requirements. Thus, there was a reorientation of budget expenditures from those oriented at the continuous increase of productivity of inputs through relatively high food prices to those directly creating the source of farmer's income, with simultaneous care for the development of rural areas and natural conditions. Thus, it can be thought that at the EU level (including, first of all, the wealthiest countries), the upper limit of further „pumping" of productivity has been reached (Czyżewski et al., 2019). It turned out that economic efficiency cannot be the only criterion for assessing EU budget expenditures on agricultural policy due to the peculiarities of the land factor and the role to be played by rural areas for the general public (Czyżewski & Polcyn, 2016; McDonagh et al., 2017).

The study covered three countries belonging to the European Union, two of them – Poland and Lithuania – since 2004, and Romania since 2007. The choice of these countries was not accidental but resulted from the aim of the research. The authors focus on small-scale family farms, as this entity is typical for the Central and Eastern European (CEE) region. Family farms have an important position in the construction of the CAP support system, thanks to which they can function in the environment of large-scale enterprises (Czyżewski & Stępień, 2017). Financing the activities of these entities is also an expression of the desire to ensure fair pay for the farmer's work. This is because under market conditions, with the limitations of the land factor, there is a depreciation of smallholder agriculture in relation to its closer and further surroundings, which is manifested in the relative income deprivation of farms. It turns out that without financial support, agricultural income in many EU countries is not only much lower than non-agricultural income but

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also insufficient to cover current operating costs (Guth et al., 2020). In the process of shaping intermediate and final demand, small-scale family farms participate to an inadequate degree in the distribution of value-added of the food supply chains (Thirtle et al., 2004; Marini et al., 2009). The consequence of this process is the disappearance of small-scale farms, which can have negative long-term environmental effects: reduction of biodiversity, landscape conversion, deterioration of soil and water quality through industrial agriculture, etc. (Babai et al., 2015). These are unquestionable reasons for supporting the agricultural sector. An intervention system such as the EU common agricultural policy is compensation for market discrimination of small-scale farms and is justified from the point of view of economic efficiency, but also for environmental reasons (Pe'er et al., 2014).

At this point, the role of small farms in sustainable development should be stressed. The Food and Agriculture Organization (FAO, 2014) emphasises the importance of small-scale farming for alleviating hunger and poverty and improving food security and living standards in rural areas while protecting the environment and biodiversity. Moreover, small family farms and related rural areas are places of residence and work for nearly 50% of the world's population (Wiggins et al., 2010). The role of smallholders in economic growth is also emphasised since small-scale agriculture has higher multiplier effects in creating demand than other sectors (World Bank, 2007; Janvry & Sadoulet, 2010). Furthermore, small farms have a positive influence on developing the density of the rural population, including the borderland and less beneficial territories. Hence, to some extent, they are responsible for rural viability (Borychowski et al., 2020). Therefore, the role of small family farms in creating a sustainable model of agriculture is global (FAO-OECD, 2012; Hanzel, 2011). At the European scale, the best concretisation of this problem is provided by the CEE countries with fragmented agrarian structures (Fritsch et al., 2010). Studies on the sustainability of agriculture in the CEE countries are numerous, and they cover different aspects. European Union's Horizon 2020 project 'SALSA' (SALSA, 2020) found that in order to develop and increase the resilience of small farms, as well as contribute to food delivery stability, it is necessary to diversify their crop and animal production. Indeed, this form of biodiversity is a way of reducing production and price risks and is recommended for farms with a high degree of self-supply.

On the other hand, small farm businesses should be able to demonstrate strong commercial performances to reinforce sustainable food and nutrition security. This requires strengthening the position of small-scale farms in the food supply chain through horizontal and vertical integration processes and shortening the marketing channels. Discussing various resilience strategies for farms in several regions in Poland and Latvia, Czekaj et al. (2020) note that economically strong individuals are more able to guarantee social and

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environmental sustainability. In turn, Sharma & Shardendu (2011) assessed the link between the improvement in the agricultural economic performance of family farming and the sustainability levels of rural regions. They identified a positive relationship between these two dimensions, similarly to Volkov et al. (2020). However, achieving favourable financial results in small-scale family farming requires external support. Bojnec & Fert˝o (2019) and Guth et al. (2020) appraised the impact of CAP subsidies on the stabilisation of farm incomes and their sustainability and resilience.

Family farms account for 97 per cent of the 12 million farms in the European Union (Eurostat, 2021), and a large part of them are small-scale units, located particularly in Central and Eastern Europe and peripheral regions, such as the Northern Scandinavia, Scotland and Ireland, South-eastern Europe, the Mediterranean countries and mountain ranges (Claros, 2014; Pinter and Kirner, 2014; Salvioni et al., 2014). Because of their contribution to environmentally sustainable rural development, specific support programs have been launched, reflected in the agricultural policy priorities for 2021-2027 (European Commission, 2021). In the literature, one can find many positions indicating the importance of family farms. Such works have been published for years both at the level of political institutions, such as the European Parliament (2014), the European Commission (2013), and the Council of the European Union (2013), as well as in the scientific sphere (e.g. Hill, 1993; Christiaensen & Swinnen, 1994; Allen & Lueck, 1998; Darnhofer, 2010; Davidova et al., 2013; Matthews, 2013; Gioia, 2017; Stępień & Maican, 2020). They largely present quantitative analyses and modelling using publicly available statistical data (e.g. Eurostat, 2021; FADN, 2021) or survey data.

As in the sources cited above, the aim of this article is to assess the environmental sustainability of small-scale faming. However, unlike many quantitative works, the authors tried to reach the farmers' subjective opinion on a specific problem. This approach made it possible to get to know the farmers' way of thinking, their motivations, and attitudes and to understand the determinants of the analysed entities' actions (Gaskell, 2000). The application of this method gives a chance to draw reliable and accurate conclusions about the studied reality. Additionally, the nature of the assessed phenomenon makes the use of in-depth interviews possible to register many elements that could be omitted using other methods (e.g. traditional questionnaire survey). Thus, the work forms a complementary part of research on the sustainability of small-scale family farms, which is its main added value. To the best of our knowledge, qualitative studies covering the impact of those farms on environmental sustainability are rare, which makes a significant contribution to existing scientific research. The use of data from three different EU member states – Poland, Romania and Lithuania – provides a basis for comparative

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analysis, which is a unique feature of the research. The structure of the paper is as follows: the next section indicates materials and methods, followed by research results and discussion, and finally, conclusions.

Material and research methods

The analysis covered three countries belonging to the European Union, two of them – Poland and Lithuania – since 2004 and Romania since 2007. Data on these countries were obtained as part of a scientific project titled 'The role of small farms in the sustainable development of the food sector in Central and Eastern European countries'. In this project, apart from the three mentioned, Serbia and Moldova were included. However, the latter two countries do not belong to the European Union and are not covered by the support mechanism of the common agricultural policy, hence they were excluded from this study. The choice of these countries, both for the project and for publication, was the effect of a similar path of economic transition of the countries belonging to the so-called Soviet bloc and the transformation from a socialist economy system to a market economy. As a result, a dual structure of agribusiness has emerged, with large-scale enterprises and small-scale family farms participating side by side. The latter, due to their multifunctional character, is crucial for the functioning of rural areas, hence the important question about the attitudes of agricultural producers towards sustainable development. At the same time, these three countries are covered by the support of the common agricultural policy, the system which seeks to strengthen the environmental role of smallholder farms.

Different definitions of a small family farm were used in the selection of units for the study. The literature most often points to criteria such as agricultural area, economic strength, number of animals, and market participation (Guiomar et al., 2018; European Commission, 2011). For example, very small farms can be defined as those whose agricultural area is less than 2 ha or 5 ha (Lowder et al., 2016), while small farms are those whose area does not exceed 20 ha (Gruchelski & Niemczyk, 2016). In turn, Eurostat and the Farm Accountancy Data Network, by taking into account the classification of economic strength (SO[1]), apply the upper limit for small farms as 25 thousand euros (FADN, 2021). Additionally, in order to emphasize the family character of the farm, the criterion of the dominant share of the farm family members' work is adopted to exclude from the analysis those persons who, although possessing agricultural land, actually work outside agriculture (Zegar, 2012). Taking these elements into account, for the purposes of this study, the following criteria were adopted: agricultural area up to 20 ha, standard production up to 25 thousand euros and at least 75% of family members' labour input.

DOI: 10.34659/eis.2022.81.2.450

In the first stage, the analysis was based on surveys conducted in Poland in 2018 and in 2019 in Romania and in Lithuania. The samples numbered 710 farms in Poland, 1000 in Lithuania and 900 in Romania. Data were collected in the form of direct interviews by agricultural advisors. Questions concerned economic, social and environmental sustainability. In the second stage, using these data, we ordered farms according to the synthetic sustainability measure applying the CRITIC-TOPSIS method. The criteria importance through inter-criteria correlation (CRITIC) method is based on the standard deviation and uses correlation analysis to measure contrasts between criteria (Odu, 2019). The technique for order preference by similarity to ideal solution (TOPSIS) method refers to the determination of the best alternative nearest to the ideal solution (with the shortest Euclidean distance) and farthest from the negative ideal solution (Helmy et al., 2021). Table 1 presents the set of variables (stimulants and destimulants) taken into account to determine the synthetic sustainability measure. Weights for particular coefficients were determined by the CRITIC method on the basis of standard deviations and correlation between the coefficients. A distinctive feature of that method is assigning higher weights to features that have high rates of variability, along with a low correlation with other features. The weight coefficients w_j were determined according to the following formula:

$$w_j = \frac{c_j}{\sum_{k=1}^{m} c_k}, j = 1,2,\dots,m; \; c_j = s_{j(z)} \sum_{k=1}^{m} (1 - r_{ij}), j = 1,2,\dots,m, \quad (1)$$

where: c_j is the measure of the informational capacity of the j feature, $s_{j(z)}$ is the standard deviation calculated from of the standardised values of the j feature, r_{ij} is the correlation coefficient between features j and k. The sum of the coefficients is 1 (Borychowski et al., 2020b).

Next, farms were ordered according to the synthetic measure and a group of the most sustainable farms, the so-called Top-20, was determined for further research in each country.

Table 1. Variables used to determine the synthetic measure of the sustainability of surveyed farms in Poland, Romania, and Lithuania

Sustainability component	Variable name	Variable type*	Weight of variable for the individual sustainability component	Weight for the synthetic measure of sustainability
Economic	Income gap indicator (difference between average income in the national economy and total income of the agricultural holding)	D	0.1280	0.3304
	Subjective assessment of the household's financial situation	S	0.3398	
	Level of agricultural investment	S	0.3356	
	Estimated market value of the holding	S	0.1967	
Social	Dwelling/house furnishing index	S	0.1819	0.3089
	Usable floor area of dwelling/house per family member	S	0.0959	
	Participation in lifelong learning system	S	0.1511	
	Participation in social or cultural events	S	0.2823	
	Membership in an organisation, club, association etc.	S	0.2887	
Environmental	Livestock Units (LSU) per ha of UAA**	D	0.1383	0.3608
	Monoculture index	D	0.2730	
	Eco-efficiency (according to DEA – data envelope analysis)	S	0.1133	
	Share of forest in the farm area	S	0.0315	
	Share of permanent grassland in the farm area	S	0.0784	
	Share of arable land covered with vegetation during winter	S	0.1992	
	Balance of soil organic matter***	S	0.1664	

* Variable type: S – stimulant, D – destimulant.
** Livestock Unit (LSU) – is a reference unit that facilitates the aggregation of livestock of various species and ages according to convention by using specific coefficients established initially on the basis of the nutritional or feed requirement of each type of animal.
*** Calculated according to the methodology of the Institute of Soil Science and Plant Cultivation in Pulawy, Poland.

Source: authors' work based on methods accepted.

Table 2 presents descriptive statistics for individual sub-measures (economic, social and environmental) and the synthetic one, i.e. the arithmetic mean and the standard deviation, taking into account the division into analysed countries. As the data shows, the highest value of the synthetic sustainability index was observed in Poland, followed by Romania and Lithuania. In Poland, the highest value among sub-measures is achieved by economic sustainability (0.57), similarly in Romania (as much as 0.58), with relatively

DOI: 10.34659/eis.2022.81.2.450

small standard deviations (0.17 and 0.15, respectively). In both countries, the lowest value is recorded for the environmental sustainability sub-measure – in Poland 0.49 and in Romania only 0.38. Therefore, it can be assumed that small-scale farms in Romania are the least sustainable in terms of the environmental component. Lithuania indicates a different situation – the environmental sustainability index, in relation to the economic and social one, is the highest (0.55). The economic component is particularly low (0.35). This structure may indicate a relatively strong commitment of farms to environmental issues at the expense of poorer financial performance.

Table 2. Descriptive statistics for the individual (economic, social and environmental) and the synthetic measure of sustainability for farms in Poland, Lithuania and Romania (the arithmetic average and in brackets-standard deviation)

Country/measure	Sub-measures			Synthetic measure
	economic	social	environmental	
Poland	0.57 (0.17)	0.54 (0.09)	0.49 (0.18)	0.54 (0.11)
Lithuania	0.35 (0.11)	0.54 (0.16)	0.55 (0.15)	0.48 (0.10)
Romania	0.58 (0.15)	0.46 (0.17)	0.38 (0.27)	0.52 (0.14)

Source: authors' work based on methods accepted.

The third stage of the research was qualitative and included in-depth interviews with 'Top-20' farms from Poland, Romania and Lithuania (20 in each country). In-depth interviews offer a comprehensive picture of reality as perceived by the individual. They can be used to describe phenomena and develop and test theories (Van Maanen, 1998). Therefore, our use of in-depth interviews lets us obtain information that, according to (Miles, 1979), is „succinct, complete, real, creating access to causality" and which meets the criteria of interpretative evaluation, as focused on the individual perspective, on the unit and on his/her interpretation of reality (Konecki, 2000; Denzin & Lincoln, 2000). Thus, interviews provided plausible as well as reasonable explanations for a deeper understanding of the reasons why small farms undertake, if any, activities for the conservation of natural resources. The main objective of our analysis was to find out and compare the opinions of the owners of small-scale farms about their role in a sustainable development of rural areas. The interview was conducted by members of the research team in a scientific project (including one of the authors of this study) in 2020 and covered economic, social and environmental issues. In this article, due to the volume of research, we focused on the environmental sustainability aspect. Thus, the questions asked to farmers concerned about identifying actual and planned measures with beneficial impacts on natural resources.

DOI: 10.34659/eis.2022.81.2.450

Besides, the respondents were asked to assess the implementation of pro-environmental activities in the group of small family farms, including an assessment of their own activity. Respondents were asked the following questions:

- Do you think that your farm and other small-scale family farms are environmentally friendly? If so, in which aspects? If not, why? What is the assessment in comparison to the group of large-scale farms?
- What measures has your farm implemented to improve the environment?

The final step of this stage was to 'clear' and code the responses and classify them according to the method adopted. SPSS (Statistical Package for the Social Sciences) software was used for the analytical part.

Research results and discussion

The table below presents the basic statistics of the analysed units. The average area of farms where the in-depth interviews were conducted ranged from 10.3 ha in Lithuania to 13.4 ha in Poland (Table 3).

Table 3. Basic statistics for the 'Top-20' farms, 2020 (values in brackets for the entire population involved in the questionnaire survey)

Farm characteristics	Average value		
	Poland	Romania	Lithuania
Farm area (ha of UAA)	13.4 (14.1)	13.2 (12.1)	10.3 (10.5)
Standard output (EUR/year)	17.905 (12.830)	12.650 (10.320)	7.501 (5.614)
Household income (EUR/month) – only from agriculture	1.917 (1.843) 1.076 (985)	1.219 (1.106) 751 (693)	1.230 (1.022) 533 (433)
Share of support in agricultural income	35% (35%)	57% (50%)	55% (55%)
Estimated farm value (thous. EUR)	209.6 (n/a)	25.7 (24.5)	51.5 (49.7)
Estimated farm liabilities (thous. EUR)	6.6 (n/a)	3.0 (2.6)	0.4 (0.5)
Age of farm manager	49 (49)	46 (47)	48 (48)
Level of education of farm manager*	4.6 (4.6)	4.8 (4.5)	5.1 (4.9)

* Level of education in the range from 1 to 7, where 1 – no education, 7 – higher education

Source: authors' work based on interviews data.

More pronounced differences between countries can be observed in the case of production and farm income – in Poland, they were the highest, while in Lithuania the lowest. However, the most significant discrepancies were observed in the case of estimated farm assets.

Such a large gap in farm value between Poland and the other two countries could be due to higher prices of land and other real estate on the Polish

DOI: 10.34659/eis.2022.81.2.450

market (Palen et al., 2018). Interestingly, the high value of assets does not translate into the level of indebtedness of the surveyed units. It is relatively low in all countries, which confirms the risk aversion of farms (see also Binswanger & Sillers, 1983; Theuvsen, 2013; Sulewski et al., 2020). As for demographic variables – age and education – they are similar in the three cases.

All farmers surveyed (100%), regardless of the country, stated that their farms were environmentally friendly. They unanimously answered that they use less mineral fertilisers and chemical plant protection products than in the case of larger farms. Lack of money was often mentioned as the reason for this. Besides, they unanimously stated that lower fertilisation results from taking care of their own and their family members' health, as much of the food produced was consumed in the household. The following statements appeared in the questionnaires: „We use and eat everything we produce ourselves, so the products are really good", „I grow products for my children, grandchildren and family". On this basis, it can be concluded that the self-sustaining nature of smaller farms has a positive impact on their environmental sustainability. Also, the experience and tradition passed down from generation to generation, so characteristic for smaller farms, are of great positive importance for their management in an environmentally sustainable way. This aspect was particularly emphasised by Polish farmers. They argued as follows: „my father taught me, and his father taught him, etc.". They indicated that they grew plants that enrich and decorate the landscape (e.g. blueberries), applied extensive animal husbandry, reused resources, maintained natural meadows, applied crop rotation, and did not pollute nature.

However, some differences between the countries concerned farmers' intentions related to environmental activities. Polish farmers indicated the need for more precise fertilisation, which in their opinion should be reinforced by training in this field. They noted that such actions would increase the environmental benefits of their production. On the contrary, farmers from Lithuania and Romania claimed that it would be better if they did not have to change anything in their current activities related to the use of artificial fertilisers and plant protection products. Only three of them (two in Lithuania and one in Romania) noted that more widespread financial support for pro-environmental agriculture would encourage actions to obtain organic farm certification. At the same time, Romanian farm owners complained most about the current support system under the EU's common agricultural policy. They argued that agri-environmental payments are taken over by big actors. However, the in-depth discussion revealed a low level of knowledge about the possibilities of applying for EU funds. In Poland and Lithuania, education in this field was at a relatively high level.

Concluding this part of the research, it should be stated that the results confirm the high level of environmental sustainability of small farms, which

DOI: 10.34659/eis.2022.81.2.450

is often emphasised in the literature. The respondents' answers indicate that the high sustainability of this group of farms is due to the favourable influence of tradition, care for their own and family member's health (the self-supply character of smaller farms), and, paradoxically, the unfavourable economic situation, which determines the lack of financial resources to purchase chemical fertilisers and plant protection products. It is also worth emphasising that farmers are aware of the fact that their farms are environmentally friendly. This is supported by the activities undertaken, which have a positive impact on the natural environment. Furthermore, farmers from the analysed countries in the vast majority do not feel the need to change their pro-environmental activities.

Farmers were aware of their environmental friendliness. Their view of the pro-environmental nature is also reflected in the literature. Indeed, many researchers have proved that the characteristic of small farms is their relatively high environmental sustainability. This is due to the peculiarities of these producers, especially highlighted by comparative analysis with large farms. Herrero M. et al. (2017) demonstrated that in agricultural production, diversity decreases with increasing farm size.

On the other hand, Ricciardi et al. (2018) confirmed that small-scale farms have significantly higher biodiversity than their larger counterparts. The former generate landscape diversity and stimulate biodiversity (Ebei, 2020) but also provide numerous valuable ecosystem services to the society (Chen, 2010). This is because of the multidirectional of crop production and adaptation to local environments, including low dependence on external inputs (Holt-Giménez, 2012). Among the indications in our survey were those of lower fertiliser and chemical plant protection use in relation to lager units, either because of a lack of money or out of concern for food quality. This fits to earlier findings by Altieri & Nicholls (2012) and Holt-Giménez & Altieri (2013), in which it was shown that small farms are less dependent on commercial inputs than large ones. Small farms benefit from a wide range of resources, such as manure and compost produced on the farm. In addition, Wibbelmann et al. (2013) found that small farms tend to use less machinery than large farms and therefore consume less fossil fuel, which reduces their operating costs and, at the same time, increases their environmental sustainability. Assessing the environmental sustainability, the farmers interviewed also highlighted the beneficial impact of their cultivated experience and traditions. This was recognised earlier by Wibbelmann et al. (2013) and Koohafkan (2019), noting that peasants benefit from traditional ecological knowledge embedded in cultural and religious traditions and thus increase the sustainability of their farming systems. Besides, Nicholls (2018) noted that agroecological systems are deeply rooted in small-scale farming traditions. The high beneficial impact of peasant traditions on the environmental sus-

DOI: 10.34659/eis.2022.81.2.450

tainability of farms was also justified, using Mexico as an example, by Arnés et al. (2013), pointing out that the abandonment of traditional farming techniques (unsustainable in the absence of abundant family labour) significantly increases the costs of resource conservation. The cited research results, confirmed by the analysis of the statements of the owners of small family farms from Poland, Romania and Lithuania, therefore speak in favour of greater financial support for small family farms due to their pro-environmental character and their difference in this respect from large farms.

Conclusions

On the example of small family farms from three analysed countries, it was indicated that the view found in the literature that small farms perform important environmental functions in rural areas is correct and applies to countries with a fragmented agrarian structure, such as Poland, Romania and Lithuania. It results from the very essence of these farms, based on the cultivation of traditions and experience passed down from generation to generation, as well as from the family nature of these units. It is also worth emphasising that farmers are aware of their pro-environmental functions and intend to continue this attitude, which is essential from the point of view of social benefits. On the other hand, the economic performance of this group of producers is relatively worse in relation to both larger area farms and average wages in the economy. In the long run, this leads to the disappearance of this group of agricultural producers, with negative consequences for the environment and society. This argument determines the necessity of financial support for these farms, in accordance with the so-called European model of agriculture, which exposes the double function of agriculture in Europe – apart from food production, it contributes to the broadly understood development of rural areas and provides environmental public goods. The demonstrated pro-environmental behaviours implemented by small family farms justify the necessity to ensure economic conditions for their survival through appropriately adapted tools of the common agricultural policy. As indicated by the owners of the surveyed farms, the most desirable directions of aid are administratively simple area payments (which de facto function in the current CAP system), price stabilisation instruments and those increasing the added value in the food supply chain.

The article has two limitations. First, there may be some doubt regarding the small sample of farms interviewed in the research. It is worth recalling that qualitative research is characterised by labour-intensive data collection (Miles, 1979) and much more significant financial expenses than quantitative research, which weakens the charge of an insufficient number of respond-

DOI: 10.34659/eis.2022.81.2.450

ents. Moreover, as Pasikowski (2015) points out, the implementation of qualitative research in the grounded theory most often coincides with the use of a sample size of 20-30 units. The second limitation is its static approach. To demonstrate changes in the pro-environmental attitude of small farms, a dynamic approach would be required. These limitations should be considered in future research. It should also be remembered that the sample of respondents included farms diagnosed as showing the highest degree of sustainability (in economic, social and environmental order).

Further on, the research should include small farms with different degrees of sustainability, which will make it possible to generalise the results to the entire sector of small family farms. The study should also include other countries besides the three analysed. Work is currently underway to extend the scope of the survey to include the Czech Republic and Slovakia.

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Katarzyna Smędzik-Ambroży: conceptualisation, methodology, formal analysis, writing – review & editing.

Sebastian Stępień: conceptualisation, investigation and resources, writing – original draft, funding acquisition, project administration, supervision.

Anna Matuszczak: conceptualisation, literature review, methodology, formal analysis, writing – review & editing.

Aleksandra Tosovic-Stevanovic: literature review, investigation and resources, visualisation, project administration.

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USE OF HYDRAULIC MODEL IN REAL WATER LOSS REDUCTION AND WATER DISTRIBUTION NETWORK OPERATIONAL COST LOWERING

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ABSTRACT: Most of the small water companies supplying a small number of consumers with water are struggling with the extremely tight budget, often making any large-scale modernisation impossible. In effect network managed by these companies is often very leaky and unreliable. One possible and cheap way of leakage reduction is the reduction of average pressure in the network. Thanks to new computing technologies, the device selection process for pressure reduction is accurate and easy to do. This study uses the hydraulic model to select required pressure reducing valves and correct locations accurately and adequately approximate the resulting absolute water loss reduction thanks to this approach.

KEYWORDS: hydraulic, modelling, water loss, leakage, cost of exploitation, loss reduction

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Introduction

Water losses are expected in any water distribution system over its life-cycle. The simplest way to define them is by calculating a non-revenue water (NRW) level. It equals unbilled authorised consumption plus actual losses and apparent losses (Pearson, 2019). According to The European Federation of National Associations of Water Services (2021), the mean values for non-revenue water are 25% (2696 m^3/km/y) in EurEau member countries. In some cases, reported average NRW level exceeds 30%, like Bulgaria, Italy, Malta, Romania, and Slovakia. Figure 1shows the reported average NRW level in EurEau member countries.

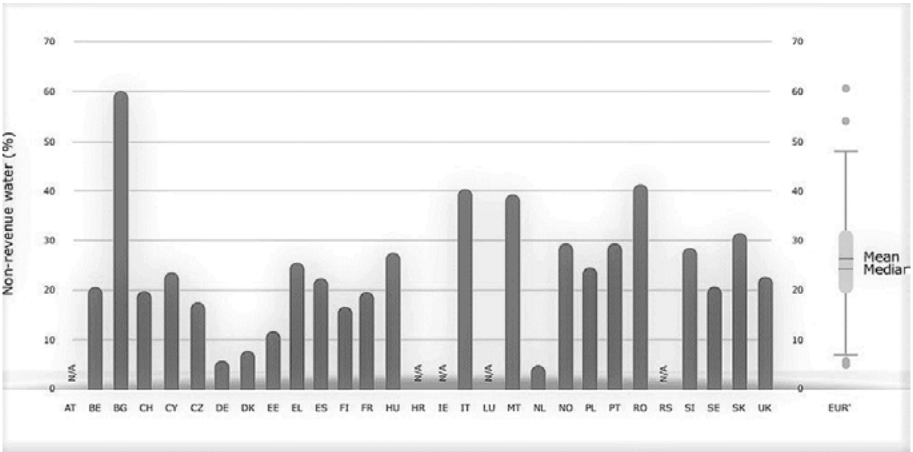

Figure 1. The average non-revenue water level reported in EurEau member countries

Source: The European Federation of National Associations of Water Services (2021), p. 22.

High water loss level in distribution networks is one of the key challenges facing water utilities Dawidowicz et al. (2021). From an economic point of view, water that never reaches customers must be treated and transported, generating additional operating costs and causing carbon dioxide emissions that could have been prevented Trębicka (2016). Moreover, negligence in the management of the water supply network also affects social and technical issues like water supply interruptions and low-pressure Gwoździej-Mazur et al. (2019).

According to Baader et al. (2011), actual losses usually represent the most critical component of water losses in developed countries. Actual water losses are associated with leakages on transmission and distribution mains, storage tank overflows and service connections. Practice shows that the best

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results in leakage level reduction are obtained by applying several integrated methods. One of them is widely used pressure management, which aims to:

- lower the amount of water lost due to pipe bursts and breaks,
- decrease the background leaks, which are related to minimum night flow,
- reduce the frequency of failures.

According to McKenzie and Wegelin (2009), reducing the water pressure in a water system can be achieved in a number of ways:

- fixed outlet pressure control,
- time-modulated pressure control,
- flow modulated pressure control.

Nowadays, hydraulic models are increasingly used to assist in operating water supply systems, including PMA (pressure management areas) zones planning Świętochowska et al. (2021).

The hydraulic model creation process includes several steps:

- representation of water system geometry, including:
  - filling internal diameters,
  - estimating roughness based on material and date of commissioning,
  - verification of connections,
  - localisation of closed valves;
- demands allocation and defining water consumptions patterns;
- recreation of water supply facilities operation;
- model calibration.

Most hydraulic models require some calibration for even basic uses, and numerous model adjustments are often required (Walski, 1986). Before any analyses are carried out, simulated results must be compared to the field's pressure and flow rate data. The model can be considered reliable if the collected time series are consistent with the simulated ones.

The calibrated model enables the user to leverage relatively few field observations into a complete picture of what is occurring in the distribution system. It allows viewing computed parameter changes over simulation time in every node point of the water distribution system. This helps to plan the future location of pressure-reducing valves (PRV), identify critical points with the lowest pressure and adjust pressure reducing valve settings. Simulated flowrates may be used to correctly choose the PRV nominal diameter to ensure the device's correct operation.

An important feature of the hydraulic model is also simulating the response of leaks to changes of pressure in a water distribution system or specific pressure management area Gwoździej-Mazur et al. (2021). It can be carried out by adding the emitter coefficient to network nodes. According to Lewis et al. (2020), emitters are used to model flow through sprinkler systems and irrigation networks. They can also simulate leakage in a pipe con-

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nected to the junction. The pressure determines the flow rate through the emitter at the node:

$$q = Cp^{\gamma}, \tag{1}$$

where:
q – flow rate through emitter,
p – pressure,
C – discharge coefficient,
γ – pressure exponent (for nozzles and sprinkler heads γ = 0.5).

Figure 2 shows the dependence of Epanet 2.2 simulated leakage outflow rate to pressure and selected emitter coefficient values.

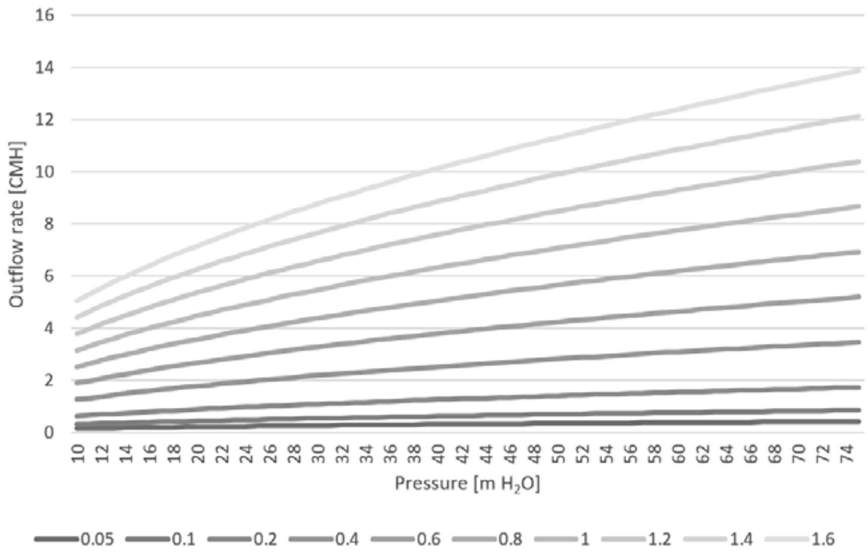

Figure 2. Dependence of Epanet 2.2 simulated leakage outflow rate to pressure and selected emitter coefficient values

Source: author's work.

Without disturbing customer service, network models can be used to replicate the behaviour of an actual system under a variety of hypothetical scenarios like checking different pressure reduction methods and valve settings. Each approach can be evaluated to determine the savings from leakage reduction. If more than one pressure management zones are designed, and funds are limited, it is possible to split the project into stages and set a priority on each one of them.

Methodology

To conduct the study, one hydraulic model consisted of two sub-models. Both of them represent existing municipal water supply systems in Silesian voivodeship. Each of them supplies at least one village. According to a census done in 2011, village A has around 3014 inhabitants and has an area of 7.1 km^2. Sub-model B supplies around 4000 inhabitants, and the total pipe length is approximately 44 km. Data about several inhabitants comes from a census done in 2011. Models were created with the use of Quantum GIS which is under an open-source license. After models were built, they were exported into the simulation software Epanet, also under an open-source license issued by USEPA.

Both models' demands were allocated using the Voronoi polygon method. This method allows for quick and accurate aggregation of water demands. Sum of demands in both models is represented in Table 1.

Table 1. Sum of demands and total supplied the population of both sub-models

Sub model	Total water demand [CMD]	Number of inhabitants
A (one village)	161.106	3014
B (one village and part of neighbouring village)	328.197	4000

Source: author's work.

Model A

Network A is connected to an external water supply main with a diameter of 1000 mm by a pipe with a diameter of 150 mm. This connection supports all normal and emergency demands that arise in the system. That water source is managed and owned by different water companies. The network manager buys water from that company at a price of 2.51 PLN/m^3. Submodel A includes the whole water supply network, which has a total length of 15.35 km of pipes. The total number of links for this sub-model equals 726, and the number of nodes equals 717. The average link length is around 21.40 m. This means that most of the water supply connections to individual recipients are represented in the model. All allocated demands have one demand pattern, which represents single-family housing.

Figure 3 shows a graphical representation of submodel A extent, complexity and structure. The white diamond symbol with a numeric label represents the location of the planned pressure reduction valve that will reduce the total pressure of water flowing to the system, located on the network water supply point. Current pressure at the supply point is maintained

DOI: 10.34659/eis.2022.81.2.474

around the value of 6 bars. Thus, reducing stress will lessen water seepage caused by pipe leakage.

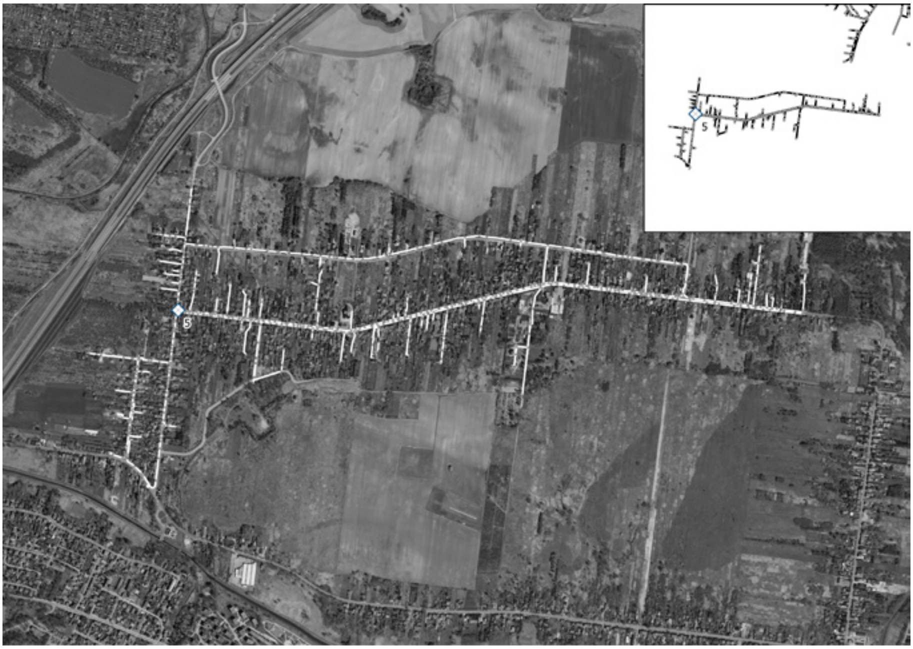

Figure 3. Graphical representation of hydraulic model A range and structure
Source: author's work.

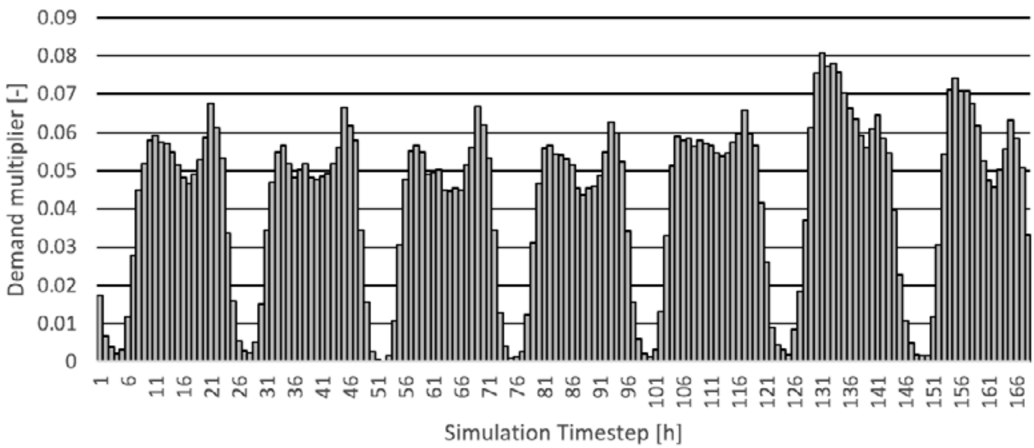

Figure 4. Demand pattern for submodel A representing single-family housing
Source: author's work.

DOI: 10.34659/eis.2022.81.2.474

The plot in Figure 4 indicates that the total simulation duration is equal to 168 hours. This allows to simulate different days of the week and achieve higher fidelity of flow and pressure in the system.

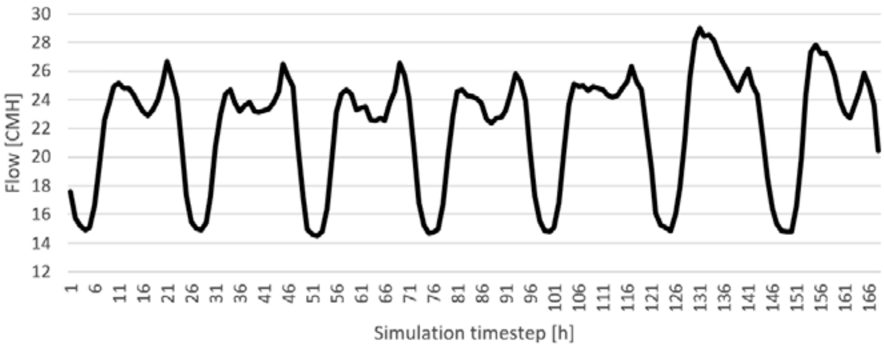

Figure 5. Subnetwork A water inflow on supply point

Source: author's work.

The plot in Figure 5 shows the distribution of water inflow. The most noticeable things are very high night flow values which oscillate around 15 m^3/h. This indicates that there might be a significant leak in the system. On closer examination, it can be concluded that, on average, 528.03 CMD of water flows into the network, and the sum of water leakage is around 366.92 CMD. This indicates the level of losses in grid A of 69.49%. Such water leakage is unacceptable and must be reduced as quickly as possible. The main problem with water leaks in the system is that they are located on individual water supply connections to individual recipients. Most of those connections are either under asphalt or pavement.

Table 2. Estimated simplified supply cost to recipients in subsystem A

Data type	Volume of water [m^3]	Money value [PLN]
Water price of 1 cubic meter	-	2.51
Inflow	192,730.340	483,753.15
Demands	58,803.508	147,596.80
Water losses due to leakage	133,926.832	336,156.35

Source: author's work.

Each year on average, the total inflow to network A is equal to 192 730 m^3. On average, the yearly water demand in the system is approximately 58 803 m^3.

This gives water losses at the level of over 133,926 m^3 and financial losses at a group of over 336,000 PLN. The overview of this data is visualised in Table 2.

Model B

Water fed to the system is similar to in-network A. Network B is connected to an external water supply main with a diameter of 1000 mm by a pipe with a diameter of 150 mm. This connection allows the collection of all regular and emergency demands that arise in the system. Water is sold to the network by the same company and at the same price as in the case of network A which is equal to 2.51 PLN/m^3. Submodel B includes the whole water supply network with 44 km of pipes. The total number of links for this submodel is 1576, and the number of nodes is 1553. The average link length is around 28.33 m. This means that, on average, most individual water supply connections to particular recipients and model complexity are very similar as in the case of submodel A. All allocated demands have one demand pattern, which represents single-family housing.

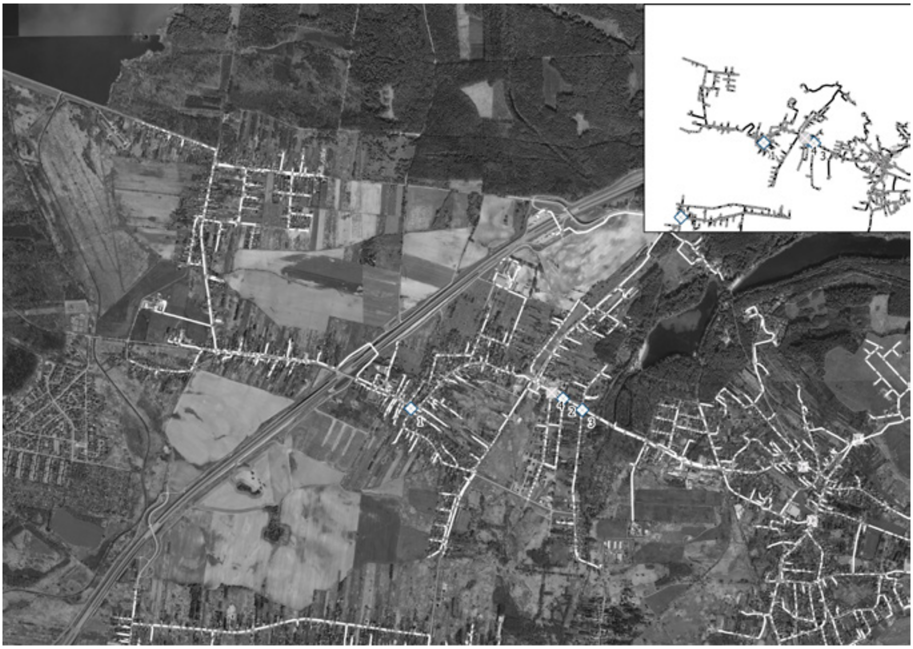

Figure 6. Graphical representation of hydraulic model B range and structure

Source: author's work.

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The image in Figure 6 shows a graphical representation of submodel B extent, complexity and structure. A red valve symbol with the number label represents the location of the planned pressure reduction valve location. Red crosses indicate valves that cut off flow to and from foreign systems connected to subsystem B.

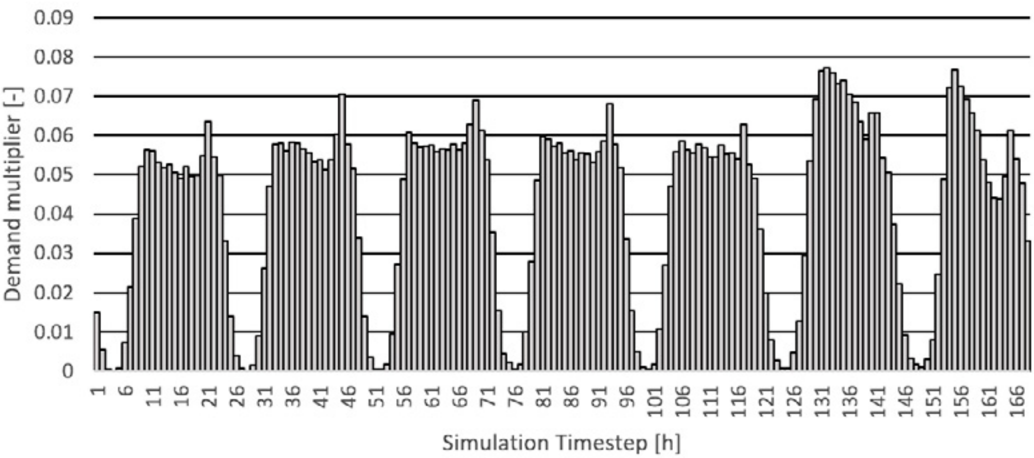

Figure 7. Demand pattern for submodel A representing single-family housing

Source: author's work.

Figure 7 indicates that the total simulation duration equals 168 hours. This demand pattern differs from the one used for subnetwork A. This allows to simulate different days of the week and achieve higher fidelity of flow and pressure in the system.

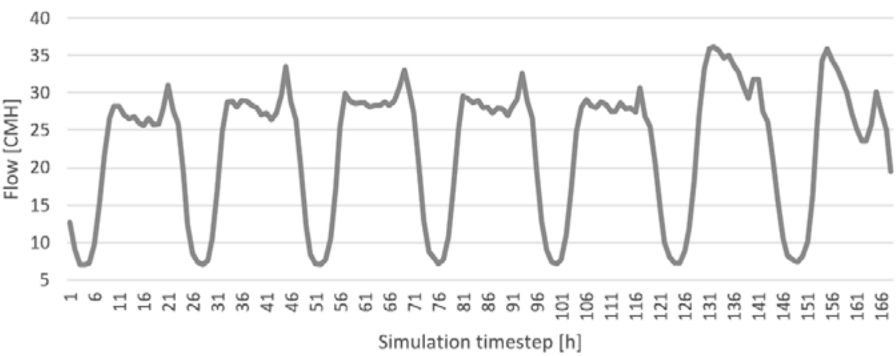

Figure 8. Subnetwork B water inflow on supply point

Source: author's work.

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The plot in Figure 8 shows the distribution of water inflow. Like in the earlier case, the most noticeable is the high values of night flow which oscillates around 7 m^3/h. This indicates there is a leak in the system. On closer examination, it can be concluded that, on average, 545.61 CMD of water flows into the network, and the sum of water leakage is around 217.41 CMD. This indicates the level of losses in grid B of 39.85%, which is lower almost by half compared to network A. Difficulties and hurdles with leakage location is identical to submodel A.

Table 3. Estimated simplified supply cost to recipients in subsystem B

Data type	Volume of water [m^3]	Money value [PLN]
Water price of 1 cubic meter	-	2.51
Inflow	199,146.764	499,858.377
Demands	119,791.905	300,677.682
Water losses due to leakage	79,354.8586	199,180.695

Source: author's work.

Each year on average total inflow into network A equals 199,146 m^3. On average, the yearly water demand in the system is approximately 119,792 m^3. This gives water losses at the level of over 79,000 m^3 and financial losses at the level of over 199,000 PLN. The overview of this data is visualised in Table 3.

In total, a water distribution company that manages networks A and B loses over 535,337 PLN each year due to actual water losses in the system. One has to remember that this company supplies around 7000 inhabitants. The combination of the fact that all water provided to the networks is bought from another company and the high level of water leakage causes the managing company not to have enough assets to carry out a thorough modernisation of the pipe network.

The first step in lowering actual water losses should be reducing the overall pressure in both systems. This pressure initially is relatively high for networks on relatively flat terrain and oscillates around 6 bars for network A and reaches up to 6.4 bars for network B. With a low initial investment; it is possible to reduce the cost of the network exploitation.

Water leaks were simulated by applying the emitter coefficient factor, which responds to changes in water pressure in the pipes. Higher the pressure, the more significant the outflow. Usage of this function allows simulating and approximating outflow reduction due to the decrease in the pressure in the system.

DOI: 10.34659/eis.2022.81.2.474

As the leak location is unknown in the case of both networks, the safest approach is to apply the emitter coefficient factor to every working node in the model's graph after the main flowmeter. Table 4 shows the sum of emitter coeff. That is spread across all nodes in the models. A total of 716 nodes in model A and 1551 in model B were assigned this parameter. For each node in the model, the A value of the parameter is equal to 0.0026599 and 0.000644 for model B.

Table 4. Summary of emitter coefficient parameters in both models

Submodel	Total value of emitter coeff. Spread on all nodes [-]	Total number of nodes with assigned value of emitter coeff.	Value of emitter coeff. assigned to each node
A	1.897328	716	0.002650
B	0.998844	1551	0.000644

Source: author's work.

Results

Model A

The pipe connecting system A to the supply point has a diameter of 150 mm, minimum flow at this point is equal to 14.50 CMH, and maximum flow is similar to 29.02 CMH. On average, through this pipe flows 22 CMH of water. Table 5 represents flow and pressure reduction values for model variant A. As it can be seen that the optimal diameter for the pressure reduction valve that will supply subnetwork A is equal to 100 mm. This unit will be available to water for firefighting purposes. Plot Figure 9 shows average pressure values for each simulation hour before and after applying pressure reducing valve, which in effect lowers the whole system pressure by 1.44 bar of pressure.

Table 5. Flow parameters for the point of pressure reduction valve installation location

Model variant	Pipediameter [mm]	Minimum flow [CMH]	Maximum flow [CMH]	Averageflow [CMH]	Pressurereduction [bar]	Optimal presure reduction valve diameter [mm]
A	150	14.500	29.022	22.001	1.44	100

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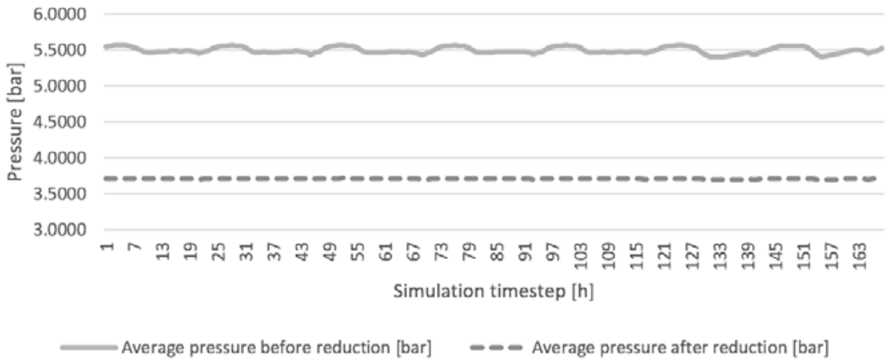

Figure 9. Average pressure for model A before and after reduction of pressure

Source: author's work.

After the average pressure in the network was reduced from around 5.5 bars to 3.7 bars by installing a pressure reduction valve at the chosen point, a decrease in flow was observed. This reduction is represented in Figure 10, showing that approximately 2 CMH reduced nighttime flows and a similar amount reduced daytime flows. The plot in Figure 11shows exact differences for flow before and after pressure reductions which were calculated in simulation software.

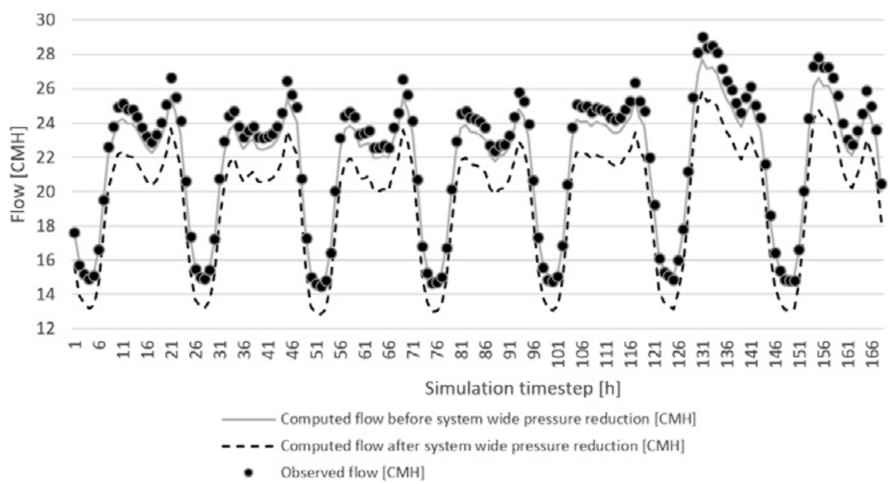

Figure 10. Plot of observed flow at inflow point of subsystem A and computed flow before and after pressure reduction in the network

Source: author's work.

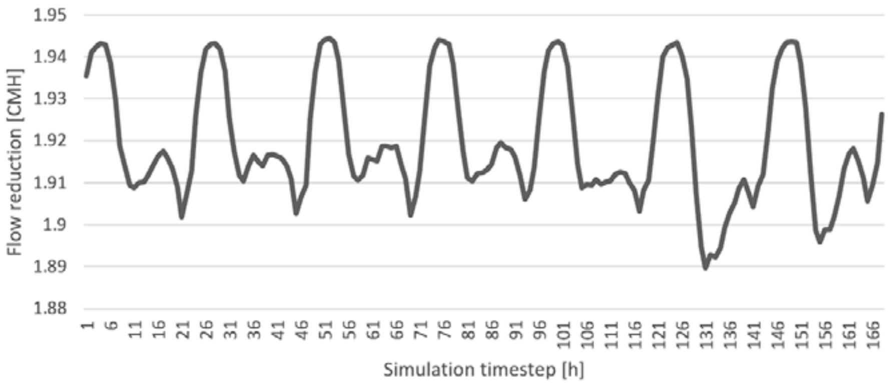

Figure 11. Difference in flow before and after pressure reduction

Source: author's work.

These results indicate that, on average, each day, it is possible to reduce leaks of the subnetwork A by approximately 46 cubic meters. This translates to 42,207 PLN each year. This can be considered a big saving considering that the pressure reduction valve costs a fraction of this value.

Model B

Due to land topography, it is impossible for system B to reduce pressure by applying pressure reducing valve at one point. This means that system-wide pressure reduction is impossible without adding expensive pumping stations Świętochowska et al. (2022). Thus, three points were selected where pressure will be reduced via the installation of pressure reducing valve and 1 point where the closure of the general-purpose valve will cut off the flow. Flow and diameter parameters for each of the said points are represented in Table 6. The plot in Figure 12 shows the average drop in pressure due to taken measures.

Table 6. Summary flow parameters at planned PRV installation and flow cutoff locations

Point	Pipediameter [mm]	Minimum flow [CMH]	Maximum flow [CMH]	Averageflow [CMH]	Pressurereduction [bar]	Optimal pressure reduction valve diameter [mm]
PRV valve 1	150	4.991	22.697	14.542	1.432	100
PRV valve 2	80	0.353	1.102	0.757	1.724	65
PRV valve 3	80	0.324	1.489	0.952	1.704	65
Flowcutoff point	110	-	-	-	-	-

Source: author's work.

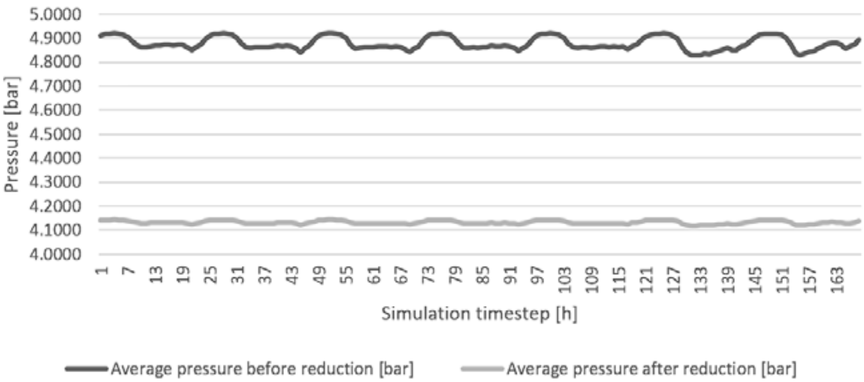

Figure 12. Average pressure for model B before and after reduction of pressure

Source: author's work.

A decrease in flow was observed after the average pressure in the network was reduced from around 4.9 bars to 4.15 at pressure reduction valves and flow cutoff at chosen points. A plot represents this reduction in Figure 13, and it shows that there is an observed reduction of approximately 0.8 CMH throughout the whole day of system work. Action in Figure 14 shows exact differences in flow before and after systemwide pressure reductions.

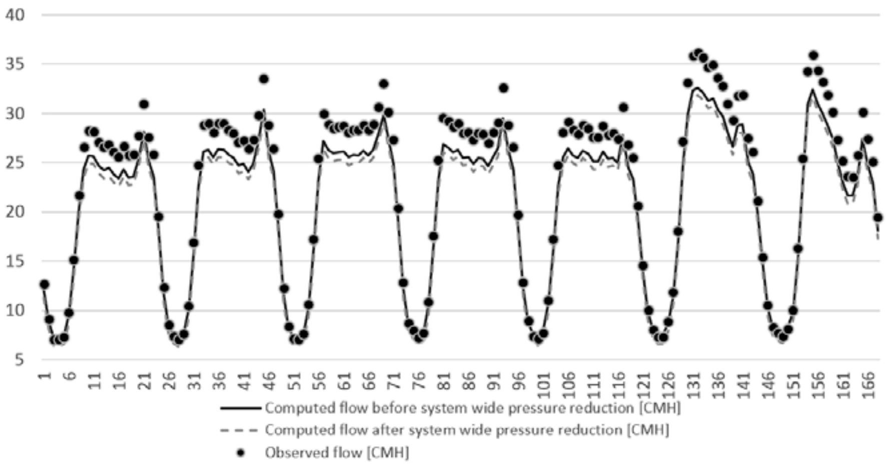

Figure 13. Plot of observed flow at inflow point of subsystem B and computed flow before and after pressure reduction in the network

Source: author's work.

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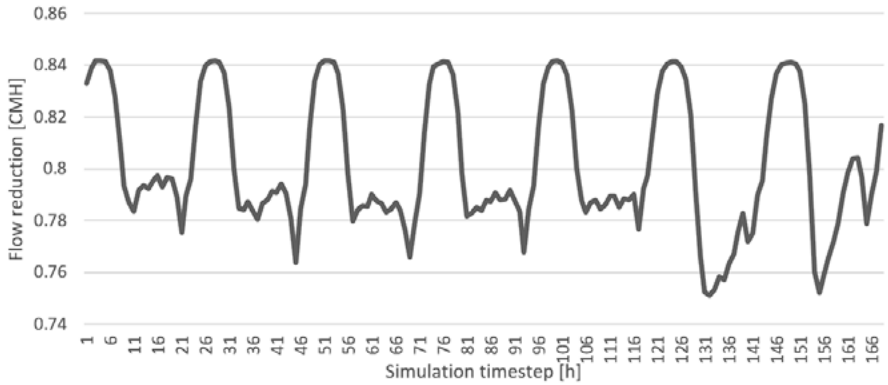

Figure 14. Difference in flow before and after pressure reduction

Source: author's work.

These results indicate that, on average, each day, it is possible to reduce leaks of subnetwork B by approximately 19.23 cubic meters. This translates to 17,625 PLN each year. This, in addition to subsystem A saving, gives 59,832 PLN lowered yearly expense of supplying end-users with water. In the perspective of 10 years, this value increases up to 598,832 PLN assuming that the price of water provided by the external company does not improve, which is unlikely when considering rising costs of energy and new environmental taxes. Such an amount for a small scale water supply company is by no means a small matter considering that all water is bought from external sources.

Conclusions

The use of computer models in water distribution system management is constantly growing. The paper focuses on the feasibility of using hydraulic modelling to estimate absolute loss reduction by implementing pressure management. For this purpose, computer models of two water distribution systems were created – submodel A and submodel B. Both of them belong to one water utility in the Silesian Voivodeship. Pressure reduction methods have been developed and simulated for each water distribution system as model scenarios.

Results have shown that in model A, average pressure in the system was reduced by 32.73% from 5.5 bar to 3.7 bar, which resulted in an expected leakage reduction by 12.88% from 130,407 m^3 per annum to 113,617.2 m^3 per annum. In model B, average pressure in the water distribution network was reduced by 15% from 4.9 bar to 4.15 bar, which may cause leakage reduction by 8.85% from 79,354 m^3 per annum to 72,335 m^3 per annum. The

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expected savings for implementing pressure reduction in both systems are 59,832 PLN per year (42,207 PLN at submodel A and 17,625 at submodel B).

Based on the research results, we can state that hydraulic modelling can effectively manage pressure in water distribution systems. In the case of splitting the investment into stages, implementation of pressure management in submodel A should be prioritised, as it yields the most significant savings. It also requires less financial investment as it only needs installing one pressure reduction point, unlike the submodel B, where three pressure reducing valves are needed.

Acknowledgements

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The contribution of the authors

The article was written in collaboration with all authors.

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ANALYSIS OF AEROBIC AND ANAEROBIC SEWAGE SLUDGE DISPOSAL CONCEPTS

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ABSTRACT: The article aimed to analyze the concept of modernisation of sludge management prepared for an exemplary sewage sludge treatment plant. Four variants of solutions, based on different processes, aerobic (oxygenic), anaerobic or – aerobic – anaerobic, were discussed. The article presents the characteristics of essential elements of the proposed solutions. The technical and technological parameters of each of the variants are exposed. The expected capital expenditure and basic operating costs are presented. A cost-effectiveness analysis of the options has also been carried out. The analysed technological processes ensure obtaining hygienically and sanitary safe end products. They contribute significantly to minimising the amount of sewage sludge. The most economically efficient, with the lowest average annual costs, is the variant with the application of anaerobic thermophilic-mesophilic sludge stabilisation. The highest average annual costs were obtained for the variant with drying and incineration of sludge.

KEYWORDS: sewage sludge, sewage sludge treatment, sewage sludge management, capital expenditure, operating costs

Introduction

A by-product of a municipal wastewater treatment plant is the sludge that arises at different stages of its treatment. Almost the entire pollutant load entering the treatment plant is processed into biomass, which is subject to the Directive of the European Parliament and of the Council of 19 November 2008. 2008/98/EC on waste (the so-called Waste Framework Directive). In accordance with the principles of sustainable development, the sludge produced should be treated as a source of recovery, recycling of the main plant nutrients and not as waste. Municipal sewage sludge is slowly beginning to be appreciated by specialists as a raw material that can be successfully returned to the natural circulation in the form of organic fertiliser. They are considered to be one of the best soil additive fertilisers and are also a source of slowly releasing into the environment biogenic compounds and microelements. However, before they are used, they must be properly rendered harmless. Effective solutions for the management of sludge treatment plants should ensure the stabilisation of sludge and its hygienization while reducing its quantity.

In order to maintain the waste treatment hierarchy, when planning the construction or modernisation of wastewater treatment plants, consideration should be given to the use of appropriate technologies that reduce the quantity and ensure the quality of municipal sewage sludge produced. In addition, the processing of municipal sewage sludge understood as its final disposal, depends to a large extent on previous treatment processes. Therefore, the technical and organisational capacity of individual sewage treatment plants significantly influences the quality of municipal sewage sludge and, consequently, the ways it is treated. It should be stressed that in the case of newly built or modernised wastewater treatment plants, these possibilities should be determined as early as the stage of determining the directions of development of investments in water and wastewater management. Incorrect determination of direction, or incorrect assumption at this stage, may result in the sludge generated on the site of a treatment plant being unsuitable for use on the ground or for thermal conversion due to non-compliance with the required parameters. According to the regulations in force in Poland, the criteria for storing municipal sewage sludge in landfills and storage yards practically exclude such a possibility.

The aim of this article was to analyse selected concepts of sludge management and to indicate ways of handling municipal sewage sludge in accordance with the current legislation. It is also important to emphasise the possibility of using the biogenic substances contained in the sludge while meeting all the requirements concerning sanitary, chemical and environmental safety.

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Research methods

For the purpose of this paper, a concept of sludge management in a municipal wastewater treatment plant was developed. Technical and technological calculations of the installation in all variants were made based on the following parameters:

- excess sludge mass of 11000 kg of dry matter per day;
- 1% concentration of dry matter in excess sludge;
- concentration of dry matter in the sludge after mechanical thickening 4-5%;
- organic matter content in the sludge is 80-85%.

The concept was performed in four variants.

Characteristics of selected concepts

Four variants of sewage sludge treatment were presented in the concept. Variant one provided for the use of autothermal thermophilic sludge stabilisation (ATAD). Variant two used an anaerobic stabilisation process. Variant three was developed using aerobic-anaerobic stabilisation. Variant four was prepared for a drying process with combustion.

Variant I ATAD

In the sludge mineralization system of the ATAD process, two first and second stage tanks are to be built in two process lines. The reactors are thermally insulated and closed to minimise the heat loss. Excess sludge from the pumping station will be directed directly to mechanical compaction. With the tanks connected in series, the temperature in the first stage of the installation is obtained in the lower thermophilic decomposition range, with maximum disinfection and the highest temperature in the last step. Daily discharge of inactivated sludge will take place only from second stage reactors. At the end of the next release, raw sludge will be fed to the first stage when the partially treated sludge is moved to the next reactor. The reactors will be equipped with aerators that provide a specific flow and control the amount of foam produced. In order to limit the temperature rise in the second stage reactors, heat exchangers will be installed, which will allow the excess energy to be used for the plant's own needs. The air discharged from the ATAD chambers will be purified in an installation consisting of a scrubber, a dryer and a photocatalytic oxidation module. Sludge stabilised after dehydration will be used for natural purposes. The scheme of sediment management is shown in

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Figure 1. The primary technical and technological parameters of reactors in this variant of sludge management are presented in Table 1.

Table 1. Technical and technological parameters of ATAD reactors

Number of reactors	2 reactors of the first stage and 2 second stage reactors	Number of reactors
Reactor dimensions	First stage	Reactor dimensions
Length	25.2 m	Length
Width	12.6 m	Width
Total height	3.1 m	Total height
Height of filling with sludge	2.4 m	Height of filling with sludge
Active volume	1,524 m^3	Active volume
The total dwell time of sludge in the installation	about 8.3 day	
Daily portion of sludge	275 m^3/day	

Source: authors' work.

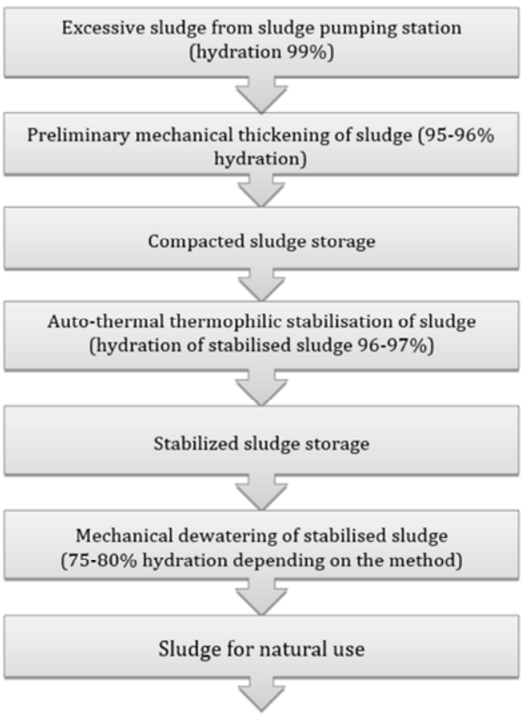

Figure 1. Scheme of sludge management using the ATAD process

Source: authors' work.

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The odour deactivation installation envisaged in this installation variant will have a capacity of 4,200 m^3/h.

Variant II fermentation

In the anaerobic thermophilic-mesophilic sludge stabilisation system, two first- and second-stage digesters in two process lines are planned. Excess sludge from the pumping station will be directly sent to mechanical thickening. The thickened sludge will go to two thermophilic digesters in the first stage. After the process, the sludge will be directed through a sludge-sludge heat exchanger (recuperator) to two more second-stage mesophilic digesters. The first and second stage chambers will be equipped with circulation pumps and external heat exchangers; in the first case, the sludge will be heated to a temperature of approximately 55°C in the exchanger, while the exchanger of the second stage chamber will only be designed to maintain a temperature of 35°C. Stabilized sludge from the digesters will be dewatered.

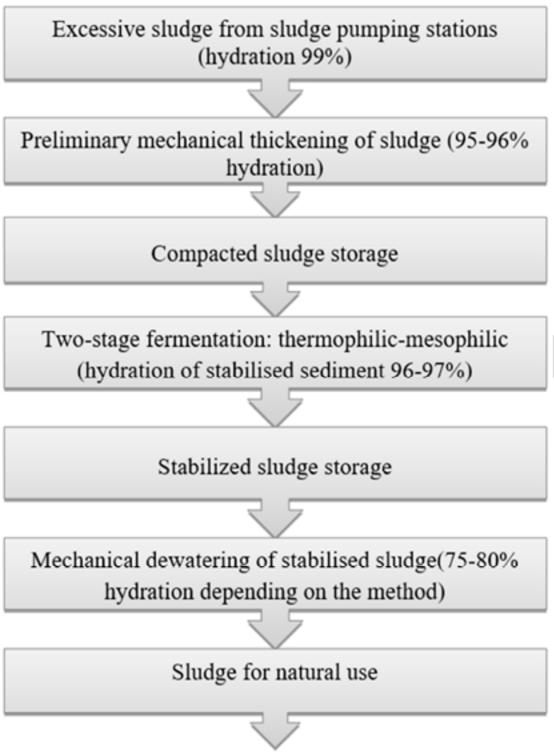

Figure 2. Scheme of sludge management using the fermentation process

Source: authors' work.

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The biogas produced in the fermentation process after desulphurisation will be collected in a diaphragm biogas tank, from where it will be directed to a boiler room equipped with a gas boiler and a cogenerator. Excess biogas will be burned in a flare. A diagram of sludge management for variant II is presented in Figure 2.

The basic technical and technological parameters of thermophilic-mesophilic fermentation reactors are presented in Table 2.

Table 2. Technical and technological parameters of thermophilic-mesophilic-fermentation reactors

Number of reactors	2 first stage reactors and 2 second stage reactors	
Reactor dimensions	First stage	Second stage
Diameter	10 m	15 m
Total height	12 m	16 m
Sludge filling height	9 m	13.3 m
Active volume	1,413 m^3	4,698 m^3
Total dwell time of sludge in the installation	5 days	17 days
Daily portion of sludge	275 m^3/day	

Source: authors' work.

This variant of sludge management additionally requires the construction of a technological building with rooms for heat exchangers, a pumping station for sludge recirculation, and a fermentation gas installation and a power unit. It was also necessary to build a 1,000 m^3 biogas tank and a torch with a capacity of 180 m^3/h.

Variant III aerobic-anaerobic

In the aerobic-anaerobic sludge stabilisation system, four first-stage ATAD tanks and two second-stage mesophilic fermentation tanks are planned. Excess sludge from the pumping station will be directed straight to mechanical compaction. The thickened sludge will go through a recuperator (sludge-sludge heat exchanger) into four ATAD chambers. Each of the ATAD reactors will be equipped with an internal exchanger to be supplied with the heating medium. After the process, the sludge will be directed through a recuperator to the following two mesophilic fermentation chambers. Fermentation chambers will be equipped with circulation pumps and an external heat exchanger. Internal heat exchangers of ATAD chambers will be designed to replenish the heat necessary to obtain a sludge temperature of 60^{o}C. The second stage chamber heat exchanger will serve to maintain the temperature of 35^{0}C. Stabilized sludge will be directed to the dewatering station. The biogas produced in the fermentation process, after possible desulphurisation, will be stored in a diaphragm gas tank, from where it will be directed to a boiler room equipped with a gas boiler and cogenerator. Excess biogas will be burned in a torch. The diagram of sludge management for variant III is shown in Figure 3.

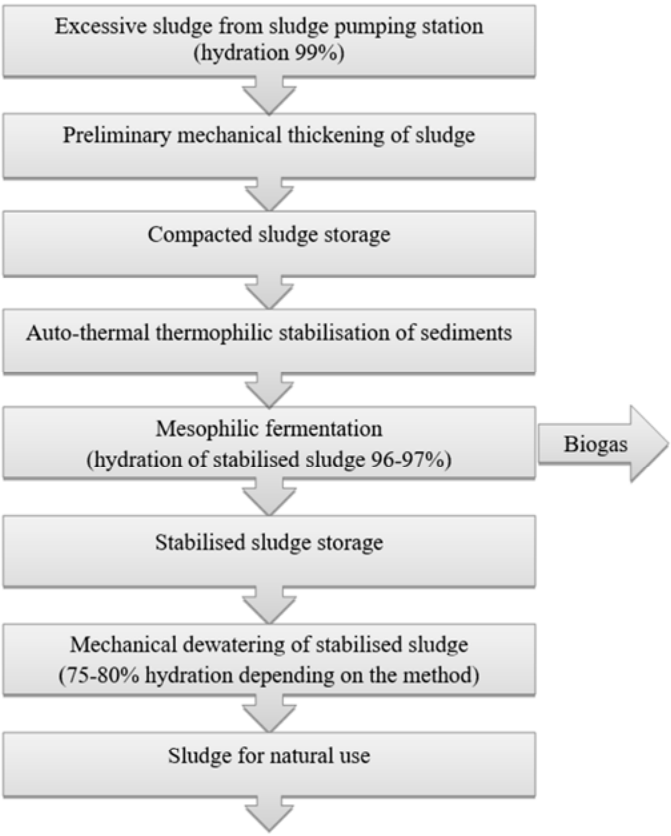

Figure 3. Scheme of sludge management with the use of the aerobic-anaerobic process
Source: authors' work.

The basic technical and technological parameters of the reactors foreseen in this option are presented in Table 3.

This variant includes the installation of odour deactivation from ATAD reactors with a capacity of 700 m^3/h.

As in variant II of sludge management, the construction of a technological building with rooms for heat exchangers, a pumping station for sludge recirculation, a fermentation gas installation and a power unit is required. It is necessary to build a biogas tank with a capacity of 1,000 m^3 and a flare with a capacity of 180 m^3/h.

Table 3. Technical and technological parameters of aerobic-anaerobic reactors

Number of reactors	4 reactors of the first stage	2 reactors of the second stage
Reactor dimensions	First stage	Second stage
Diameter	6 m	14 m
Total height	3.3 m	16 m
Sludge filling height	2.5 m	13.7 m
Active volume	283 m^3	4,216 m^3
Total dwell time of sludge in the installation	1 day	15 days
Daily portion of sludge	275 m^3/d	

Source: authors' work.

Variant IV_combustion

The system provides for constructing a common building for a sludge drying and combustion plant and a flue gas cleaning station. Excess sludge from the pumping station will be directed directly to mechanical thickening and dewatering. Thickened and dehydrated sludge will be directed to a medium-temperature dryer. The dried sludge will be transported to the next storage tank with a sliding bottom, from where it will be fed to the furnace with a screw conveyor. The burnt sludge in the form of slag will be collected in a tank, from where it will go to a waste dump. The diagram of variant IV sludge management is shown in Figure 4.

For the drying process, a belt dryer is provided, in which effective drying of sludge takes place thanks to the flow of process air heated in heat exchangers. The installation will be equipped with an exhaust air cleaning system consisting of a scrubber and biofilter. Sludge dried by means of a screw conveyor will be fed to the thermal mineralisation system. Flue gas treatment is provided in a scrubber and fluidised bed column. The sludge drying and mineralisation processes will be carried out in a 30 m x 18 m x 8 m building.

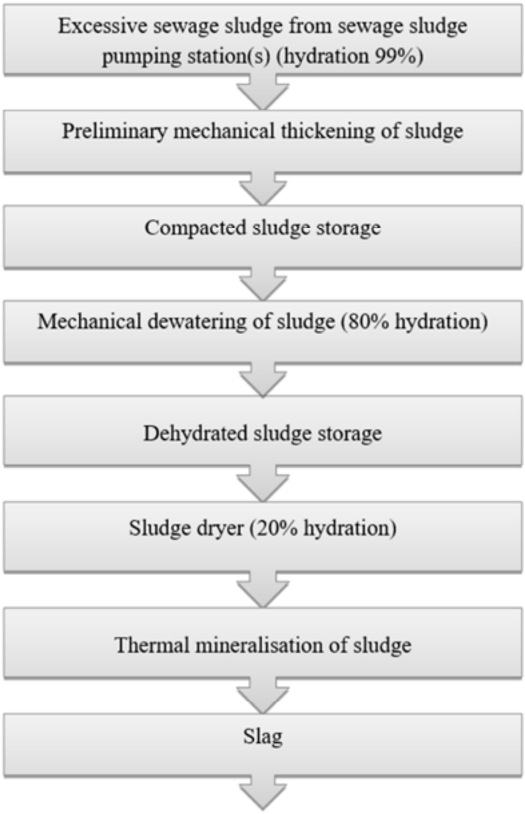

Figure 4. Scheme of sludge management using drying and combustion processes
Source: authors' work.

Results of the research

When analysing concepts of modernisation or expansion of sewage treatment plant sludge management, it is challenging to neglect the structure of investment outlays or operating costs. Each of the presented variants, apart from technological effects, is characterised by different costs resulting from its implementation. Each variant also expresses different operating expenses. Table 4 presents the investment and annual operating expenses of the proposed sludge management solutions. The outlays are expressed in percent in relation to variant I. The capital expenditures were calculated for the conceptual design based on the costs of the facilities, equipment, installations, or construction and engineering works assumed in each alternative. Operating expenditures were calculated based on the price of electricity and its consumption, as well as the total power of the designed equipment and its operation time. The expenditures were expressed as a percentage with respect to Variant I.

Table 4. Basic investment and operating expenditures of the analysed technological solutions

Proposed variant	Capital expenditures (%)	Operating expenditures (%)
Variant I	100	100
Variant II	220	16
Variant III	204	27
Variant IV	386	151

Source: authors' work.

The highest investment costs are related to the implementation of variant IV. Also the operating expenses will be the highest in case of this variant. The lowest capital expenditure in the case of variant I is associated with high operating costs.

An important part of the operating expenses are the costs of electricity consumption. It is possible to assess individual variants on the basis of technical indicators giving the amount of electricity consumption in relation to the utility effect. Calculation values of indicators are given in Table 5.

The values of indexes have been established on the basis of measured actual values in other sewage treatment plants which operate the analysed technologies and on the basis of many years' experience of the authors. The quantities of sewage sludge processed in these treatment plants, expressed in kilograms of dry mass and volume of sludge, were taken as the useful effect.

Table 5. Electricity consumption indicators for the analysed variants of sludge management

Proposed variant	Energy consumption rate in relation to kilogram of dry matter of sludge (kWh/kg)	Energy consumption rate in relation to kilogram of dry matter of sludge (kWh/m^3)
Variant I	0.565	22.582
Variant II	0.089	3.578
Variant III	0.092	3.680
Variant IV	0.589	23.564

Source: authors' work.

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On the basis of the presented indicators, the technologies used in variant IV and variant I turned out to be the most energy-consuming solution.

Each of the proposed variants of sludge management of wastewater treatment plants should be supported by a multidirectional analysis, taking into account its impact on the local environment. Of particular importance here are methods of economic efficiency assessment, which are essential tools in the decision-making process for capital investments (Hunter et al., 2009; Molinos-Senante et al., 2010; Rashid & Hayes, 2011). In addition to determining the investment and operating costs, a Cost-Effectiveness Analysis (CEA) was carried out. In this method, costs are measured in monetary units, and effects are not subject to evaluation. The index of the average annual cost of sewage sludge processing was used to assess the cost-effectiveness of the analysed solutions. It depends on the size of capital expenditures and operating costs of the WWTP and the assumed helpful life of the WWTP, and the discount rate, which are taken into account in the value of the capital recovery factor. In accordance with the assumptions of the cost-effectiveness analysis, it was carried out assuming the same utilisation effect in all cases, which was taken to be the volume of sludge treated. This analysis ignores sludge quality criteria as well as other investment effects. The average annual cost of sewage sludge disposal can then be presented as the sum of the capital interest, depreciation and annual operating costs. Calculations are performed by taking into account the investment outlay and annual operational costs, the discount rate and the depreciation rate, taking into account the imputed lifetime (Karolinczak et al., 2015; Karolinczak & Miłaszewski, 2016).

The total average annual cost of sewage sludge treatment is calculated from the formula:

$$K_r = I\alpha + K_e, \quad (1)$$

where:

K_r – the function of the total average annual cost of sewage sludge treatment, which is expressed in PLN/year,

I – the function of investment outlays defined in PLN,

α – the function of the capital return factor expressed in year^{-1},

K_e – the function of operating costs without taking depreciation into account in PLN/year.

The capital return factor is calculated from the formula:

$$R = \frac{r(1+r)^n}{(1+r)^n - 1}, \quad (2)$$

where:

r – the function of discount rate expressed in %,

n – the function of imputed lifetime expressed in years.

The assumed lifetime for all alternatives is n= 30 years. The discount rate was assumed at r = 5%. The value of capital and operating expenditure is explained in the commentary to the table (Miłaszewski, 2003). The calculation results for the concepts discussed are shown in Table 6.

Table 6. Summary of expected average annual costs of sludge processing in the analysed solutions of sludge management

Proposed variant	Average annual cost per kilogram of dry matter of sludge (PLN/kg)	Average annual cost in relation to sludge volume (PLN/m3)
Variant I	0.515	20.613
Variant II	0.385	15.385
Variant III	0.398	15.930
Variant IV	1.124	44.935

Source: authors' work.

The most economically efficient, with the lowest average annual costs, is variant II. The highest average annual costs will be obtained in the case of variant IV. For variant III, the average annual costs are similar to variant II.

Results of application of the analysed solutions

The objectives of sewage sludge management are primarily to prevent the generation of sludge or, if this is not possible, to reduce its quantity. The aim should be to eliminate the generation of sewage sludge as waste, which due to its quality, poses problems with its management in accordance with the regulations, through thermal processing, application on the ground, production of fertilisers or plant growing aids, or other. Therefore, the solution of sludge management of wastewater treatment plants should aim at increasing the amount of sewage sludge processed before it is released into the environment and increasing the amount of sewage sludge subjected to thermal transformation. We should also strive to maximise the utilisation of nutrients contained in the sludge while meeting all sanitary, chemical and environmental safety requirements.

The analysed sludge management solutions are in line with the strategic objectives of sewage sludge management. The process of autermic trimophilic stabilisation makes it possible to obtain sludge that does not rot and is free of pathogenic microorganisms, parasites and fungi (Bartkowska, 2014; Bartkowska, 2015). It significantly contributes to minimising the amount of sewage sludge and allows the production of organic fertiliser instead of waste

(Bartkowska et al., 2019; Bartkowska & Dzienis, 2019). The spontaneous acquisition of high temperatures also allows for recovery and manage excess thermal energy.

The anaerobic mineralisation of sewage sludge proposed as a two-stage thermophilic-mesophilic process also fits with the recommended management objectives. Subjecting sewage sludge to anaerobic stabilisation under thermophilic conditions allows for sludge stabilisation and hygienization. Fermentation under thermophilic conditions is faster than under mesophilic conditions, which is associated with a reduction in process time (Zawieja et al., 2016). The thermophilic step represents the acidic fermentation stage in which the complex organic substances that constitute biomass are hydrolysed and converted to volatile fatty acids. In contrast, the mesophilic stage is adapted to the methanogenic phase, where volatile fatty acids are converted to methane and carbon dioxide, leading to effective sludge stabilisation (Grübel et al., 2014). The advantages of thermophilic methane fermentation are a higher degree of organic matter reduction, generation of more easily dewatered sludge, increase in pathogen destruction. The decrease in organic matter content and biogas production is also higher when raw sludge's dry matter content increases (Wang et al., 2014). Under thermophilic conditions, biogas production is intensified, with a simultaneous decrease in methane content observed (Zawieja et al., 2016; Shin et al., 2019). The two-stage anaerobic digestion process gives the possibility to obtain good quality parameters of digested sludge, and it is characterised by an increase in biogas production efficiency, a higher degree of sludge dry matter reduction and stability of the methanogenesis course.

The use of autothermal thermophilic stabilisation with mesophilic fermentation is a much less known method. However, this arrangement of the stabilisation process offers many advantages. First of all, it provides hygienization of the sludge, which is not possible with conventional mesophilic fermentation and increases its susceptibility to anaerobic stabilisation.

The proposed autothermal thermophilic stabilisation takes 24 hours in this configuration. Additional heating of the sludge to 60°C deactivates pathogenic organisms, parasite eggs and other microorganisms (Kato et al., 2003).

In the ATAD process, relatively rapid degradation of organic matter is achieved, active sludge cells are ruptured very efficiently because thermophilic organisms release enzymes that are particularly active in this regard (Cheng et al., 2016). In the first 24 hours of the ATAD process, there is mainly hydrolysis of complex organic compounds and partial decomposition, which results in a reduction of the organic dry matter content, but not more than 10-15%. During this time, substances released from activated sludge cells reach concentrations higher than those used for consumption by thermophilic microorganisms. An increase in chemical oxygen demand and organic

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carbon content is observed. However, the important products of this stage are volatile fatty acids, which are mainly formed from the decomposition of carbohydrates and proteins. The partially processed sludge, rich in acetic acid and other forms of bioavailable organic carbon, is a good substrate for methane bacteria. This allows the anaerobic stabilisation time to be reduced to 15 days. The advantage of combining the two processes is the increased degradation of dry organic matter compared to the classical fermentation process (Pagilla el al., 2000). Changes in the amount and dynamics of biogas release are also obtained.

Pagilla et al. (2000), in their study of two-stage autothermal-thermophilic-anaerobic stabilisation, obtained a decrease in the organic matter content of sludge dry matter from 59 to 63%. Borowski and Szopa (2007) report that the two-stage system of autothermal stabilisation and fermentation results in a decrease in organic matter content of 44.2% on average. The loss of organic matter from combined ATAD and fermentation processes, according to Zupančič and Roš (2008), averages 53.5%. In other studies, the decrease in organic matter content due to combined ATAD and fermentation processes was shown to be 60-65% (Novak et al., 2011). Also, Novak et al. (2011) and Jang et al. (2013) obtained a decrease in organic matter content of 57-58%.

In parallel with the decrease in organic matter resulting from the dual stabilisation process, a decrease in chemical oxygen demand values was confirmed in the study. Jang et al. (2013; 2014), in their research, obtained a decrease in COD values of 65% on average after two stabilisation steps. With respect to the control sample, in which the sludge was only subjected to digestion, this decrease was greater by 15%. Pagilla et al. (2000) obtained a decrease in COD values in a two-stage mixed system of 67% on average. Zupančič and Roš (2008) reported an average decrease in COD values of 55.4%.

Microbiological studies of the sludge showed that the ATAD reactor was dominated by bacterial species that contribute to the hydrolysis of complex organic compounds, causing a significant increase in the methanogenic bacterial population in the digester. This interdependent activity of microorganisms leads to a significant increase in methane production (Jang et al., 2013; Jang et al., 2014). In their study, Jang et al. showed an increase in methane production by 40%. This is also supported by a study by Pagilla et al. (2000), which resulted in a 64% increase in methane production in a two-stage ATAD and fermentation system compared to a single-stage fermentation process. A similar increase in biogas production was observed by Borowski and Szopa (2007). In addition, Pagilla et al. (2000), in their study, found that biogas produced by fermentation following a prior ATAD process contains lower amounts of hydrogen sulfide. By preceding the fermentation with the ATAD process, the retention time in the digester can be reduced by 30% (Borowski & Szopa, 2007).

Thermal transformation of sewage sludge allows the removal of organic components of sludge and pathogenic organisms and reducing sludge weight by up to 90% (Hudziak et al., 2012; Gawdzik & Latosińska, 2014; Payá et al., 2019; Sall et al., 2020). Harmful and hazardous substances are disintegrated into environmentally inert substances or transformed into more stable forms, minimising the risk of ecological hazards. However, the presence of heavy metals precludes natural utilisation. Meanwhile, ongoing studies show that the predominant form of heavy metals (copper, cadmium, chromium, nickel, lead and zinc) are their immobile combinations with aluminosilicates. Thus, the presence of heavy metals in sewage sludge is not an objective criterion for assessing the threat to the environment. Bearing this in mind, it should be mentioned that the metals immobilised in sewage sludge ashes do not pose a significant threat to the environment in the toxicological aspect (Gawdzik & Latosińska, 2014).

Although there are many installations for the thermal conversion of sewage sludge, the main problem of using ash as a by-product of the process is still unresolved. Under domestic conditions, the ash generated in the installations is mainly landfilled as hazardous waste. However, studies indicate the possibilities of ash utilisation. One of the directions is to use it in the production of cement, concrete or ceramics (Payá et al., 2019; Sall et al., 2020; Chin et al., 2016). The studied ashes in terms of silicon, aluminium, iron, calcium or phosphorus oxides content show great similarities to the cement composition (Sall et al., 2020). In another study, the authors showed that the addition of ash from sewage sludge incineration to cement mortar improves the compressive strength of the material (Chin et al., 2016).

Due to their phosphorus content, sewage sludge ash can be an alternative source of this element (Hudziak et al., 2012; Herzel et al., 2016; Hartmann et al., 2020). However, ongoing studies show that the bioavailability of phosphorus in sewage sludge ash is low (Herzel et al., 2016; Hartmann et al., 2020). However, researchers have developed a novel thermochemical treatment process for sewage sludge ash that converts the ash into marketable fertiliser products. Sewage sludge ash was thermochemically treated with sodium and potassium additives under reducing conditions, resulting in the conversion of phosphate-containing mineral phases to plant-available phosphates with high bioavailability of phosphorus (Herzel et al., 2016). Other studies indicate that ash from sewage sludge can be used to produce superphosphate fertilisers (Hartmann et al., 2020). It should be emphasised that obtaining phosphorus compounds from process waste remaining after sludge incineration is possible only in mono-combustion plants.

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Conclusions

Good practice in municipal sewage sludge management can be defined as a set of methods for handling sewage sludge that effectively address the problem of sewage sludge treatment and management. At the same time, good effects of sewage treatment processes must be ensured. Sustainable development in the area of sewage sludge management should also be provided while maintaining the existing legal standards.

According to current legal standards, municipal sewage sludge can be recycled by using it in agriculture to grow crops and for fodder production. It is also recommended that sludge be used to grow crops intended to produce compost or plants not intended for food or feed production. Another recommended direction of their use is for land reclamation or land adjustment to specific needs resulting from waste management plans, spatial development plans or decisions on land development conditions.

The analysed sludge management concepts for the sample wastewater treatment plant fit into the canons dictated by legal standards. They are also consistent with the National Waste Management Plan 2022, which was adopted by the Council of Ministers on July 1, 2016. It should also be emphasised that they are modern and innovative solutions. Taking into account the location of the sewage treatment plant, there must be many willing potential customers for processed sewage sludge in the area. They declare to grow crops on which fertilisation with municipal sewage sludge is allowed. They have the appropriate equipment to spread and mix the sludge with the soil. They base their activities on the code of good agricultural practice. Restoring the nutrients accumulated in sewage sludge to the soil is not only economically appropriate but also necessary to maintain and repair the ecological balance. The examples discussed indicate just such a way of managing sewage sludge.

The conducted economic analysis showed that the investor would incur the lowest investment outlays when choosing variant I. However, it has to reckon with high exploitation costs. The highest investment and exploitation outlays are connected with picking variant IV. Despite that, it may turn out that the drying and burning method will be the final solution to the problem of organic waste.

Electricity consumption rates are lower with Options II and III. In this regard, Options I and IV are less favourable and will generate higher costs. The annual average costs of sewage sludge treatment will also be lower for variants II and III. On the other hand, the highest prices are expected for variant IV.

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The proposed technological processes ensure obtaining hygienically and sanitary safe end products. They significantly contribute to minimising the amount of sewage sludge, particularly the variant with drying and incineration.

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The contribution of the authors

Izabela Bartkowska – conception, literature review, acquisition of data, analysis and interpretation of data – 33,3%.

Dariusz Wawrentowicz – conception, literature review, acquisition of data, analysis and interpretation of data – 33,3%.

Lech Dzienis – conception, literature review, acquisition of data, analysis and interpretation of data – 33,3%.

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Waldemar **KOZŁOWSKI**

DEVELOPMENT OF ENVIRONMENTAL POLICY INSTRUMENTS FOR RENEWABLE ENERGY SOURCES BY MUNICIPALITIES

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ABSTRACT: An increase in the share of renewable energy in total energy consumption is one of the priorities of the European Union. Poland should have achieved the level of 21% renewable energy by 2030. Research problems discussed in the article: lack of studies in communes regarding the comprehensive assessment of unused reserves of energy from renewable energy; lack of analyses regarding the costs of obtaining and using power from renewable sources, lack of clear vision of communes as subjects in the climate and energy-related policy. Considering these research problems, this paper analyses the instruments of support for energy generation from renewable sources applied by communes. The study covers one hundred communes in the voivodship of Warmia and Mazury. The following hypothesis can be put forward in the methodological context: renewable energy use in a commune depends mainly on the undertaken activities and local initiatives.

KEYWORDS: development, renewable energy, commune, instruments

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Introduction

The global energy system has entered a new phase of a radical transformation. Overall, this set of shifts is usually called an Energy Transition; however, ideas about the rate of this transformation and the depth of this process are very considerably (Smil, 2018). The scenarios describing the transformation taking place at varying speeds will be discussed in the next section. This section is devoted to analysing the two main drivers of these transformations – the rapid development and the diffusion of new technologies and changes in energy policy (European Commission, 2018). The process of conversion to a model of sustainable development is based on the formation of the energy sector with a predominance of renewable energy sources, the use of which is growing extremely fast around the world. It is estimated that alternative energy sources will provide more than 40% of global demand by 2040.

According to the International Renewable Energy Agency, the share of renewable energy in the energy sector should increase from 25% in 2017 to 85% in 2050. By 2050, renewable energy sources may account for more than 60% of the total final consumption of many countries, which is 2.5 times higher than the current rate of renewable energy. For example, China is able to increase the share of renewable energy in its total energy consumption from 7% in 2015 to 67% in 2050, and the EU's claim may be increased from 17% to more than 70% (Kalinina et al., 2021).

Wholesale electricity prices in European countries are, on average, 30% higher than in the US. Wholesale natural gas prices are still nearly twice as high as in the US. Such price differences (compared to one of the most competitive economies in the world) have a significant impact on the situation and competitiveness of the EU industry, in particular when considering its energy-intensive sectors (Hansen & Percebois, 2015). The analysis of the renewable energy sector is somewhat optimistic in light of the above indicators. European companies representing this industry have a combined annual turnover of 129 billion euros and employ over one million people (European Commission, 2015).

An overview of the literature

Energy is essential in promoting sustainable development (Agenda, 2020). Many countries are striving to achieve this goal. Create a new concept of energy development and evaluate their energy systems in terms of compliance with the goals of sustainable development (Borys, 2010; Borys, 2011). The rapid changes in the natural environment and the challenges faced in

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energy management have motivated the European Union countries to update the assumptions regarding climate and energy-related issues (Ministerstwo Gospodarki, 2015; Strategia, 2017). The energy generation model valid until the end of 2020 was based on a 20% reduction in the GHG emissions, a 20% increase in the renewable energy share in the total energy consumption and a 20% improvement of energy efficiency compared to the 1990 level (Krajowy plan, 2011).

Due to the dynamics of adverse changes in the climate and energy-related areas, new, more ambitious goals were set for the EU countries for the period until 2030: 40% reduction of GHG emission, 32% increase in the renewable energy (RES) share in the total energy consumption, 32.5% increase in energy efficiency (Skoczkowski, 2002). As part of this new climate and energy system, the EU member states undertook to develop long-term national strategies and to ensure their consistency with the national plans for energy and environment by 2030 (Sokołowski, 2010).

As a member of the European Union, Poland actively participates in creating the community energy policy and implements its primary goals in the specific national conditions, considering the protection of the recipients' interests, energy resources at its disposal and technological needs of energy generation and transfer (Lorek, 2007). An increase in the share of renewable energy in total energy consumption is one of the priorities of the European Union in the climate and energy policy. Considering the progress in RES development and the national economic and legal environment, each country has the level set by the European Commission, which it is supposed to achieve pole (Ciepielewska, 2016). Poland should have achieved a 21% renewable energy share in the total energy consumption by 2030, which is an ambitious goal given the current progress. The estimated percentage of renewable energy in the total energy consumption in Poland was 11.7% as of the end of 2018. The Ministry of Energy assumes that the goal will be achieved in stages: 15% of the RES share by 2022, subsequently 17% – by 2025, and 19% – by 2027 (Polityka, 2018).

An increase in renewable energy generation becomes increasingly important in the context of the economic and political crisis that Europe has been experiencing in recent years pole (Wierzchowska, 2016). When formulating the guidelines for the energy policy, the European Union subordinated them to the principle of sustainable development, which has been adopted as a rule for the socio-economic development of the entire Union (Tomaszewski, 2018). Therefore, the European Union has departed from having an energy policy in its traditional sense, i.e., to generate energy in an amount sufficient to satisfy the demand from a specific country, without paying much attention to the environmental consequences (Czech, 2016).

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There are two tendencies observed in the European energy policy: globalisation and the development of local energy generation (Gielen et al., 2019). They are developing independently and are equally important but on a different scale. In line with the EU strategy, the perspectives for further development depend on the ability to raise the level of innovation through institutional incentives in all Member States (Cirani et al., 2016). The responsibility for creating conditions for innovation-driven growth fell on Regional Authorities – they have responded by forming Regional Innovation Strategies (RIS is the essential tool for shaping the innovation policy at the regional level).

Investments in renewable energy and its efficient use are the basic actions aimed at developing renewable energy generation effectively. These actions have to be expected on the local scale, in communes, and local communities. In the Polish institutional environment, the local government should be jointly responsible for the national energy policy by creating the local energy policy based on its energy potential. The relationship between the local and national energy policy is different for each commune, and it depends on the conditions specific to a particular territorial unit (Piechota, 2014). The specificity and quality of these relationships are decided by the commune authorities, who can approach the policy they create strategically or improvise. In the former case, the local authorities plan and carry out specific actions which make up the energy policy process.

In contrast, in the latter – they wait for the activity and involvement of government authorities. The energy policy implemented by local authorities is becoming increasingly popular in Poland. Unfortunately, this is mainly among the institutions, organisations and experts involved in energy-related issues daily.

Regarding the renewable energy sector, local governments restrict themselves to following the legal regulations, with minimal or no work of their own (Schuh et al., 2012). One of the essential elements of the modern energy sector, its democratisation, is being observed consisting in the described bottom-up arising new sources of renewable energy in a distributed system. This way, a new model has created a market where there will be fewer and less customers dependent on producers and distributors (Kurtyka, 2021).

The participation of communes in the renewable energy sector support system and indicating the potential organisational and legal framework in which the commune can perform its activities is one of the significant issues associated with the practical implementation of the law by communes (Ustawa, 2020). In accordance with the Communal Local Government, the commune's tasks include electricity, heat and gas supply". It appears that a commune's activities related to electricity generation from renewable sources are within the sphere of the commune's tasks related to the electricity supply

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(Gawlikowska-Fyk, 2014). In theory and practice, two types of applied instruments of environmental policy can be distinguished: direct, the so-called administrative and legal, used almost exclusively from the beginning, and indirect, the so-called economic and market, which appeared along with the need to economise the ecological policy (Fiedor & Graczyk, 2006; Graczyk, 2015).

However, one should note that it is not the commune that supplies electricity to its residents, but rather it is done by a power supply company. Nevertheless, the commune is one of the major entities participating directly or indirectly in pursuing the climate and energy-related goals set by the European Union. Moreover, prosumer/low-wave energy generation could contribute to the stimulation of development in less-developed regions (Graczyk, 2018). The paper analysed the commune management of energy from renewable sources. The following issues should be mentioned when justifying the subject choice: lack of studies in communes regarding the comprehensive assessment of unused reserves of energy from renewable energy; lack of analyses regarding the costs of obtaining and using energy from renewable sources, and lack of clear vision of communes as subjects in the climate and energy-related policy.

Research methods

Considering these research problems, this paper analyses the instruments of support for energy generation from renewable sources applied by communes. The aim of the research is to analyse the level of renewable energy use in the surveyed municipalities through the prism of the available methods and tools enabling the development of renewable energy sources. The study covers one hundred communes in the Voivodship of Warmia and Mazury. The following hypothesis can be put forward in the methodological context: accomplishing the objective of increasing the share of energy from renewable sources in the total energy consumption depends mainly on communes' initiatives. The energy policy and the energy sector are the basis for the effective functioning of the European and Polish economy. Poland faces the following threats if appropriate actions aimed at using renewable energy sources (at the commune level) are not implemented: an increase in the production costs, an economic slowdown in the area and, later, slow depopulation and an economic crisis. The paper methodology involves (on a general level) the regional realism theory. It will be used to illustrate the particular interests of individual communes regarding the use of the energy generation sector instruments. The subjects of the research are 100 communes in the Warmian-Masurian Voivodeship. The basic tool used for collecting factual

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knowledge is internal documents of communes, as well as surveys among various social groups living in the studied communes: local government employees, entrepreneurs, and residents. The survey consists of 5 main research areas, including 50 specific questions. The research was conducted in 2020. The survey return rate was 90%. The statistical and survey research will make it possible to carry out analyses related to the assessment of the potential of renewable energy, the analysis of the conditions related to the use of renewable energy in municipalities and the evaluation of the effectiveness of tools and instruments used by municipalities in the development of renewable energy.

Results of the research

Energy generated from renewable sources accounted for 18% of the energy consumed in the power industry, heat supply and transport as of 31.12.2020 (Directive, 2018). Meanwhile, according to the EU plan, energy from renewable sources should account for 20% of the total energy consumption at the end of 2020. Poland, which is supposed to have reached the 15% level by 2020, had achieved 11.8% by the end of 2020 (Figure1).

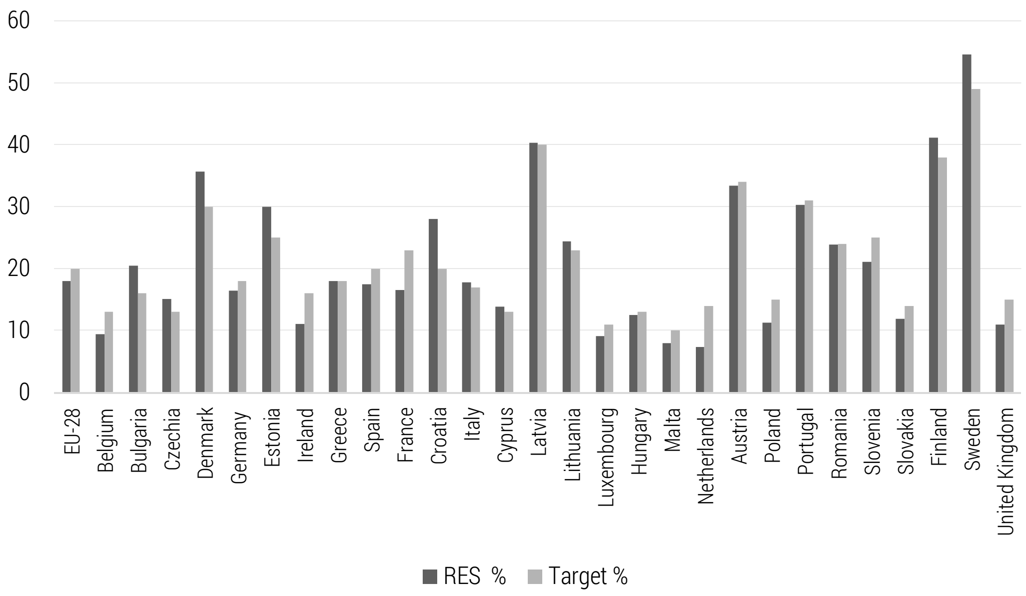

Figure 1. The level of renewable energy (RES) in relation to the 2020 target in EU countries as of 31/12/2020 [%]

Source: Eurostat, 2020.

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The situation has not changed, and even it has been slightly worse for several years. In 2015, energy from renewable sources accounted for 11.7% of the total energy consumed in Poland. It means that the situation regarding energy generation from renewable sources has not changed for several years. Currently, the level of Poland meeting its commitment regarding the share of energy from renewable sources in the national energy mix is decreasing, which, in the future, could result in sanctions imposed by the European Commission. According to the Supreme Chamber of Control (Report on development of renewable energy sources sector Supreme Chamber of Control 2018), neglect in this area can result in billions of PLN of costs to be incurred by Poland. The cost of incomplete accomplishment of the goal of the RES share in the total energy consumption is estimated at PLN 111-120 billion by 2030.

To guarantee the attainment of the 21% share of the RES goal by the end of 2030, Poland should take additional actions immediately aimed at providing incentives to use RES in all sectors. So far, the energy policy of Poland has focused on the attainment of goals associated with energy security, improvement of the sector competitiveness, improvement of the energy efficiency of the economy and restriction of the negative impact on the environment. However, due to the changes and challenges that have appeared in the area of climate and energy in recent years, it has been necessary to update the directions in which actions in the Polish power sector and – indirectly – in the Polish economy should be taken (Ligus, 2010).

The main tasks before the Polish energy policy by 2040 include the optimal use of its own energy resources, expansion of the energy generation and network infrastructure, diversification of oil and gas supplies and growth of the network infrastructure, development of the energy markets, implementation of nuclear power generation, development of the renewable energy sources sector, development of heat generation and cogeneration and improvement of the energy efficiency of the economy pole (Malko, 2009).

The current state of the power sector, the structure and forecasts for energy consumption in the national economy are of critical importance for the development of the renewable energy sector. The decision regarding the coal-based economy is also of great importance – the investments made then have long-term economic, social and territorial consequences. At the same time, international commitments have to be met, and technological progress and general economic development necessitate continuous changes in the sector (Kozłowski, 2016). Energy from renewable sources in Poland includes solar energy, energy generated from wind and water, geothermal energy and energy generated from solid and liquid biofuels and biogas, as well as energy generated with heat pumps. The structure of energy generation from renewable sources is shown in Table 1.

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Table 1. The structure of the installed power of renewable energy in Poland in 2016-2020

Installed power [MW]					
Type of RES	2016	2017	2018	2019	2020
Biogas power plants	212.5	234.0	235.1	237.6	245.4
Biomass power plants	1,122.7	1,281.1	1,362.0	1,362.8	1,492.9
Solar power plants	71.0	99.1	104.0	147.0	477.7
Wind power plants	4,582.0	5,807.5	5,848.7	5,864.4	5,917.2
Hydroelectric power plants	981.8	994.0	988.4	981.5	973.1
Total	6,970.0	8,415.5	8,538.4	8,593.4	9,106.3
Y to y increase	941.4	445.5	122.8	55.1	512.8

Source: URE, 2021.

Wind power plants, hydroelectric power plants and biomass have the most significant share in the Polish RES market. However, due to the intensive growth of photovoltaics, especially in the micro-installation sector, it can soon become the technology with the second largest (after wind power) share in the RES sector in Poland. Table 1 covers only small photovoltaic installations over 50 kW and those with a licence to sell electricity, which produced a total of nearly 478 MW of power as of 31.12.2020. Meanwhile, the real power of all installations (including prosumer ones) is close to 990.51 MW and is growing steadily. A considerable increase in the interest in photovoltaic micro-installations in recent years is caused by a rapid increase in electricity prices and the price rates used by entrepreneurs. There were 155,189 solar installations making use of solar radiation installed as of 31.12.2020, with a total power of 990.51 MW.

Specifies the areas of commune activities which should be performed with a view to the development of renewable energy sources, e.g.:

- seeking and developing local potentials for energy generation from RES,
- enabling the full use of the available renewable resources, mainly wind, hydroelectric, solar energy, biomass and geothermal energy,
- creating programmes of RES development and propagation, emphasising a coherent system of information and support for investors and local governments,
- creating favourable conditions for using financial resources for RES development,
- defining strategic goals and striving for financial predictability based on strategic planning.

The strategy assumes that the goal of regional policy will be to ensure more sustainable development of the country by integrated interventions

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using local resources and the potential of individual territories and providing sufficient resources for initiation of sustainable growth and creating jobs in areas where conditions are less favourable to development (A European strategy, 2006).

In the first stage of the study, the annual average electricity and heat consumption by communes was analysed, and the energy consumption for a commune's needs was determined. The energy consumption by communes under study in 2020 was estimated to amount to 23,469,801 MWh. The largest amounts of energy are consumed by urban-rural communes (48 communes): 16,173,597 MWh of electricity and 7,907,975 MWh of heat. Rural communes consume 55% less electricity and 46% less heat than urban-rural communes (Table 2).

Table 2. Energy consumption in the communes under study – 2020 data

Type of commune	Number of communes	Population	Area [km^2]	Consumption of electricity in communes [MWh]	Consumption of heat in communes [MWh]	Consumption of electricity by communal resources [MWh]	Consumption of heat in communes [MWh]
Rural	52	352,485	9991	7,296,203	3,668,417	511,005	204,495
Urban-rural	48	995,263	13594	16,173,597	7,907,975	1,182,126	578,756
Total	100	1,347,748	23585	23,469,801	11,576,392	1,693,131	783,251

Source: Local Data Bank, 2021.

It is a research problem that the amount of electricity and heat consumed by communes may vary from one year to another, which may be a consequence of atmospheric conditions and actions taken by the entities aimed at reducing the energy consumption. The annual average electricity consumption by one urban and one rural commune in 2020 amounted to 336,950 MWh, and a rural commune consumed 140,312 MWh on average. An urban-rural commune consumed an annual average of 164,750 MWh of heat, and a rural commune consumed 70,546 MWh. A comparison of the average yearly energy consumption in the communes of the Voivodship of Warmia and Mazury shows that the rural communes consume less electricity and heat by an average of 40% than the urban-rural communes (Table 3). Both the urban-rural communes and rural communes use an average of 7% of the total electricity and heat consumption to satisfy their own needs. In 2020, the rural communes needed 9,827 MWh of electricity and 3,933 MWh of heat to satisfy their needs. The urban-rural communes needed 24,628 MWh of electricity and 2,057 MWh of heat. This is similar regarding the consumption of electricity and heat by the commune, where the rural communes need 60% less electricity and 67% less heat than the urban-rural communes (Table 3).

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Table 3. Annual average consumption of energy in communes of the Warmia and Mazury Voivodeship in 2020 [MWh/commune/year]

Type of commune	Quantity	Average consumption of electricity	Average consumption of heat	Average consumption of electricity by communal resources	Average consumption of heat by communal resources
Rural	52	140,312	70,546	9,827	3,933
Urban-rural	48	336,950	164,750	24,628	12,057
Total	100	477,262	235,296	34,455	15,990

Source: Local Data Bank, 2021.

The annual consumption of renewable energy in the communes of the Voivodship of Warmia and Mazury is estimated to amount to 991,115 MWh, which accounts for 4% of the total energy consumption in the Voivodship. The consumption differs from the national data, according to which the consumption of energy from renewable sources in the Voivodship of Warmia and Mazury is 10.7%. This may arise from the method of measurement of the difference between the installed power and that actually used. The wind is the dominant source of renewable energy in the Voivodship, accounting for 58% of all the energy from RES. Geothermal energy accounts for the smallest portion of energy from RES – 1.5% (Table 4).

Table 4. Consumption of energy from renewable sources in the communes of the Voivodship of Warmia and Mazury [MWh/year]

Voivodship of Warmia and Mazury	Wind energy	Energy from photovoltaics	Energy from biomass	Energy from biogas	Geothermal energy	Hydroelectric energy
Communes	580,000	37,800	198,760	111,400	14,375	49,177
Total	991,115					

Source: Local Data Bank, 2021.

An analysis of renewable energy source locations in the Warmia and Mazury Voivodeship shows that the largest number of communes (92) have photovoltaic installations in their areas. Wind energy and biomass installations can be found in 70 communes. Biogas installations can be found in the smallest number of communes – 11 (Table 5). When conducting the study by the survey method, the officials found it difficult to determine the amount and the size of the installation because of the lack of formalised knowledge of this matter as well as frequent changes in regulations regarding issuing permits for RES installations. This issue requires further studies.

DOI: 10.34659/eis.2022.81.2.454

Table 5. The number of communes in which energy from renewable sources (RES) is used

Type of commune	Wind energy	Energy from photovoltaics	Energy from biomass	Energy from biogas	Geothermal energy	Hydroelectric energy
Rural	32	44	36	5	13	28
Urban-rural	38	48	34	6	26	24
Total	70	92	70	11	39	52

Source: Local Data Bank, 2021.

The largest number of communes (77) use photovoltaic energy to satisfy their own needs. Only four communes use wind energy and energy from biomass. The communes practically do not use energy from biogas, hydroelectricity or geothermal energy to satisfy their needs (Table 6). Local boiler houses and small photovoltaic installations, e.g., bus stops, local lighting, etc., are the most common ways of using energy from renewable sources.

Table 6. The number of communes using RES to satisfy their own needs

Type of commune	Wind energy	Energy from photovoltaics	Energy from biomass	Energy from biogas	Geothermal energy	Hydroelectric energy
Rural	0	34	1	0	0	0
Urban-rural	4	43	3	0	0	0
Total	4	77	4	0	0	0

Source: Local Data Bank, 2021.

Local communal initiatives aimed at acquiring energy from renewable sources are also an essential issue in energy policy. According to the study findings, the communes consume 80,105.09 MWh for their needs, which accounts for 8% of the total energy from renewable sources generated in the Voivodship of Warmia and Mazury (Table 7).

Table 7. Amount of energy from RES consumed by the communes for their own needs [MWh/year]

Type of commune	Wind energy	Energy from photovoltaics	Energy from biomass
Rural	0	12,101.9	306.7
Urban-rural	14,902.5	50,831.1	1,962.9
Total	80,105.1		

Source: Local Data Bank, 2021.

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Energy from photovoltaics is the primary type of energy from renewable sources consumed for the communes' needs (79% of the total energy from renewable sources consumed by the communes). Photovoltaic installations are used by communes mainly in small infrastructure objects, such as bus stops, individual technical infrastructure buildings, etc. The communes use facilities that enable energy generation from biomass, mainly in local boiler houses. Energy from renewable sources is consumed mainly by commune institutions such as schools, kindergartens, commune offices, etc. Having a RES development strategy or plan is one of the key issues for renewable energy industry development in the communes. The study found that 83 communes have no RES development strategy in their areas, and, in consequence, they do not have any analyses of the RES potential or the possibility of its use in their areas (Table 8). This limits RES usability by the communes. This study has shown that the communes mistake the "Plan for energy and gas supply to the commune", which is an administrative document rather than a strategic one, for a "RES development strategy". The number of communes that have RES development strategies in their areas is shown in Table 8.

Table 8. The number of communes that have RES development strategies

Type of commune	With RES development strategies in place	Without RES development strategies in place
Rural	1	51
Urban-rural	16	32
Total	17	83

Source: author's work.

All of the 32 urban-rural communes which did not have an RES development strategy in place expressed their interest in developing one, with support from external specialists. Only 38 were interested in preparing such a document, while 13 saw no sense in doing so (Table 9).

Table 9. Communes' interest in preparing an RES development strategy

Type of commune	The number of communes interested in preparing an RES development strategy	The number of communes not interested in preparing an RES development strategy
Rural	38	13
Urban-rural	32	0
Total	70	13

Source: author's work.

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The communes' implementation of the energy policy adopted by the EU with respect to energy from renewable sources included various actions taken by communes, with the thermal improvement of buildings in the commune (97 communes took actions in this area). Thermal improvement contributed to a decrease in energy consumption, encouraging owners to modernise their energy sources. Subsequently, communes acquired funds from EU programmes for the power industry (95 communes acquired such funds) and made investments in RES (92 communes). Detailed data are shown in Table 10.

Table 10. Communes' actions in the RES area

Type of commune	Thermal improvement	Investments in RES	Acquiring funds from EU	Educating the population	Other
Rural	49	45	48	34	6
Urban-rural	48	47	47	35	7
Total	97	92	95	69	13

Source: author's work.

Studies regarding the benefits the communes perceive with respect to RES development give varied findings. The most significant number of communes (78) see benefits for the environment. This is associated mainly with meeting the constantly growing challenges set by the EU regarding the environment, as well as improvement of the quality of life, with the improvement of the air, soil and water quality as its manifestations. Further, communes see RES development as a factor that brings them economically (64 communes) and social (63 communes) benefits. The former involves the stimulation of demand for goods and services in the local markets. Social benefits apply perceptible improvement of the population's health and quality of life. As much as 25% of the communes under study see no benefits from RES development in their area, which may result mainly from the specific nature of the communes and the RES potential at their disposal (Table 11).

The study involved the communes defining the most frequently occurring barriers that they have to overcome in the process of RES development in their area. These include legislation regarding environmental protection (87 communes) with the accompanying legal restrictions (74 communes). The defined barriers to RES development are a consequence of the changing legal environment and constantly growing environment-related requirements from the EU. Moreover, the environmental protection legislation applies to the area of 1,122,000 km^2 in the Voivodship of Warmia and Mazury,

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which accounts for 46.7% of the voivodship area. A smaller number of communes mentioned financial barriers associated with acquiring capital (57 communes) as well as social barriers (57 communes) involving public resistance to the construction of RES installations, mainly wind farms (Table 12).

Table 11. Benefits from RES development as seen by the communes

Type of commune	Benefits							
	Economic	Social	Environ-mental	Promotion of communes	Tourism development	New jobs	Other	No benefits
Rural	29	28	37	18	16	19	12	9
Urban-rural	35	35	41	32	23	24	9	16
Total	64	63	78	50	49	43	21	25

Source: author's work.

Table 12. The most frequently occurring barriers associated with RES development

Type of commune	Barriers				
	financial	legal	environmental	social	not known
Rural	32	37	44	26	10
Urban-rural	25	37	43	31	9
Total	57	74	87	57	19

Source: author's work.

As part of the study, the communes listed the types of activities which would contribute to RES development in their areas. The largest number of communes (75) would like to cooperate with the University of Warmia and Mazury and organise training sessions on this subject matter. Another activity that the communes would like to pursue is the cooperation with external experts (69 communes), who could prepare a strategy, conduct training sessions, and open consultations for an RES investment. The smallest number of communes (13) consider so-called "other actions" (otherwise not classified), and 34 communes see potential benefits in establishing energy cooperatives (Table 13).

Studies have also shown that the main obstacle that the communes under study have to overcome is insufficient knowledge of energy from renewable sources, which independent local government entities cannot acquire. This is why various initiatives are recommended, such as organising symposiums and scientific conferences and establishing cooperation with scientific centres and public benefit institutions.

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Table 13. Communes' actions aimed at more effective use of RES in the communes

Type of commune	Communes' activities							
	Seminar/ Conference	RES development programme	Cooperation with an expert	Establishing cooperation with UWM	Training on RES	Assis-tance in acquiring EU funds	Establishing energy cooperatives	Other
Rural	14	25	32	35	36	24	18	6
Urban-rural	15	26	37	40	39	30	16	7
Total	29	51	69	75	75	54	34	13

Source: author's work.

Conclusions

Development of renewable energy generation slowed down between 2016 and 2020, which may result in a failure to meet the EU goals for the level of renewable energy in total energy consumption. The relative cost-effectiveness of different energy generation technologies will have changed by 2030. In particular, the cost of energy generation from coal will increase. The development of wind and photovoltaic installations, particularly prosumer energy generation, will require assistance – not only financial assistance but also as part of the regional policy.

The accomplishment of the long-term goal of an increase in the share of renewable energy sources in the total energy consumption depends largely on the use of local energy potentials. This, in turn, depends on the activity and usage of different kinds of instruments of renewable energy development by communes. A study of the application of renewable energy development support instruments in 100 communes of the Voivodship of Warmia and Mazury indicated the following:

- renewable energy had a 4% share in the total energy consumption in the Voivodship of Warmia and Mazury as of 31.12.2020,
- 8% of the total renewable energy generated in the Voivodship of Warmia and Mazury during the period under study was consumed to satisfy the communes' own needs,
- photovoltaics is the basic renewable source used to generate energy for the communes' own needs, and this energy accounts for 79% of the total renewable energy consumed for the communes' own needs,
- 83% of the communes under study do not have a renewable energy development strategy in their area, but they are interested in preparing one,

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- thermal improvement and acquiring funds for micro-investments are the most common actions aimed at saving and acquiring new energy sources by communes,
- the main benefits that local governments see in renewable energy development are environmental benefits associated with improvement of the quality of life in the area,
- the main barriers seen by the most significant number of local governments include environmental acts and constantly changing EU legislation,
- the communes see opportunities for renewable energy development mainly in cooperation with the University of Warmia and Mazury and in training in these matters, as well as in cooperation with an external expert.

Studies have confirmed that there is still great untapped potential for supporting the communes in developing a strategy of renewable energy development, both in legal matters and practically.

Environmental considerations are the basic determinant in investment in renewable energy in the Voivodship of Warmia and Mazury. The lack of a strategy for renewable energy development in most communes is a barrier to making use of its potential. Because of different legal interpretations and social attitudes, there is a need to conduct and publicise in-depth analyses, especially regarding the environmental impact of renewable energy installations. Energy-related planning should be more highly correlated with spatial planning as an important instrument for the planning and developing of renewable energy. In particular, communes should establish zones for wind energy and see to it that waste and regional biomass resources are made use of. Prosumer energy generation should also be supported.

Proposals for practical activities of the commune in the field of development of renewable energy installations in the current legal status concerning both the functioning of communes and renewable energy sources:

- organise an Agency for Renewable Energy in the commune to support local communities in terms of promotion and organisational support in obtaining EU funds for renewable energy,
- to organise energy clusters by the commune to implement investment projects in the field of renewable energy installations,
- establishment of energy cooperatives associating entities related to the production and distribution of renewable energy in order to develop a strategy for the development of renewable energy,
- initiation of the Smart grid model consisting in the use of smart energy grids using renewable energy resources in the first place, which also enables, in a strategic perspective, optimisation of energy costs for the local community and business, investment inflow and job growth. Renewable

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energy can provide an essential stimulus for the socio-economic development of communes in the Voivodship of Warmia and Mazury.

Social challenges and directions of activities related to the development of renewable energy in the commune should take into account: social aspects of energy transformation, social dialogue and effective communication, solidarity and joint responsibility of residents and authorities, strengthening cooperation and synergy of activities in the commune (Worek et al., 2021).

Energy is an essential factor in promoting sustainable development. Many countries strive to achieve this goal, create a new concept of energy development and evaluate their energy systems in terms of compliance with the goals of sustainable development. However, effective use of renewable energy resources requires the cooperation of all the entities concerned, especially local governments and scientific institutions, with a view to preparing detailed analyses of locations for renewable energy installations. It would be justified to establish a Warmia and Mazury Renewable Energy Agency to deal with organisational and analytical issues associated with using energy resources.

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ANALYSIS OF THE POSSIBILITY OF USING PLASTIC POST-PRODUCTION WASTE IN CONSTRUCTION

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ABSTRACT: This paper presents the possibility of managing plastic post-production waste, i.e. ordinary and heat-shrinkable film, in the construction sector. For this purpose, two types of lightweight 16 mm aggregate were produced from plastics using proprietary technology (i.e. polyethylene terephthalate (PET) and PET/PVC/OPS (MIX) mixtures). The raw material was sourced from post-production waste generated during the production of film labels. The results of the experimental testing of aggregate properties (bulk density, grain density, absorbability, compressive strength) are presented, the aggregate being sourced from recycled plastics. This paper presents the physical and mechanical properties of the plastic, as well as other popular lightweight aggregates (Certyd and Kermazyt) used in construction. In addition, the financial efficiency of lightweight aggregate production from the by-products of plastic label production was analysed. The economic analysis has shown that the use of plastic waste for the production of lightweight aggregate is rational, not only in terms of environmental protection but also the financial benefits to companies that generate significant amounts of plastic waste.

KEYWORDS: PET waste; aggregate; recycling; artificial lightweight aggregates; economic analysis

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Introduction

Plastics were designed to replace natural resources. Since then, they have been shaping the world, ensuring safety, hygiene, comfort, and social well-being.

Modern plastics are currently manufactured in endless varieties of products and uses, making it possible to reduce energy consumption, CO_2 emissions, and water consumption. They also make an important contribution to the idea of a ‘closed-loop’ and prevention of climate change. However, in order to fully exploit the potential of these materials, it is necessary to minimise their landfilling by reusing them, e.g. in the industrial sector.

The ‘Plastics 2030’ voluntary commitment (Plastics Europe, 2022) elevated the plastics industry to the next level of engagement through the establishment of ambitious goals and initiatives aimed at preventing plastics from entering the environment, improving the degree of reusing and recycling of waste (in the form of plastic containers), and offering benefits for the efficient management of natural resources.

The technical data in Figure 1 (sourced from 2018) concerning the European and worldwide production of plastics shows that as much as 348 million tons of plastics were produced worldwide in 2017, of which 64.4 million tons came from Europe (Plastics Europe, 2022). The trend of plastics production is upward, with an increase of 11 million in 2018, compared to 2017. However, it should be noted that there was a reduction in plastic production in Europe by approximately 4%.

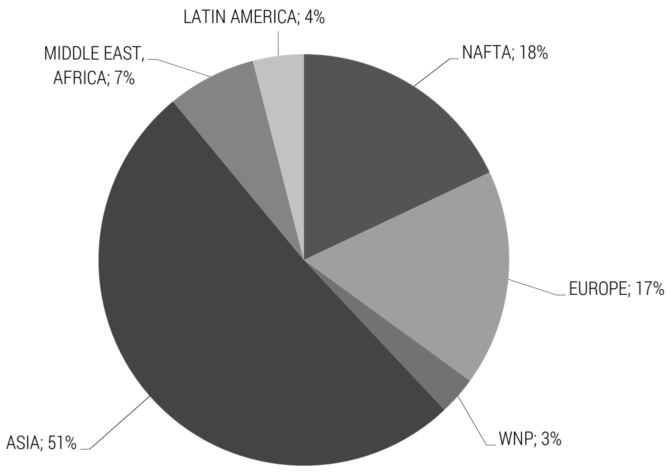

Figure 1. The proportional share of continents in the production of plastics
Source: Plastics Europe, 2022.

The market analysis presented in Figure 2 shows that, in the years 2006-2018, the recycling of plastics increased each year, with an increase of 100% since 2006 (9.4 million tons). On the other hand, Landfilling decreased by as much as 44%, yet it is still relatively high at 7.2 million tons (Plastics Europe, 2022).

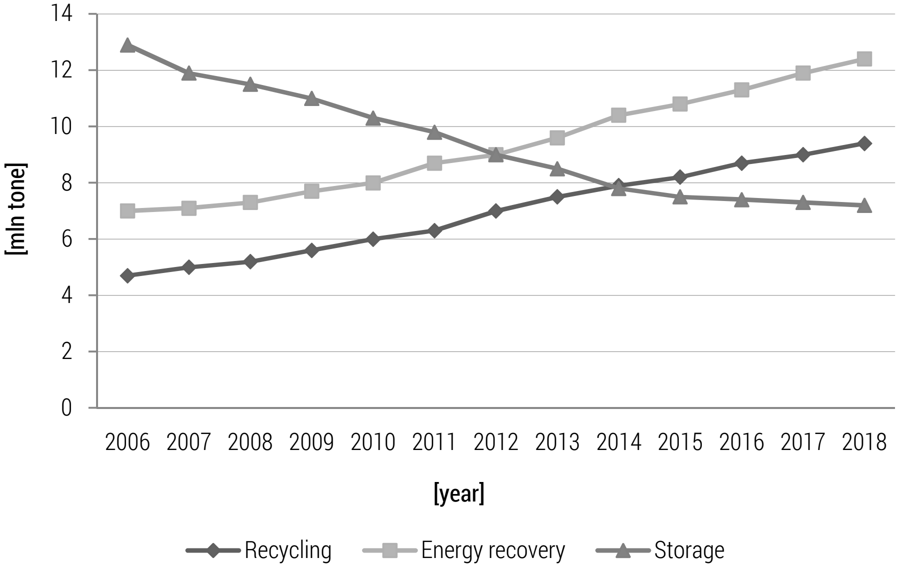

Figure 2. Management of post-consumer plastic waste in the years 2006-2018 (million tons)
Source: Plastics Europe, 2022.

In Poland, the recycling rate of plastic waste is as low as 26.8%, while 44.1% (759 thousand tons) of waste is landfilled; the rest is used in energy recovery (Sokołowski, 2020).

Marine litter is a global problem, and the fact that waste, including plastic waste, enters the natural environment is unacceptable. Plastics are a valuable resource, providing society with many benefits and offering solutions consistent with the principles of sustainable development in various sectors. One of the examples presented in this paper is the possibility of using plastic waste in the construction sector.

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The technology of production of artificial aggregate

Two series of plastic aggregates, with a 16 mm fraction, i.e. PET (polyethylene terephthalate) and a PET/PVC/OPS mixture, were produced (Szlezyngier & Brzozowski, 2015; PLASTEM, 2022). The raw material was sourced from post-production waste generated during the production of film labels.

A single-screw extruder with a screw diameter of 25 mm, four heating zones, and a gravity feed was used for the production of aggregate. In the first stage of production, strips of film were shrunk under the influence of increased temperature in order to obtain a pre-densified raw material. A plastic mill was then used, which made it possible to obtain a fine fraction (approximately 5 mm diameter). The drying of plastic was performed for 4 hours at a temperature of 120°C (Figure 3) (Wilczyński, 2011). The final stage consisted of re-melting the plastic waste until a light aggregate (with a fraction of 16 mm) was obtained (Figure 4 and Figure 5).

Figure 3. Drying stage of milled plastic to reduce its moisture content

Source: author's work.

The goal was to obtain an optimised process of production (i.e. reduced energy consumption without the need to flush contamination from the original material), which is required for the reduction of landfilled plastic waste

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and its successful use in construction concrete. This makes it possible to produce an innovative light aggregate, which constitutes an alternative to traditional raw materials, e.g. Keramzyt and Certyd.

Figure 4. Aggregate produced from PET film
Source: author's work.

Figure 5. Aggregate produced from a mixture of PET, PVC, and OPS films
Source: author's work.

Methods and Materials – Research procedures and properties of the produced light aggregate

Tests for bulk density were performed according to PN-EN 1097-3:2000. Absorbability and grain density were tested according to PN-EN 1097-6: 2013-11. The compressive strength of the plastic aggregate was tested according to PN-EN 13055:2016-07.

Bulk density

The apparatus used for testing the bulk density of the aggregate was compliant with the general requirements of PN-EN 932-5:2012.

Before commencing the tests, aggregate samples were dried at a temperature of 110±5°C to constant weight. An empty cylindrical container was weighed and then filled with aggregate to overflow. The excessive amount of aggregate was removed from the upper surface of the container. The last stage consisted of weighing the filled container and recording its mass, with an accuracy of 0.1%. This was determined for three aggregate samples (PN-EN 1097-3:2000, PN-EN 932-5:2012).

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According to PN-EN 1097-3:2000, the bulk density of aggregate in its loose state is calculated using Eq. (1):

$$\rho_b = \frac{m_2 - m_1}{V}, \qquad (1)$$

where:
ρ_b – bulk density in a loose state,
m_2 – the mass of the container and tested sample,
m_1 – the mass of the empty container,
V – the volume of the container.

Table 1. Bulk density test results for plastic aggregate

Technical data			
Type of plastic	Grain diameter (mm)	Bulk density (kg/m³)	Average (kg/m³)
PET	8	648.89	648.40
		651.85	
		644.44	
PET	16	617.78	613.33
		613.33	
		608.89	
MIX (PET,OPS,PVC)	16	635.56	635.75
		638.52	
		633.19	

Source: author's work.

Grain density and absorbability

The testing of grain density and absorbability was performed according to PN-EN 1097-6:2013-11.

Grain density and absorbability tests were performed on aggregate with a 16 mm diameter grain size. Before commencing the tests, the samples were dried in a laboratory drier at a temperature of 110 ±5°C, to constant weight. Then a pycnometer with a funnel (Figure 6) and the first sample were weighed. The next step consisted of filling the pycnometer with water and weighing it after removing air bubbles, and refilling the water to the appropriate level. These actions were repeated after 24 h. The final stage consisted

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of transferring the aggregate to an absorbent cloth, removing water from its surface and then weighing the tested sample (PN-EN 1097-6:2013-11).

Figure 6. Pycnometer for determining grain density and absorbability
Source: author's work.

According to PN-EN 1097-6:2013-11, grain density ρ_a and absorbability W_F are calculated using Eq. (2, 3):

$$\rho_{rd} = \rho_w \cdot \frac{M_4}{M_1 - (M_2 - M_3)}, \tag{2}$$

where:
ρ_{rd} – specific density of aggregate,
ρ_w – density of water in a temperature of 22°C,
M_1 – the mass of saturated and air surface-dried aggregate,
M_2 – the mass of pycnometer with a sample of saturated aggregate,
M_3 – the mass of pycnometer filled with water only,
M_4 – masa of analytical sample dried in a dryer.

$$W_F = \frac{M_W - (m_2 - m_1)}{(m_2 - m_1)} \cdot 100, \tag{3}$$

where:
W_F – absorbability of light aggregate,
m_1 – a mass of pycnometer, funnel, and net,
m_2 – a mass of pycnometer, funnel, dry test sample, and net,
M_w – a mass of dry surface aggregate in the final stage of measurement.

Table 2. Absorbability test results for plastic aggregate

Technical data		
Type of plastic	**Absorbability (%)**	**Average (%)**
PET	5.04	5.31
	5.67	
	5.23	
MIX (PET, OPS, PVC)	1.28	1.66
	1.94	
	1.76	

Source: author's work.

Table 3. Determination of grain density for plastic aggregate

Technical data		
Type of plastic	**Grain density (kg/m³)**	**Average (kg/m³)**
PET	1094	1114
	1146	
	1103	
MIX (PET, OPS, PVC)	1114	1101
	1092	
	1098	

Source: author's work.

Compressive strength

Testing of the compressive strength of the aggregate from plastic waste was performed according to PN-EN 13055:2016.

The pre-prepared sample of light aggregate was placed in a steel cylinder and densified by vibration. Then, a piston was placed on the upper surface of the aggregate. The depth to which the piston was pressed was set to 20 mm. Afterwards, the test set was placed in a hydraulic press, and the force exerted on the piston was increased so that it was pushed down 20 mm for approximately 100 s. Compressive strength was calculated using Eq. (4):

DOI: 10.34659/eis.2022.81.2.467

$$C_a = \frac{L + F}{A}\,, \tag{4}$$

where:
C_a – compressive strength of aggregate, determined according to the method I,
L – force exerted by the piston,
F – force necessary to press down the piston,
A – piston area.

Table 4. Results of compressive strength testing on plastic aggregate

Technical data		
Type of plastic	Grain diameter (mm)	Average compressive strength (MPa)
PET	8	5.30
PET	16	4.34
MIX (PET, OPS, PVC)	16	6.26

Source: author's work.

Results and Discussion

Comparison of properties of light aggregates

From the aggregates available on the market, CERTYD (Figure 7) was selected for comparison. CERTYD is a sintered fly ash aggregate produced by lightweight sintered aggregate technology through the autothermal sintering of waste sourced from CHP plants. The raw material is characterised by low bulk density, good thermo-insulating properties, frost resistance, and resistance to fungi, mould, and pests (Aggregate Certyd. 2022).

Figure 7. Certyd light aggregate

Source: author's work.

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Moreover, Leca Keramzyt (Figure 8), a light ceramic aggregate, was also used for comparison. It is characterised by high thermal and acoustic insulation and owes its characteristics to its porous internal structure, enclosed in a rugged ceramic coating. Due to its properties, Leca Keramzyt aggregate is used in construction, e.g. for the insulation of ground floors, the structure of walls and ceilings, the insulation of ceilings and flat roofs, underground installations, drains, and floating tank covers (Leca LWA aggregate, 2022).

Figure 8. Keramzyt light aggregate
Source: author's work.

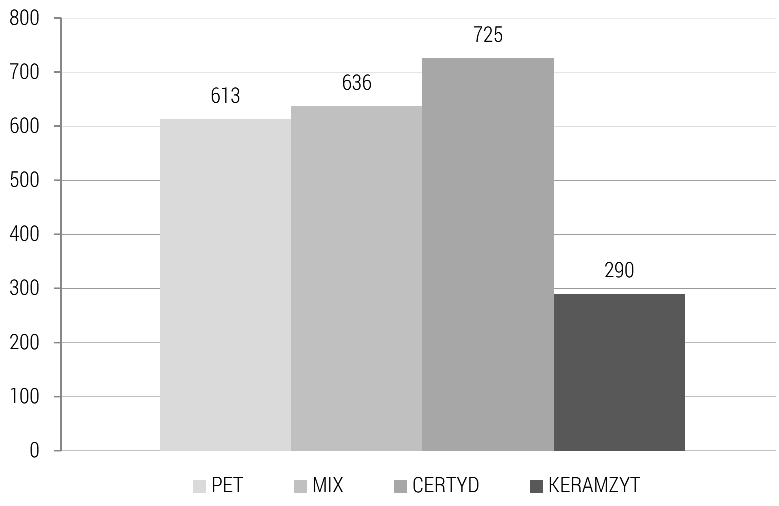

Figure 9. Comparison of bulk densities of selected light aggregates [kg/m^3]
Source: author's work according to PN-EN 1097-3:2000.

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When comparing the properties of CERTYD sintered fly ash aggregate, whose bulk density is 725 kg/m^3, with the aggregate produced from plastic, it is clear that the innovative raw material is characterised by a bulk density which is lower, by as much as 15% (Figure 9). Moreover, bulk density can be reduced to 460 kg/m^3 by using a blowing agent (Grygo et al., 2021).

Table 5. Summary of grain densities for selected light aggregates (according to PN-EN 1097-6:2013-11)

Technical data		
Type of plastic	Grain density (kg/m^3)	Average (kg/m^3)
PET	1094	1114
	1146	
	1103	
MIX (PET, OPS, PVC)	1114	1101
	1092	
	1098	
CERTYD	1360	1360
KERAMZYT	1250	1250

Source: author's work.

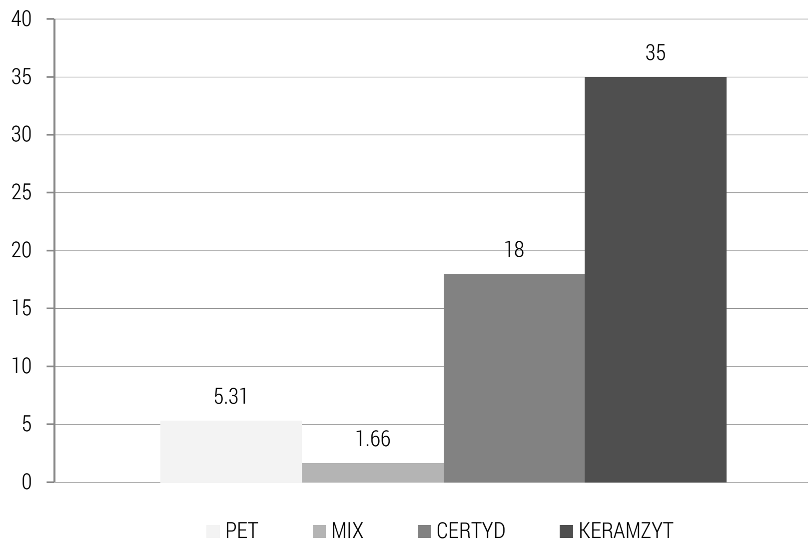

Figure 10. Comparison of absorbability for selected light aggregates [%]
Source: author's work according to PN-EN 1097-6:2013-11.

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When comparing the values of grain density of sintered fly ash aggregate, whose density is 1360 kg/m^3, and the aggregate produced from plastics, it is clear that the obtained material is characterised by a lower grain density, by as much as 20% (Table 5).

When comparing the absorbability of CERTYD sintered fly ash aggregate, whose absorbability is 18%, with the absorbability of the aggregate produced from MIX (PET/PVC/OPS) plastics, it is clear that the innovative raw material is characterised by an absorbability which is lower, by as much as 90% (Figure 10).

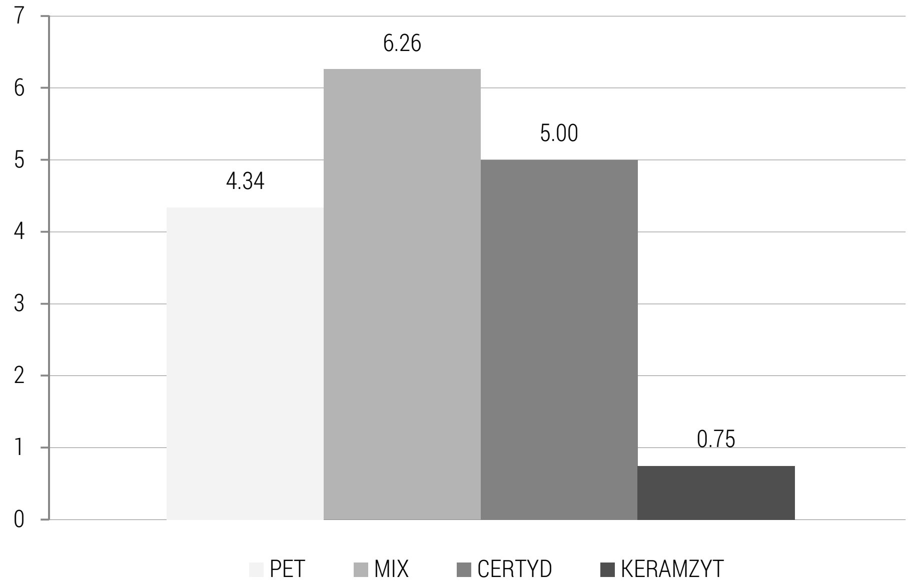

Figure 11. Comparison of compressive strength of light aggregates [MPa]
Source: author's work.

When comparing the compressive strength of CERTYD sintered fly ash aggregate, whose load-bearing capacity is 5 MPa, with the total produced from MIX plastics, it is clear that the produced material is characterised by a 25% increase in strength (Figure 11).

Economic analysis

To analyse the economic aspects, data collected from several companies that produce waste of the studied kind was used and statistical data. The appropriate amounts of energy consumed per hour, the number of processed plastics, and depreciation of the equipment necessary for its production were also included.

DOI: 10.34659/eis.2022.81.2.467

Data sourced from the companies showed that the monthly generation of waste from a single company was approximately 100 tons. The cost of waste plastic, on the other hand, was calculated in three variants, i.e. A – cost of waste purchased from recycling companies (2.40 PLN), B – cost of waste (0 PLN) and C – cost of waste (-0.50 PLN); companies that produce waste often pay for the disposal of post-production waste. The annual depreciation was 14% in the case of machines for the production of plastics and the chemical industry (Depreciation rates, 2022). The rate of electricity was fixed at 0.87 PLN/kWh (Electricity rates, 2022). The machine's performance for the calculations was 500 kg/h; however, due to maintenance and possible downtime, the actual productivity was adopted at 300 kg/h.

Moreover, information obtained from the producers of extruders showed that the average power consumption was 0.4 kW/kg. A summary of the production costs of the aggregate from plastic waste is presented in Table 6, while a comparison of the prices of the aggregates is shown in Figure 12. The analysis does not include operating, employee, or real estate costs.

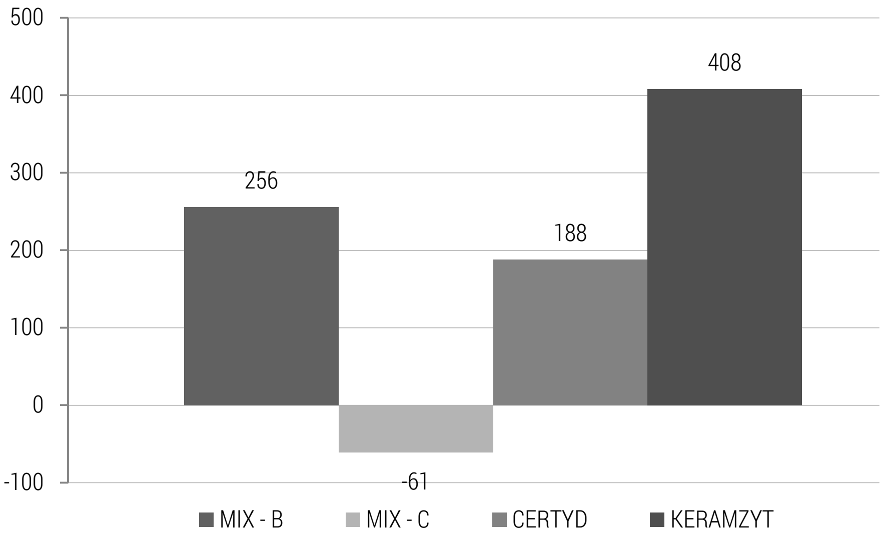

Figure 12. Comparison of costs of production of MIX aggregate with the market prices of CERTYD and KERAMZYT light aggregates [PLN/m^3]

Source: author's work.

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Table 6. Summary of production costs of 1 m^3 of aggregate

Name	A		B		C	
	Consumption	Unit cost (PLN)	Consumption	Unit cost (PLN)	Consumption	Unit cost (PLN)
Energy	120 (kW)	0.87 (PLN/kWh)	120 (kW)	0.87 (PLN/kWh)	120 (kW)	0.87 (PLN/kWh)
Waste plastic	300 (kg/h)	2.40 (PLN/kg)	300 (kg/h)	0.00 (PLN/kg)	300 (kg/h)	-0.50 (PLN/kg)
Bulk density	635 (kg/m^3)					
Productivity	0.47 (m^3/h)					
Depreciation	34.00 (PLN/m^3)					
Production costs	1780.13 (PLN/m^3)		256.13 (PLN/m^3)		-61.37 (PLN/m^3)	

Source: author's work.

When analysing the costs presented in Table 6 and Figure 12, it should be noted that the production of aggregate from plastic sourced from post-production waste is beneficial, not only because of the environmental aspects but because it can also compete on price with the light aggregates already on the construction market.

Conclusions

When comparing the summary of the values of bulk density for light aggregates presented in this paper, it should be noted that MIX aggregate is lighter than the aggregate produced from waste generated as a result of the combustion of hard coal by more than 10%. In addition, it is possible to obtain a lower bulk density by more than 35%. When analysing the density of light aggregate grains, a decrease of approximately 20% was also noted.

By far, the most significant advantage of MIX aggregate is its low absorbability, which is lower by over 90% in comparison with the competing light aggregates (Keramzyt, Certyd) used in construction. As a result, this enables the easier formation of architectural concretes and prefabricated elements by minimising the problem of adjusting the amount of water in the concrete mixture.

An additional benefit of aggregate from plastic waste is its compressive strength, which is greater by 25%. Owing to this, it is possible to build warm floors in residential and industrial buildings, contributing to reduced CO_2 emissions and heating costs.

Moreover, the economic analysis confirmed the possibility of using MIX aggregate in the construction sector. Variant C comprises the collection of waste from manufacturing companies and is the most beneficial, as it is pos-

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sible to sell the aggregate, after production, for 0 PLN/m^3, with a profit of 61.37 PLN/m^3. Moreover, during the construction of buildings, attention should be paid not only to the product's price, but also to the benefits of its use, as a lower weight of construction elements translates to a reduction in cross-sections, which results in lower investment costs and shorter completion times.

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The contribution of the authors

Robert Grygo: conception – 50%, literature review – 40%, experimental research – 50%, analysis and interpretation of data – 40%.

Kevin Bujnarowski: conception – 30%, literature review – 40%, experimental research – 50%, analysis and interpretation of data – 40%.

Jolanta Anna Prusiel: conception – 20%, literature review – 20%, analysis and interpretation of data – 20%.

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PN-EN 1097-6:2013-11 Tests for mechanical and physical properties of aggregates – Part 6: Determination of particle density and water absorption.

PN-EN 13055:2016-07 Lightweight aggregates.

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GENERAL ENVIRONMENTAL AND SOCIAL PROBLEMS

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ENVIRONMENTAL, SOCIAL AND ECONOMIC DETERMINANTS OF SUSTAINABLE DEVELOPMENT IN THE PROCESS OF MANAGING MUNICIPALITIES ILLUSTRATED USING THE EXAMPLE OF THE LESSER POLAND VOIVODESHIP

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ABSTRACT: In an age of climate change and increasing negative environmental effects of the development of urban agglomeration, it is becoming more and more important to implement sustainable development principles in governing urban municipalities (Polish: gminy). The three areas of sustainable development: social, economic and environmental, have been extensively explored in scientific research over recent years. These studies have mostly covered international or regional areas and, to a lesser extent, local ones. Six environmental, economic and social indicators of sustainable development were examined for 14 urban municipalities located in Lesser Poland Voivodeship. Only a selected group of indicators from these areas was assessed due to limited data availability. Social and economic measures showed a strong Spearman's rank correlation. Based on the collected research material, benchmarking was developed for the units under evaluation, indicating that over the period between the year 2014 and 2019, the city of Krakow occupied the highest position, on average, among urban municipalities of Lesser Poland Voivodeship, considering the measures analysed.

KEYWORDS: environment, sustainable development factors, management, municipalities

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Introduction

Natural environment degradation has led to severe climate change worldwide, bringing natural disasters (droughts, floods, hurricanes, tornadoes) that have had far-reaching consequences for humans. More and more countries realise that economic expansion has harmed the environment, leading to depletion of natural resources, problems with smog, access to clean water, etc. Many years of discussions, climate summits and scientific research have made it clear that this is a complex problem that affects many aspects of life. This has led to the search for ways to stop the adverse effects of human activity on the natural environment and to create the concept of sustainable development. This concept is treated as one of the ways to solve contemporary social and environmental problems. Implementation of sustainable development strategies reduces social disparities, reduces environmental pollution, and facilitates rational development of economic, ecological and environmental goals (Bocian, 2007, p. 143–160). It is essential to move towards an increased environmental awareness through an appropriate action strategy by the local authorities. A task of municipalities as territorial government units operating at a local level is to promote and encourage the building of community in line with the concept of sustainable development (Giordano, 2005, p. 34). Municipal authorities are perceived as a body with a significant potential to contribute to the creation of a sustainable economy; they can employ coercive measures to reduce activities that are not in line with the idea of sustainable development (Rosa et al., 2005, p. 112; Matysiak, 2010, p. 12). Looking at the literature on the subject, one can notice that sustainable development is mainly referred to in the context of three dimensions: economy, society and the environment (Keiner, 2004, p. 381). Both residents of a municipality and municipal authorities actively participate in the propagation and creation of sustainable development. Engaging economic entities operating in a given area and other local government units or central and EU authorities is also necessary.

To achieve appropriate results in sustainable development, actions need to be planned in the long run (Krupa, 2013, p. 50). Moreover, implementing sustainable development principles in municipalities depends on how a given unit is governed. Changes taking place in organisations and their environment brings about new problems. New challenges and dilemmas emerge with organised activities and initiatives. However, what has changed over the years is mainly the conditions under which leaders operate, as well as their fundamental principles and character of governance (Anderson et al., 2014, p. 18; Waśniewska, 2015, p. 86).

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This paper aims to identify determinants of sustainable development in the process of governing urban municipalities, particularly in the aspect of environmental factors and their quantification. In order o accomplish the above-stated aims, the environmental dimensions of sustainable development indicators were analysed in urban municipalities located in Lesser Poland Voivodeship from 2014 to 2019.

An overview of the literature

The sustainable development paradigm occupies a prominent position in global, regional and local strategies. This concept is fundamental at a local level in dynamically developing cities (Guo et al., 2020, p. 6571; Gunzenova, 2019, p. 217-224; Sciarelli et al., 2021, p. 39-56). Factors stimulating and reducing sustainable development have a significant impact on the development of the concept in the urban municipalities' sustainable development paradigm. At the same time, the local urban development system is complex (although it covers the smallest area) and requires effective coordination across many different types of organisations or groups of stakeholders that significantly impact the concept's development. Often, the task of municipal authorities is to create a system that combines all components (public and private sector organisations, citizens and enterprises, institutions and development agencies) and maximises all available resources, knowledge and experience. The essential idea of sustainable development is based on the premise of ensuring a sustainable increase in the quality of life of the present and future generations by developing reasonable proportions between the economy, society and ecology (Piontek, 2011, p. 19; Makhosheva et al., 2018, p. 28; Klarin, 2018, p. 67-94). Concerning the elements of the natural environment, the necessity of taking care of its resources, i.e. soil, minerals, water, plants and animals, is highlighted. Also, such values as landscape or ecosystems are recognised. The environmental dimension of sustainable development is oriented towards preserving biological diversity and ecosystem balance. Attention is focused not on single elements of the environment but on the relationships between the components of individual ecosystems (Preisner, 2002, p. 440-447; Holden et al., 2018). Environmental elements are directly linked to the capability of using the natural environment and ecosystem utility. Their availability translates into satisfying human needs, which is necessary to improve the quality of life. Ensuring that the environment is as intact as possible requires, in the first place, identifying its potential (Preisner, 2008, p. 484-487; Lenox & Chatterji, 2018, p. 4; Carboet al. 2018, p. 9, 68, 138, 155-158). Gotowska (2013, p. 28), among others, notes a strong correlation between the quality of life of people living in municipalities and sus-

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tainable development. Linking the quality of citizens' life with the concept of sustainable development is also crucial because of the environmental aspect. The environmental quality of the area where people live impacts the satisfaction of human needs such as health and safety. By appropriately managing a social life, social contact and support can be provided, thus preventing social helplessness, social exclusion and marginalisation (Preisner & Pindór, 1999, p. 13-23; Bhandari 2019, p. 97-128). Moreover, apart from individual satisfaction (personal preferences concerning quality), it also ensures collective satisfaction of residents, leading to the quality of life being rated higher at the local level (Woźniak, 2015, p. 79-99). At the same time, the way a municipality is governed determines to what extentae high quality of life and sustainable development are achieved. Thus municipal authorities should concentrate on issues related to improving quality of life through governance (Michalska-Żyła, 2016, p. 57).

Research on the social determinants of sustainable development was carried out, among others, by Basar & Eren (2021). They assessed the relationship between the regional human development index and public investment expenditure, terrorist attacks and population density in 12 regions of Turkey. Their findings and recommendations are also considered beneficial to countries with a similar social and economic situation to Turkey. Research on the determinants of the human development index was also conducted by Khan et al. (2019). The study's authors modelled the relationship between ICT, economic growth, and the Human Development Index (HDI), considering urbanisation, foreign direct investment (FDI), and trade in Pakistan. The study of the economic and social determinants of sustainable development of small and medium-sized enterprises (SMEs) was carried out by Cicea et al. (2019). The novelty and originality of their research were defined in terms of addressing the performance of SMEs from a new perspective, using an econometric basis in a macroeconomic view. In turn, the assessment of the financial and economic determinants of sustainable development using the functional coefficient model was carried out by Herwartz & Walle (2014). The presented research directions concerned various areas of sustainable development but focused primarily on the regional approach.

Sustainable development indicators are assessed regionally and internationally, as summarised in annual reports (Sustainable Development Report, 2022). Indicators of sustainable development for all member states of the UN were presented in multiple reports, such as the one by Sachs et al. (2021). As prepared by teams of independent experts at the Sustainable Development Solutions Network (SDSN) and the Bertelsmann Stiftung. The interactive SDR 2021 studied counties were assessed regarding the impact of the COVID-19 pandemic on sustainable development goals. Action priorities were identified based on the visual representation of countries' performance by SDG.

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On the other hand, a team of independent researchers at the Sustainable Development Solutions Network (SDSN), together with SDSN Europe and the Institute for a European Environmental Policy (IEEP), created the Europe Sustainable Development Report (2021). This report was prepared based on evidence-based methods introduced in the annual Sustainable Development Report, as well as the SDG Index and Dashboards provided by the SDSN and Bertelsmann Stiftung since 2016. However, studies addressing the assessment of sustainable development indicators for municipalities are scarce.

The governance of a municipality in the context of sustainable development should be defined as a set of interrelated tasks executed by a municipality's governing bodies and subordinate institutions to achieve cohesion as well as territorial, economic and environmental sustainability. This process enables the local authorities and population to identify and prioritise needs and, simultaneously, ensure the necessary means to satisfy them (Brandenburg, 2003, p. 202). These are activities integrated with the general system of local government administration that involves strategic planning, and considering rational use of local resources. To achieve cohesion in different areas of development, efficient instruments and methods must be used (Paluch, 2013, p. 526-527). The issues of local-level governance are closely connected with the local authorities establishing the direction of sustainable development actions, which is expressed through adopted policies and specifies types of tasks to be executed and means used for that purpose (Pietrzyk, 2000, p. 32). Local authorities play an important role in managing and stimulating sustainable development, but in order to ensure progress, the existing ways of governing public entities need to be constantly improved. Being responsible for the municipality's level of development, local authorities have to develop techniques that support transformations contributing to sustainability-based development correlated with the natural environment. Such techniquetos make it possible to fulfil different expectations and social aspirations through which the municipalities' living environment is created (Nonaka & Toyama, 2005).

Research methods

The paper represents an attempt to analyse sustainable development indicators in the following 14 urban municipalities (Polish: gminy) of Lesser Poland Voivodeship: Bochnia, Gorlice, Limanowa, Mszana Dolna, Grybów, Nowy Targ, Bukowno, Oświęcim, Jordanów, Sucha Beskidzka, Zakopane, Krakow, Nowy Sącz, and Tarnów. The municipalities vary in terms of sustainable development conditions. The analysed municipalities include both large, urban areas (e.g. the city of Krakow) and smaller, typically tourist towns (e.g.

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Zakopane, Sucha Beskidzka). The economic, social and environmental variation in the studied municipalities makes it possible to show the conditions of sustainable development specific to each city. The municipalities are located in the southern part of Poland, covering around 15 thousand square km. (one of the smallest voivodeships in Poland, bounded on the west by Silesian Voivodeship, on the north by Świętokrzyskie Voivodeship, on the east by Subcarpathian Voivodeship, and on the south by Slovakia). Lesser Poland Voivodeship comprises 22 powiats (counties) and 182 municipalities (3 cities with powiat rights: Tarnów, Nowy Sącz and Krakow). The Voivodeship is located within the following physical and geographical units: Oświęcim Basin, Sandomierz Basin, the Western Carpathians, Krakovian Gate, Nida Basin, the Krakow-Czestochowa Upland, which makes its environment relatively varied. The research was conducted at the turn of 2020-2021. The study period covered the years 2014-2019 to ensure comparability of data in all municipalities. The indicators were developed based on the Local Data Bank, where the information is made available with a two-year delay.

The assessment of the level of sustainable development of municipalities consists of monitoring a set of constructed individual and group indicators describing the economic, environmental and social aspects. In the literature on the subject, one can find various proposals for measuring sustainable development at individual levels of territorial division (local, regional, subregional, national, and international) (Poskrobko, 2011). Nourry (2008) compared the results of eight methods of assessing sustainable development. The overall findings were that every method had limitations. Therefore, the methods for sustainable development assessment require critical analysis as the final conclusions are method-specific. Paris and Kates (2003) noted that despite the persistent definitional ambiguities associated with sustainable development, much work (over 500 research efforts) has been devoted to developing quantitative indicators of sustainable development. They have concluded that no indicator sets are universally accepted, backed by compelling theory, rigorous data collection and analysis, and influential in the policy. Also, Evans et al. (2015) concluded that there is still no single method of assessing the sustainability of development that is widely accepted as suitable. All methods developed have inadequacies that prevent an accurate measure of sustainable development from being determined. Alfsen and Greaker (2007) state that most indicators fail due to a large number of indicators, often representing measurements that are not backed up by theoretical rationale and only focus, to a limited extent, on crucial sustainable development parameters. The development of a set of indicators that enable measurement of the effects of implementing the principles of sustainable development results from the operationalization of the concept, supervision of the implementation of goals indicated in planning, as well as strategic or

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political documents prepared at individual territorial levels (Lawn, 2003; Poskrobko, 2011). Korol (2008) points out that at the regional level, there are three dimensions of indicators: economic (GDP, sustainable energy development, entrepreneurship and professional activity, sustainable transport, sustainable tourism development, sustainable rural development, infrastructure availability); environmental (water quality – water and sewage management, protection of natural resources, air protection, radiation protection, landscape and nature protection, climate protection, access to environmental information) and social (poverty level, health protection, demography, public safety, education, culture, housing, equality, partnership).

Creating a database of sustainable development indicators should become the overriding research goal and, at the same time, a joint action of local governments, involving the contribution of local government units to the spread of the idea of sustainable development (Dahl, 2012). In practice, only some of the indicators are often analysed. Correct assessment is also undermined by low availability or lack of statistical data comprising an appropriate time and spatial perspective that can form the basis for comparisons. This contributes to difficulties in creating a comprehensive assessment and the emergence of information gaps. Numerous attempts to quantify the idea of sustainable development do not solve the problem of the lack of availability of material for comparisons.

Table 1. Environmental, economic, and social indicators of sustainable development

Symbol	Environmental indicators	Economic indicators	Social indicators
W1	Expenditure on municipal economy and environmental protection per capita [PLN]	Own revenue of gmina budgets per capita [PLN]	Total net migration per 1000 population
W2	Expenditure on climate and air protection per capita [PLN]	Budget expenditure per capita [PLN]	Expenditure on culture and art per capita [PLN]
W3	Population connected to wastewater treatment plants in % of total population	The share of investment expenditure of gminas in total expenditure [%]	Expenditure on physical education and sport per capita [PLN]
W4	Consumption of water per capita in [m^3]	Dwellings completed per 1000 population	The share of registered unemployed persons in population in the working age [%]
W5	Mixed waste collected during the year in total per capita in [kg]	Entities by size classes per 1000 population total	Expenditure on social welfare per capita [PLN]
W6	The share of parks, lawns and green areas of the housing estate areas in the total area [%]	Entities newly registered by ownership sectors per 1000 population	Expenditure on education and upbringing per capita [PLN]

Source: authors' work.

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Table 1 provides the symbols and names of the sustainable development indicators. Six indicators related to the environmental, economic and social aspects of the areas of sustainable development were selected. Such a selection of indicators was influenced by the availability of data from the analysed municipalities.

The indicators were developed based on quantitative data obtained from Statistics Poland (BDL). Descriptive statistics and correlational analyses were used to gain insight into trends, differences and relationships between variables in obtained quantitative data. The environmental governance indicators covered the aspects of climate change, air protection, waste management and the size of urban green areas. A significant indicator was the municipal budget expenditure for environmental protection and municipal services management. The way the indicators of implementation of sustainable development concept are selected is a subject of continuous discussion. However, it should be emphasised that the main aim of the presented indicators is to show how this idea was developed for the selected municipalities in Lesser Poland Voivodeship.

Results of the research

The indicators of sustainable development in urban municipalities were quantified considering environmental, social and economic dimensions. Due to a large number of indicators in each dimension, selected six measures were examined. Table 2 presents the measurement of environmental factors for urban municipalities of Lesser Poland Voivodeship. Analysis of the expenditure for environmental protection and municipal services management shows a positive trend – an increase in the indicator relative to the base year – in 11 examined municipalities. In contrast, a decrease was recorded in the following municipalities: Bochnia, Limanowa, and Nowy Targ. The high average expenditure for environmental protection and municipal services management can be observed in Zakopane (X = 711.93) and Krakow (X = 663.53), both of which are tourist destinations. These municipalities, due to their proximity to many areas of protected wildlife (Zakopane) and the problem of pollution of the environment (Krakow), emphasise raising ecological awareness. As a result, the expenditure for environmental protection is recorded at higher rates in these areas. It should be stressed that in the municipality of Limanowa, the average value of the indicator is also at a high level (X = 621.91). This results from the actions undertaken by the municipality to increase the quality of the environmental infrastructure and improve urban public infrastructure. In addition, the municipality emphasises the development of active tourism, recreational and cultural infrastructure, and

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Table 2. Sustainable development indicators in the environmental area of urban communes of the Lesser Poland Voivodeship in 2014-2019

Specification	Krakow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
W1 – Expenditure on municipal economy and environmental protection per capita [PLN]														
2014	446.59	253.07	268.19	849.04	254.79	1068.59	414.15	241.94	651.2	421.9	303.82	249.86	582.08	500.66
2015	558.44	278	272.09	366.78	228.47	1004.33	386.23	248.16	463.56	386.56	322.14	346.97	572.8	599.78
2016	674.78	357.8	346.86	332.16	189.31	301.54	298.94	268.24	288.08	371.56	312.27	273.42	526.26	617.76
2017	707.7	370.7	360.36	443.4	222.55	434.06	239.45	262.66	353.74	406.64	351.4	359.53	413.27	874.44
2018	748.72	423.16	377.13	415.26	240.66	673.6	571.99	356.48	477.18	510.83	418.92	462.54	521.77	1024.01
2019	844.91	487.18	457.97	844.91	1005.57	249.35	507.91	396.41	599.61	517.39	882.53	456.73	919.16	654.91
2014-2019	663.52	361.65	347.10	541.92	190.48	621.91	403.11	295.65	472.23	435.81	431.85	358.17	589.22	711.93
W2 – Expenditure on climate and air protection per capita [PLN]														
2014	47.11	11.09	1.57	0	41.42	0.65	178.56	0	0.51	2.61	4.21	0.56	219.71	no data
2015	46.4	25.69	7.78	0.76	1.96	0.05	182.58	0	1.73	7.06	3.35	94.07	218.49	no data
2016	89.97	30.97	43.02	0.59	1.85	3.25	90.77	0	11.71	7.38	2.78	0	173.42	no data
2017	115.69	4.31	41.86	2.71	15.96	6.74	2.23	8.13	51.26	43.79	5.03	52.27	46.34	no data
2018	71.42	25.15	21.08	56.31	5.24	70.02	152.77	75.58	36.85	100.74	10.5	102.01	126.51	no data
2019	58.65	5.05	27.02	34.79	4.06	28.32	18.18	4.2	41.76	41.89	26.08	17.67	92.04	no data
2014-2019	71.54	17.04	23.72	15.86	11.74	18.17	104.18	14.65	23.97	33.91	8.66	44.43	146.08	no data
W3 – Population connected to wastewater treatment plants in % of total population [%]														
2014	97.56	86.31	99.59	97.32	99.23	81.57	53.84	64.32	94.59	67.07	98.43	37.7	88.54	97.98
2015	98.64	93.35	99.61	94.66	99.5	81.3	54.87	64.44	95.59	67.03	98.1	37.7	90.03	97.98
2016	98.33	95.25	99.98	95.29	99.76	83.23	55.45	6.19	96.01	67.17	98.31	37.7	91.36	97.97
2017	97.72	92.87	96.47	95.59	99.72	84.75	56.88	62.4	96.21	77.38	97.09	37.7	92.38	97.96

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Specification	Krakow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
2018	97.26	94.12	97.62	95.91	99.86	86.41	59.58	62.93	96.24	80.73	96.55	37.7	94.77	97.45
2019	96.25	94.71	99.97	96.57	99.97	86.4	60.03	63.23	92.21	78.84	96.16	37.27	95.91	98.11
2014-2019	97.63	92.77	98.87	95.89	99.67	83.94	56.77	53.92	95.14	73.03	97.44	37.62	92.16	97.63
W4 – Consumption of water per capita in [m3]														
2014	70.8	40.2	155	63.9	40.3	41.9	17.3	11.2	31.2	865.5	229.7	25.5	38.5	82.4
2015	69.3	40.3	147.3	65	37.3	44.5	17.2	11.8	29.6	924.9	232.8	26.1	38.3	87.2
2016	69.2	40	139.1	64.1	37.9	44.1	16.8	11.7	29.9	801.5	231.1	24.8	40.1	92
2017	70.3	40.7	149.1	65.8	38.5	45.4	17.5	14.7	31.1	908.5	261.5	23.8	41.2	95
2018	73.9	41	151.1	68.6	38.6	45.1	17.5	12.5	32.8	1175.4	266.4	23.8	44	97.2
2019	71.4	42.9	146.4	70.6	38.6	46.5	17.7	12.8	34	1053.7	285.2	23.6	44.8	99.3
2014-2019	70.82	40.85	148.00	66.33	38.53	44.48	17.33	12.45	31.43	792.44	251.12	24.60	41.15	70.82
W5 – Mixed waste collected during the year in total per capita in [kg]														
2014	253.5	231.2	244.2	227.8	244.4	231.6	192	191.3	215.1	269.1	319	147.7	161.9	433.9
201	248.8	235.4	195.4	234.6	235.2	249.5	202.7	209.9	225	271.8	321	172.3	37.4	455.6
2016	326.1	244.8	267.6	233.9	258.3	275.8	188	220.4	238.2	282.1	325.9	98.3	186	539.3
2017	283.3	261.2	262.3	236.6	273.7	297.4	209.4	218.7	223.5	298.1	333	162.7	208.2	571.6
2018	291.2	242.3	287	259.5	278.1	314.3	196.1	222.5	251	290.9	343.2	191.9	236.9	587.1
2019	284.3	245	290.9	225.9	281.3	317.3	192.5	209.5	245	285.5	347.1	198	365.2	606.4
2014-2019	281.20	243.32	257.90	236.38	261.83	280.98	196.78	212.05	232.97	282.92	331.53	161.82	199.27	532.32
W6 – The share of parks, lawns and green areas of the housing estate areas in the total area [%]														
2014	4.8	1.6	1.9	1.7	1.9	0.6	0.2	0.6	0.8	0.4	3.8	0.2	0.4	0.6
2015	4.9	1.9	1.8	1.7	1.9	0.6	0.2	0.5	0.6	0.4	3.8	0.2	0.5	0.6

Specification	Krakow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
2016	5.1	1.9	1.9	1.7	2	0.7	0.2	0.5	0.7	0.2	3.8	0.2	0.5	0.9
2017	5.3	1.9	1.9	1.7	2	0.7	0.2	0.5	0.6	0.2	3.8	0.2	0.5	0.9
2018	5.5	1.7	1.8	1.7	2.1	0.7	0.2	0.6	0.6	0.2	3.7	0.2	0.5	0.6
2019	5.8	1.7	1.8	1.7	2.1	0.7	0.2	0.6	0.6	0.3	3.7	0.2	0.5	0.6
2014-2019	5.23	1.78	1.85	1.70	2.00	0.67	0.20	0.55	0.65	0.28	3.77	0.20	0.48	0.70

Source: authors' work based on BDL.

leisure spaces. Analysis of the indicator of the expenditure for air and climate protection shows a decrease in its value in three municipalities. This refers to the following cities: Nowy Sącz, Gorlice, Sucha Beskidzka and Mszana Dolna. In other municipalities, the value of this indicator increased. The highest increase was recorded in the municipality Nowy Targ (in 2014, the value of the indicator was PLN 0.51, while in 2019 – PLN 41.76) and in the municipality Bochnia, where in 2014, the expenditure for that purpose amounted to PLN 0 and increased to PLN 34.79 in 2019. The highest average amount of expenditure in the analysed period was recorded in Sucha Beskidzka (X = 146.08). The municipality is implementing the „Low Emission Reduction Programme for the municipality Sucha Beskidzka", which involves the fulfilment of residents' needs and expectations about heat management. Information about air and climate protection expenditure was not made available by the municipality Zakopane.

Table 2. Sustainable development indicators in the environmental area of urban communes of the Lesser Poland Voivodeship in 2014-2019

Specification	Krakow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
W1 – Expenditure on municipal economy and environmental protection per capita [PLN]														
2014	446.59	253.07	268.19	849.04	254.79	1068.59	414.15	241.94	651.2	421.9	303.82	249.86	582.08	500.66
2015	558.44	278	272.09	366.78	228.47	1004.33	386.23	248.16	463.56	386.56	322.14	346.97	572.8	599.78
2016	674.78	357.8	346.86	332.16	189.31	301.54	298.94	268.24	288.08	371.56	312.27	273.42	526.26	617.76
2017	707.7	370.7	360.36	443.4	222.55	434.06	239.45	262.66	353.74	406.64	351.4	359.53	413.27	874.44
2018	748.72	423.16	377.13	415.26	240.66	673.6	571.99	356.48	477.18	510.83	418.92	462.54	521.77	1024.01
2019	844.91	487.18	457.97	844.91	1005.57	249.35	507.91	396.41	599.61	517.39	882.53	456.73	919.16	654.91
2014-2019	663.52	361.65	347.10	541.92	190.48	621.91	403.11	295.65	472.23	435.81	431.85	358.17	589.22	711.93
W2 – Expenditure on climate and air protection per capita [PLN]														
2014	47.11	11.09	1.57	0	41.42	0.65	178.56	0	0.51	2.61	4.21	0.56	219.71	no data
2015	46.4	25.69	7.78	0.76	1.96	0.05	182.58	0	1.73	7.06	3.35	94.07	218.49	no data
2016	89.97	30.97	43.02	0.59	1.85	3.25	90.77	0	11.71	7.38	2.78	0	173.42	no data
2017	115.69	4.31	41.86	2.71	15.96	6.74	2.23	8.13	51.26	43.79	5.03	52.27	46.34	no data
2018	71.42	25.15	21.08	56.31	5.24	70.02	152.77	75.58	36.85	100.74	10.5	102.01	126.51	no data
2019	58.65	5.05	27.02	34.79	4.06	28.32	18.18	4.2	41.76	41.89	26.08	17.67	92.04	no data
2014-2019	71.54	17.04	23.72	15.86	11.74	18.17	104.18	14.65	23.97	33.91	8.66	44.43	146.08	no data
W3 – Population connected to wastewater treatment plants in % of total population [%]														
2014	97.56	86.31	99.59	97.32	99.23	81.57	53.84	64.32	94.59	67.07	98.43	37.7	88.54	97.98
2015	98.64	93.35	99.61	94.66	99.5	81.3	54.87	64.44	95.59	67.03	98.1	37.7	90.03	97.98
2016	98.33	95.25	99.98	95.29	99.76	83.23	55.45	6.19	96.01	67.17	98.31	37.7	91.36	97.97
2017	97.72	92.87	96.47	95.59	99.72	84.75	56.88	62.4	96.21	77.38	97.09	37.7	92.38	97.96

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Specification	Krakow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
2018	97.26	94.12	97.62	95.91	99.86	86.41	59.58	62.93	96.24	80.73	96.55	37.7	94.77	97.45
2019	96.25	94.71	99.97	96.57	99.97	86.4	60.03	63.23	92.21	78.84	96.16	37.27	95.91	98.11
2014-2019	97.63	92.77	98.87	95.89	99.67	83.94	56.77	53.92	95.14	73.03	97.44	37.62	92.16	97.63
W4 – Consumption of water per capita in [m3]														
2014	70.8	40.2	155	63.9	40.3	41.9	17.3	11.2	31.2	865.5	229.7	25.5	38.5	82.4
2015	69.3	40.3	147.3	65	37.3	44.5	17.2	11.8	29.6	924.9	232.8	26.1	38.3	87.2
2016	69.2	40	139.1	64.1	37.9	44.1	16.8	11.7	29.9	801.5	231.1	24.8	40.1	92
2017	70.3	40.7	149.1	65.8	38.5	45.4	17.5	14.7	31.1	908.5	261.5	23.8	41.2	95
2018	73.9	41	151.1	68.6	38.6	45.1	17.5	12.5	32.8	1175.4	266.4	23.8	44	97.2
2019	71.4	42.9	146.4	70.6	38.6	46.5	17.7	12.8	34	1053.7	285.2	23.6	44.8	99.3
2014-2019	70.82	40.85	148.00	66.33	38.53	44.48	17.33	12.45	31.43	792.44	251.12	24.60	41.15	70.82
W5 – Mixed waste collected during the year in total per capita in [kg]														
2014	253.5	231.2	244.2	227.8	244.4	231.6	192	191.3	215.1	269.1	319	147.7	161.9	433.9
201	248.8	235.4	195.4	234.6	235.2	249.5	202.7	209.9	225	271.8	321	172.3	37.4	455.6
2016	326.1	244.8	267.6	233.9	258.3	275.8	188	220.4	238.2	282.1	325.9	98.3	186	539.3
2017	283.3	261.2	262.3	236.6	273.7	297.4	209.4	218.7	223.5	298.1	333	162.7	208.2	571.6
2018	291.2	242.3	287	259.5	278.1	314.3	196.1	222.5	251	290.9	343.2	191.9	236.9	587.1
2019	284.3	245	290.9	225.9	281.3	317.3	192.5	209.5	245	285.5	347.1	198	365.2	606.4
2014-2019	281.20	243.32	257.90	236.38	261.83	280.98	196.78	212.05	232.97	282.92	331.53	161.82	199.27	532.32
W6 – The share of parks, lawns and green areas of the housing estate areas in the total area [%]														
2014	4.8	1.6	1.9	1.7	1.9	0.6	0.2	0.6	0.8	0.4	3.8	0.2	0.4	0.6
2015	4.9	1.9	1.8	1.7	1.9	0.6	0.2	0.5	0.6	0.4	3.8	0.2	0.5	0.6

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Specification	Krakow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
2016	5.1	1.9	1.9	1.7	2	0.7	0.2	0.5	0.7	0.2	3.8	0.2	0.5	0.9
2017	5.3	1.9	1.9	1.7	2	0.7	0.2	0.5	0.6	0.2	3.8	0.2	0.5	0.9
2018	5.5	1.7	1.8	1.7	2.1	0.7	0.2	0.6	0.6	0.2	3.7	0.2	0.5	0.6
2019	5.8	1.7	1.8	1.7	2.1	0.7	0.2	0.6	0.6	0.3	3.7	0.2	0.5	0.6
2014-2019	5.23	1.78	1.85	1.70	2.00	0.67	0.20	0.55	0.65	0.28	3.77	0.20	0.48	0.70

Source: authors' work based on BDL.

In the case of the large and medium-sized cities included in the analysis (cities with more than 20 thousand residents), almost the entire population is connected to wastewater treatment plants (over 90% of the population). On the contrary, in smaller towns, a lower percentage of residents is connected to wastewater treatment plants, with the exception of municipalities Sucha Beskidzka and Limanowa (where 90% and 80% of residents are connected to treatment plants, respectively). It is also noticed that in many smaller municipalities, this percentage is increasing, while regress is observed in some larger cities. This can be primarily attributed to the development of single-family households not connected to the urban sewage system. The highest average value of this indicator (X = 99.67) is in Gorlice. Since this value is nearly 100%, most residential properties in this municipality must have a sewage system connection. In almost all of the analysed municipalities, water usage was significantly increased. This is a negative trend in the study area, leading to faster use of one of the most essential natural resources. The highest average value of the indicator, markedly higher than other analysed units, is observed in the municipality Bukowno (X = 792.44), the municipality Oświęcim (X = 251.11) and the municipality Tarnów (148). It should be highlighted, however, that higher water usage in these municipalities relates to the development of manufacturing and industry.

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In the municipality of Bukowno, industrial production accounts for over 90% of the total water usage, in the municipality Oświęcim – over 80%, whereas in the city Tarnów – over 60%.

Meanwhile, the high value of this indicator in the municipality of Zakopane is linked with the development of tourism. In most of the analysed urban municipalities, the amount of waste collected in the analysed years increased. This relates to an increase in consumption in Poland. Particularly noteworthy is the large amount of waste relative to the number of residents within the municipality Zakopane. The average value of this indicator in this city is the highest and equals (X = 532.32). This is because Zakopane is a tourist destination, meaning visitors leave a significant proportion of the waste. It is also worth mentioning the average value of the indicator in the municipality Jordanów (X = 161.82), which is lower than other analysed units. Moving on to the indicator of the share of urban green areas in the city's total area, the highest average value was recorded in the municipality of Krakow (X = 5.23).

Moreover, it showed an increase throughout the years. This may relate to the fact that the residents and authorities of the city are more aware of the benefits of having green areas, especially in areas affected by smog. Zakopane, in turn, recorded a slight increase over the entire study period (in 2016 and 2017, the indicator's value was 0.9). Still, in the following years, the indicator's value was at the same level as in the base year. This may result from the constant development of tourist infrastructure in this city, which limits the creation of green areas. In the case of other municipalities, the share of green areas changed slightly. Table 3 presents the calculated indicators of sustainable development for the economic and social areas. As the main topic of the study are environmental determinants of sustainable development, especially economic and social indicators, it was decided to present the values for the initial period (2014), the end period (2019), and the average values for 2014-2019 period in Table 3. The purpose of presenting the data in this way was to improve clarity. The presentation of data for individual years for 12 indicators would have been very extensive.

In the analysed years, almost all municipalities in the Lesser Poland Voivodeship recorded a negative migration balance, apart from the largest agglomeration – Krakow (X = 4.28; SD = 2.96), which seems obvious due to the city's position and progress in the Lesser Poland Voivodeship. The majority of the communes showed an increase in expenditure per capita in relation tMost of the communes showed an increase in expenditure per capita concerning the base year for physical education and sport. The exceptions include the municipalities of Limanowa, Nowy Targ and Zakopane, which were characterised by a downward trend. In the case of Nowy Sącz, the Spearman's correlation coefficient showed that with the increase in spending

Table 3. Sustainable development indicators in the economic and social area of urban communes of the Lesser Poland Voivodeship in 2014-2019

Years	Krcow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
Economic area														
W1 – Own revenue of gmina budgets per capita [PLN]														
2014	3653.1	2222.7	2407.9	2174.3	1690.1	2454.9	1234.2	1130.7	1881.2	2475.4	2431.3	1669.5	1898.5	2928.8
2019	4947.3	3251.5	3263.7	2709.3	2414.4	2525.6	1756.5	1425.3	2831.6	3679.7	3430.1	2293.5	2415.4	4303.5
2014-2019	4231.81	2685.53	2776.58	2463.83	1915.89	2513.54	1561.35	1254.16	2184.04	2938.16	2954.08	1970.40	2153.69	3595.23
W2 – Budget expenditure per capita [PLN]														
2014	5362.6	5048.3	4838.8	3460.7	2673.3	4853.5	2938.6	2865.1	3760.4	3638.9	3766.7	2599.5	3125.6	4062.6
2019	8017.0	7581.0	7858.9	5338.6	4738.8	6351.8	4712.4	5581.7	5039.8	5751.1	5854.9	5253.6	5544.5	6057.7
2014-2019	6468.58	6179.51	6180.90	4141.42	3578.29	5236.07	3962.30	4028.44	3926.47	4092.66	4915.09	3758.53	4264.59	5315.75
W3 – The share of investment expenditure of gminas in total expenditure [%]														
2014	16.4	10.5	9.3	17.3	15.2	32.7	19.4	3.4	33.2	25.6	11.7	2.4	23.9	14.6
2019	13.6	8.8	18.1	17.3	19.2	24.6	12.7	17.2	17.6	27.7	13.9	22.9	24.1	16.8
2014-2019	13.32	9.82	13.12	13.35	16.17	23.68	19.67	8.40	17.35	17.03	17.13	9.87	22.73	20.25
W4 – Dwellings completed per 1000 population														
2014	9.6	3	1.8	6.5	2.7	2.9	1.5	1	2.3	1.5	1.7	1.5	1.3	4.3
2019	16.8	2.1	2.2	4.1	2.6	3.2	1.6	1.3	5.5	1.2	2.1	1.7	1.9	4.5
2014-2019	12.33	2.70	2.15	3.52	1.77	2.75	2.32	0.88	3.27	1.22	1.70	2.40	1.88	5.23
W5 – Entities by size classes per 1000 population total														
2014	161.6	114	100	115.2	92.8	115.8	103	74.7	141.3	103.8	109.3	113.1	138.1	208.7
2019	188.6	121	110.7	121.2	96.4	123.3	115.5	82	150.5	103.8	114.4	128.4	147.4	228
2014-2019	176.92	117.05	103.72	117.08	91.88	118,55	108.05	76.88	144.35	101.12	110.67	120.28	142,.0	216.17

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Years	Krcow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
W6 – Entities newly registered by ownership sectors per 1000 population														
2014	13.5	11	8.3	8.9	8	11.4	11.4	10.7	11.2	7.3	7.5	9.6	9	13.8
2019	15.8	10.5	8.8	8.3	7.1	9.1	10.6	7.5	10.7	7	7.8	7.3	9.2	14.6
2014-2019	15.23	10.33	8.68	11.32	7.25	10.67	11.10	9.23	10.93	6.41	7.45	10.82	9.23	14.97
Social area														
W1 – Total net migration per 1000 population														
2014	2	-2.3	-5.3	-2.5	-6.1	-5.4	-0.6	-4.1	-2.2	-4.1	-2.6	2.8	-3.7	-2.2
2019	9	-2.9	-5,95	-7.45	-5.14	-6.33	-4.15	-3.98	-2.25	-1.77	-4.38	-6.73	-5.92	-3.69
2014-2019	4.28	-3.06	-4.23	-3.95	-5.41	-4.47	-1.39	-4.28	-2.13	-1.79	-4.14	-1.27	-5.00	-1.60
W2 – Expenditure on culture and art per capita [PLN]														
2014	415	61	90	129	89	168	74	32	72	122	231	77	139	188
2019	385	77	249	161	118	886	255	294	148	168	284	212	1 105	224
2014-2019	331.50	71.00	151.00	146.00	129.83	354.00	165.83	94.67	90.00	142.33	268.50	109.33	599.00	286.17
W3 – Expenditure on physical education and sport per capita [PLN]														
2014	159	120	128	159	130	132	19	16	587	364	180	14	78	152
2019	217	233	397	185	242	39	257	307	325	770	307	10	81	122
2014-2019	191.0	201.0	269.33	183.17	139.67	81.83	67.83	74.17	297.00	449.67	517.17	15.00	114.83	165.83
W4 – The share of registered unemployed persons in population in the working age [%]														
2014	4.6	7.6	7.7	6	8.8	10.5	11	7.9	8.8	7.8	7.2	5.6	6.3	9.9
2019	2.1	2.5	3.7	2.1	3.7	4.7	6.4	4.7	3.5	4.4	3.5	2.6	4.3	6.5
2014-2019	3.28	4.87	5.62	3.98	6.17	7.40	7.72	5.85	5.73	5.78	4.92	3.57	4.68	8.53

Years	Krcow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
W5 – Expenditure on social welfare per capita [PLN]														
2014	490	863	611	393	569	566	434	644	414	348	542	399	423	415
2019	462	525	428	228	268	329	170	273	180	211	479	217	170	329
2014-2019	553.17	773.83	591.00	393.17	491.00	543.17	403,17	567,33	385,50	330,50	544,33	405,50	381,00	436,33
W6 – Expenditure on education and upbringing per capita [PLN]														
2014	1396.0	1928.1	2011.1	1093.2	840.5	1464.6	1149.6	1189.9	862.86	1057.4	1101.7	952.1	1062.1	1082.4
2019	1912.2	2575.6	2746.8	1436.2	1069.2	1731.8	1511.1	1585.6	1203.5	1334.9	1390.5	1290.4	1483.9	1343.3
2014-2019	1619.96	2184.18	2327.26	1250.02	937.67	1591.91	1297.76	1422.83	1012.67	1157.50	1216.07	1088.59	1241.05	1258.05

Source: authors' work based on BDL.

on culture and art per capita, the expenditure on physical education and sport also increased per capita (Rho = 0.9; $p < 0.05$). The same is true for Tarnów and Limanowa (Rho = 0.9; $p < 0.05$). The value of the Rho coefficient was not statistically significant for the remaining communes. The highest average expenditure on education and upbringing per capita was recorded in the Commune of Tarnów (X = 2327.26; SD = 275.45), for which the values of the Spearman correlation coefficient showed that with the increase in expenditure on culture and art per capita, expenditure on education and upbringing also increased per capita (Rho = 0.93; $p < 0.05$), similarly in the commune of Limanowa (Rho = 0.98; $p < 0.05$), Gorlice (Rho = 0.97; $p < 0.05$), Bukowno, Jordanów and Oświęcim (Rho = 0.92; $p < 0.05$).

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Within the period 2014-2019, a relatively low unemployment rate was recorded in Poland, as well as in municipalities (in 2014, it was 12.3% and decreased to 5.4% in 2019). Analysis of the proportion of registered unemployed individuals in the working age population revealed that all analysed communes faced a visible regression. The lowest average level of unemployment is in Krakow (X = 3.29, SD = 0.98). It is a positive social phenomenon, reducing poverty and increasing the activity of the population. Moreover, the area is characterised by a high degree of urbanisation, and therefore many jobs are available. In the case of Krakow, the values of Spearman's correlation coefficient showed that with the increase in the employed in the working-age population, the proportion of registered unemployed individuals in the working-age population decreased (Rho = -0.98; $p < 0.05$). A similar correlation was found in Nowy Sącz (Rho = -0.98; $p< 0.05$), Oświęcim (Rho= -0.94; $p < 0.05$), Limanowa and Nowy Targ (Rho= -0.92; $p < 0.05$), and Jordan (Rho = -0.88; $p < 0.05$). In the case of the remaining localities, the value of the Rho coefficient was not statistically significant. In the analysed period, a decrease in the expenditure of municipalities allocated to social welfare was observed (except for 2016, in which this category included funds from the „Family 500 plus" program, and in 2017, expenditures allocated to family assistance were assigned to a separate budget classification category). Average spending on social welfare were higher in cities such as Nowy Sącz, Tarnów, and Oświęcim.

Focusing on the assessment of economic indicators, the first two, the incomes and expenditures of the surveyed municipalities per capita, showed progress in the analysed period. The highest average ratio of own revenue per capita was recorded in Krakow (X = 4231.81; SD = 511.28). The municipalities' revenue is mainly influenced by taxes and local fees, as well as revenues from PIT and CIT. The lowest average own revenue of the commune per capita in the analysed years can be observed in Grybów (X = 1254.16, SD = 148.7), which suggests the commune's low-income independence. In 2014, the share of municipalities' own revenue was 49.3%, and between 2018 and 2019 – 43.3%, suggesting a decrease in the income independence of these entities. A high increase in expenditure per capita was recorded in Krakow (X = 6468.58; SD = 1022.94), Tarnów (X = 6180.90; SD = 1148.82) and Nowy Sącz (X = 6179.51, SD = 1023.74). It also results from the increased demand for expenses due to municipalities' greater number of tasks. The values of the Spearman correlation coefficient for the city of Krakow showed that with the increase in the commune's revenue per capita, the commune's expenses per capita increased (Rho = 0.99; $p < 0.05$), similarly in the case of Sucha Beskidzka (Rho = 0.97; $p < 0.05$), Bochnia (Rho = 0.96; $p < 0.05$), Nowy Sącz (Rho = 0.94; $p < 0.05$), Nowy Targ and Oświęcim (Rho= 0.90; $p < 0.05$). In the case of the remaining localities, the value of the Rho coefficient was not statistically significant. In the years 2014-2019, the highest average share of

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investments in expenditure can be observed in the Limanowa commune (X = 23.68; SD = 7.84) and the lowest in the Grybów commune (X = 8.6; SD = 5.62). Municipalities showed a slowdown in investment activity in the period 2014-2016 (from 18.2-11.2%) and 2019 (16.9%). The period 2017-2018 was characterised by a substantial improvement in investment activity (from 14.6 to 20.6%). The investment regression in 2019 resulted from the COVID-19 pandemic and the introduction of a new debt ratio, limiting the possibility of obtaining debt capital by municipalities.

Considering the index of dwellings completed per 1000 individuals, only in some of the analysed communes there is an upward trend, positively influencing the construction industry. The average value in the analysed period is highest in the city of Krakow (it should be emphasised that this value is significantly higher than the average in other analysed communes). This shows a significant development of the real estate market, which is related to the phenomenon of economic migration. In smaller cities of the region, the real estate market is changing less dynamically, with the commune of Zakopane having a high average level of newly built apartments, which can be rented for tourism purposes. A positive upward trend is observed when analyzing the entities by size classes per 1000 individuals. The highest average values were noted for the city of Zakopane (X = 216.17, SD = 7.21) and Krakow (X = 176.92; SD = 9.70). This is because Zakopane is one of the most prominent tourist centers in Poland. In turn, Krakow is focused both on tourism and city development. The above trend concerns the entities newly registered by ownership sectors per 1000 individuals in the commune of Krakow (X = 15.23; SD = 0.87) and Zakopane (X = 14.97; SD = 0.84). A slight decrease in the value of the indicator was noted in the municipalities of Gorlice, Limanowa, Mszana Dolna, Grybów, Nowy Targ, Bukowno, Oświęcim and Jordan.

Based on the sustainable development indicators in the area of environmental determinants calculated for urban municipalities in Lesser Poland Voivodeship, an attempt was made to carry out a benchmarking evaluation (Table 4).

Table 5 presents the ranking of sustainable development indicators in the economic, social and environmental areas in the first – 2014 and the last year of the analysis – 2019.

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Table 4. Ranking position of sustainable development indicators in the environmental area of urban communes in 2014-2019 – benchmarking evaluation

Specification	Krakow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
Ranking position W1 – Expenditures on environmental protection and municipal management per capita [PLN]														
2014	6	11	10	2	14	1	8	13	3	7	9	12	4	5
2015	4	11	12	8	14	1	7	13	5	6	10	9	3	2
2016	1	5	6	7	14	9	10	13	11	4	8	12	3	2
2017	2	7	8	3	14	4	13	12	10	6	11	9	5	1
2018	2	9	12	11	14	3	4	13	7	6	10	8	5	1
2019	4	10	11	5	1	14	9	13	7	8	3	12	2	6
Ranking position W2 – Expenditure on climate and air protection per capita [PLN]														
2014	3	5	8	12	4	9	2	13	11	7	6	10	1	-
2015	4	5	6	11	9	12	2	13	10	7	8	3	1	-
2016	3	5	4	11	9	10	2	13	6	7	8	12	1	-
2017	1	11	6	12	7	9	13	8	3	5	10	2	4	-
2018	6	10	11	8	13	7	1	5	9	4	12	3	2	-
2019	2	11	7	5	13	6	9	12	4	3	8	10	1	-
Ranking position W3 – Population connected to wastewater treatment plants in % of total population [%]														
2014	6	9	1	5	2	10	13	12	7	11	3	14	8	4
2015	3	8	1	7	2	10	13	12	6	11	4	14	9	5
2016	3	8	1	7	2	10	12	14	6	11	4	13	9	5
2017	3	8	5	7	1	10	12	13	6	11	4	14	9	2
2018	4	9	2	7	1	10	13	12	6	11	5	14	8	3
2019	5	8	2	4	1	10	13	12	9	11	6	14	7	3
Ranking position W4 – Consumption of water per capita in [m3]														
2014	10	6	12	9	7	8	2	1	4	14	13	3	5	11
2015	10	7	12	9	5	8	2	1	4	14	13	3	6	11
2016	10	6	12	9	5	8	2	1	4	14	13	3	7	11
2017	10	6	12	9	5	8	2	1	4	14	13	3	7	11
2018	10	6	12	9	5	8	2	1	4	14	13	3	7	11
2019	10	6	12	9	5	8	2	1	4	14	13	3	7	11
Ranking position W5 – Mixed waste collected during the year in total per capita in [kg]														
2014	11	7	9	6	10	8	4	3	5	12	13	1	2	14

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Specification	Krakow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
2015	11	10	3	8	9	12	4	5	6	13	7	2	1	14
2016	13	7	9	5	8	10	3	4	6	11	12	1	2	14
2017	10	7	8	6	9	11	3	4	5	12	13	1	2	14
2018	11	5	9	7	8	12	3	2	6	10	13	1	4	14
2019	8	6	10	4	7	11	1	3	5	9	12	2	13	14
Ranking position W6 – The share of parks, lawns and green areas of the housing estate areas in the total area [%]														
2014	1	6	4	5	3	8	13	10	9	12	2	14	11	7
2015	1	4	5	6	3	8	13	10	9	12	2	14	11	7
2016	1	5	4	6	3	8	13	10	9	12	2	14	11	7
2017	1	5	4	6	3	8	13	10	9	12	2	14	11	7
2018	1	5	4	6	3	8	13	10	9	12	2	14	11	7
2019	1	5	4	6	3	8	13	10	9	12	2	14	11	7

Source: authors' work based on Table 2.

Table 5. Ranking position of sustainable development indicators in the economic, social and environmental area of urban communes of the Lesser Poland Voivodeship in 2014 and 2019

Years	Krakow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
Economic area														
W1 – Own revenue of gmina budgets per capita [PLN]														
2014	1	7	6	8	11	4	13	14	10	3	5	12	9	2
2019	1	5	6	8	11	9	13	14	7	3	4	12	10	2
W2 – Budget expenditure per capita [PLN]														
2014	1	2	4	9	13	3	11	12	7	8	6	14	10	5
2019	1	3	2	10	13	4	14	8	12	7	6	11	9	5
W3 – The share of investment expenditure of gminas in total expenditure [%]														
2014	7	11	12	6	8	2	5	13	1	3	10	14	4	9
2019	12	14	6	8	5	2	13	9	7	1	11	4	3	10

Years	Krakow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
W4 – Dwellings completed per 1000 population														
2014	1	4	8	2	6	5	10	12	7	10	9	10	11	3
2019	1	8	7	4	6	5	12	13	2	14	8	11	10	3
W5 – Entities by size classes per 1000 population total														
2014	2	7	12	6	13	5	11	14	3	10	9	8	4	1
2019	2	8	11	7	13	6	9	14	3	12	10	5	4	1
W6 – Entities newly registered by ownership sectors per 1000 population														
2014	2	5	10	9	11	3	3	6	4	13	12	7	8	1
2019	1	5	8	9	13	7	4	11	3	14	10	12	6	2
Social area														
W1 – Total net migration per 1000 population														
2014	2	5	10	6	12	11	3	9	4	9	7	1	8	4
2019	1	4	11	14	9	12	7	6	3	2	8	13	10	5
W2 – Expenditure on culture and art per capita [PLN]														
2014	1	13	8	6	9	4	11	14	12	7	2	10	5	3
2019	3	14	7	11	13	2	6	4	12	10	5	9	1	8
W3 – Expenditure on physical education and sport per capita [PLN]														
2014	4	9	8	4	7	6	11	12	1	2	3	13	10	5
2019	8	7	2	9	6	12	5	4	3	1	4	13	11	10
W4 – The share of registered unemployed persons in population in the working age [%]														
2014	13	8	7	11	4	2	1	5	4	6	9	12	10	3
2019	10	9	6	10	6	3	2	3	7	4	7	8	5	1
W5 – Expenditure on social welfare per capita [PLN]														
2014	7	1	3	13	4	5	8	2	11	14	6	12	9	10
2019	3	1	4	8	7	5	12	6	11	10	2	9	12	5
W6 – Expenditure on education and upbringing per capita [PLN]														
2014	4	2	1	8	14	3	6	5	13	11	7	12	10	9
2019	3	1	2	8	14	4	6	5	13	11	9	12	7	10
Environmental area														
W1 – Expenditure on municipal economy and environmental protection per capita [PLN]														
2014	6	11	10	2	14	1	8	13	3	7	9	12	4	5

Years	Krakow	Nowy Sącz	Tarnów	Bochnia	Gorlice	Limanowa	Mszana Dolna	Grybów	Nowy Targ	Bukowno	Oświęcim	Jordanów	Sucha Beskidzka	Zakopane
2019	4	10	11	5	1	14	9	13	7	8	3	12	2	6
W2 – Expenditure on climate and air protection per capita [PLN]														
2014	3	5	8	12	4	9	2	13	11	7	6	10	1	-
2019	2	11	7	5	13	6	9	12	4	3	8	10	1	-
W3 – Population connected to wastewater treatment plants in % of total population [%]														
2014	6	9	1	5	2	10	13	12	7	11	3	14	8	4
2019	5	8	2	4	1	10	13	12	9	11	6	14	7	3
W4 – Consumption of water per capita in [m3]														
2014	10	6	12	9	7	8	2	1	4	14	13	3	5	11
2019	10	6	12	9	5	8	2	1	4	14	13	3	7	11
W5 – Mixed waste collected during the year in total per capita in [kg]														
2014	11	7	9	6	10	8	4	3	5	12	13	1	2	14
2019	8	6	10	4	7	11	1	3	5	9	12	2	13	14
W6 – The share of parks, lawns and green areas of the housing estate areas in the total area [%]														
2014	1	6	4	5	3	8	13	10	9	12	2	14	11	7
2019	1	5	4	6	3	8	13	10	9	12	2	14	11	7

Source: authors' work based on Table 2 and 3.

To ensure clarity of the presented data, it was decided to present the indicators for the years 2014 and 2019, on the basis of which the benchmarking of three areas of sustainable development of urban communes was prepared. The benchmarking evaluation was extended to include indicators of sustainable development in the economic, social and environmental area. The test results are presented in Table 5.

When assessing the economic area, it can be noticed that the smallest changes in the ranking positions in 2014 and 2019 were recorded by the W1 (Own revenue of gmina budgets per capita) and W5 (Entities by size classes per 1000 population total) indicators. The city of Krakow (1st place) and Zakopane (2nd place) are the leaders in this aspect, while Grybów occupied the 14th place. In the years 2014-2019, the municipalities were characterised by a progression of their own revenues, Nowy Sącz recorded a change in the ranking from 7th to 5th and Nowy Targ from 10th to 7th. The majority of the companies surveyed maintained their position in the ranking. Own income is an essential source of financing for municipal activities, which can thus finance their activities, including sustainable development. The deficits in self-financing illustrate the application for funding under EU programmes, which are crucial for the development of municipalities. The leader in the ranking for the W2 (Budget expenditure per capita) indicator is Krakow (1st place), and Zakopane came on the 5th position. The financial capacity of the municipalities has determined the steady increase in budgetary expenditure. Compared to 2014 in 2019, two cities showed a significant change in the ranking of the W2 indicator, with Grybow moving from 12th to 8th place and Jordans from 14th to 11th. Only two cities recorded a slower increase in per capita spending: Mszana Dolna (from 11th to 14th place) and Nowy Targ (from 7th to 12th place). Compared to 2014, there was a rapid increase in capital expenditure, particularly in the period 2017-2018. Unfortunately, the year 2019 was characterised by a slowdown in investment activity in Polish municipalities, as compared to the previous year, there was a negative dynamic (decrease of more than 13%) in terms of capital expenditure as a proportion of total expenditure. This has also been reflected in the ranking of municipalities in the Lesser Poland Voivodeship. The leaders in the W3 index (The share of investment expenditure of communal in total expenditure) were Bukowno (change from 3rd to 1st) and Limanowa (2nd place). The municipalities that rose in the ranking are Jordanów (from 14th to 4th place), Tarnów (from 12th to 6th place) and Grybów (from 13th to 9th place). Significant decreases in the ranking were recorded by Mszana Dolna (from 5th to 13th place), Kraków (from 7th to 12th place) and Nowy Sącz (from 11th to 14th place). Minor changes can also be noticed in the case of the W4 indicator (Dwellings completed per 1000 population), where the city of Krakow is also the leader (1st place). Zakopane ranked third, while a significant change can be noticed in the case of Bochnia, which dropped from rank 2nd to 4th, while Nowy Targ from rank 7th in 2014 to 2nd recorded in 2019. In the case of the W6 (Entities newly registered by ownership sectors per 1000 population) indicator, the best note in 2014 was recorded by the city of Zakopane (1st place) and Krakow (2nd). In 2019, the notes of these cities switched around, the leader was the city of Krakow, instead of Zakopane. Similar scores in the ranking were registered for the W5 indicator (W5 – Entities by size classes per 1000 population total) – Zakopane with the leading position (1st), followed by Krakow (2nd). Nowy Targ (3rd), Sucha Beskidzka (4th), Gorlice (13th) and Grybów (14th) retained stable positions.

Indicators in the social area are characterised by the diversity of ranking positions. Only for the W5 (Expenditure on social welfare per capita) indicator in the first and last year of the analysis did Nowy Sącz (1st place) emerge as the leader, Krakow was promoted from (7th) to (3rd), and Zakopane from (10th) to (5th). Changes in the ranking were not shown by Nowy Sacz (1st), Limanowa (5th) and Nowy Targ (11th). The increase in social assistance

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spending was mainly driven by the introduction of the Family 500+, 300+ social programme package from 1 April 2016. Since 1 July 2019, the programme has been fundamentally modified by including every child in the family regardless of the income threshold. The programme has contributed to a significant improvement in families' financial situation, but also an increase in municipalities' income and social expenditure. With the launch of this programme, the share of expenditure on family policy increased significantly from 1. 78% of PKB in 2015 to 4% of PKB in 2021. Since 1 February 2022, ZUS has started receiving applications for entitlement to benefits, so municipalities do not represent funds for income and expenditure from this area, which will lead to a decrease in municipal expenditure on social assistance and consequently to a change in the ranking of municipalities. In the case of the W1 indicator (Total net migration per 1000 population), Krakow was promoted from note (2nd) to (1st), while the W2 indicator (Expenditure on culture and art per capita) from (1st) to (3rd). Expenditure on culture and art per capita (W2) was characterised by progression during the analysed period. There are significant changes in the 2019 ranking compared to 2014. Sucha Beskidzka from the 5th place ended up in 1st place and Limanova from 4th place in 2nd place. Krakow recorded a decline from the leading position to 3rd place in the ranking. Oswiecim took 5th place and Zakopane 3rd. This shows an increase in cultural and art spending in smaller towns in the Lesser Poland Voivodeship compared to larger ones like Krakow, Zakopane or Oświęcim, which are most popular among tourists. The percentage of expenditure on culture and the arts is relatively low compared to the total expenditure of Polish municipalities. It was around 3.5% in 2014 and 3.3% in 2019. Unfortunately, the Covid 19 pandemic has not had a positive impact on the community's activities in these areas and has not favoured the intensification and caused the temporary closure of art and cultural sites, which could significantly impact the ranking after 2019. The share of municipal expenditure on physical fitness and sport also decreased: in 2014, it accounted for 2.7% of the total budget expenditure of Polish municipalities, and in 2019 it was 2.4%. The index W3 (Expenditure on physical education and sport per capita) also shows major changes in the ranking of urban municipalities in the Lesser Poland Voivodeship. Bukovno recorded a decline from (2nd) to (1st), while Nowy Targ recorded a decline from (1st) to (3rd place). Significant changes in benchmarking can be seen in cities such as Krakow (from 4th to 8th place). Zakopane (from 5th to 10th), Limanowa (from 6th to 12th), and also Tarnów (up from 8th to 2nd) and Mszana Dolna (up from 11th to 5th). The change in the ranking of the leaders in the W4 indicator (The share of registered unemployed persons in the population in the working age) affected Zakopane (from 3rd to 1st) and Mszana Dolna (from 1st to 2nd). They are struggling with the highest unemployment rates. The significant increase in

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unemployment also affected municipalities such as Sucha Beskidzka (from 10th to 5th) and Jordanów (from 12th to 8th). These are tourist destinations where seasonal affiliation determines unemployment during the year. In 2019, cities such as Limanowa and Grybów were ranked 3rd, Tarnów and Gorlice 6th and Nowy Targ and Oswiecim 7th. The lowest unemployment rates were recorded in Krakow, ranked last in the ranking of the years studied. It is the largest city in the region, which is attractive for professionally active people. Expenditure on education represents a significant proportion of the total budget expenditure of Polish municipalities, amounting to 35.8% in 2014 and falling to 29.3% in 2019. Nowy Sącz and Tarnów were the leaders in the W6 (Expenditure on education and upbringing per capita) index, noting the first and second places, respectively. In other cities, changes were slight, and a constant score was recorded by Grybów (5th), Mszana Dolna (6th), Bochnia (8th), Bukowno (11th), Nowy Targ (13th) and Gorlice (14th position).

In the environmental area, the W6 (The share of parks, lawns and green areas of the housing estate areas in the total area) and W4 (Consumption of water per capita) indicators showed the lowest changes in the benchmarking compared to 2014 and 2019. For the W6 indicator, the city of Krakow maintained its leading position (1st), and the last place was occupied by Jordanów (14th). In turn, the leader for the W4 indicator was Grybów (1st), and the last position was recorded by Bukowno (14th). Water consumption in the face of climate change and drought in many areas, including the cities of the Lesser Poland Voivodeship, is a challenge for JST in Poland. In 2019, except for Krakow, Tarnow and Jordanow, all other municipalities surveyed recorded increased water consumption per capita. In the case of the W5 (Mixed waste collected during the year in total per capita) indicator, both in 2014 and 2019, the last place in the ranking was taken by the city of Zakopane (14th), while Jordanów dropped to (2nd) from the (1st place). The problem of sewage treatment is very complex, and the construction of sewage treatment plants requires time and money. In view of the drought and scarcity of water resources, municipalities should step up their efforts in this regard. Proper management of water resources by cities and investments to restore polluted waters are crucial in the face of fast-paced climate change. The share of expenditure on the municipal economy and environmental protection amounted to 9.4% of the total expenditure of Polish municipalities in 2014 and 9.3% in 2019. When analysing the share of capital expenditure on the municipal economy and environmental protection in the total budget of Polish municipalities, major changes can be observed: in 2014, the ratio was 18.7%, and in 2019, it was 9.4%. The already mentioned slowdown in investment activity has also been reflected in the Expenditure on the municipal economy and environmental protection. The municipalities of the Lesser

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Poland Voivodeship have also noted significant changes in the measure studied. The best results for the W3 indicator (Population connected to wastewater treatment plants in % of the total population) were recorded in Tarnów – 1st position in 2014 and 2nd in 2019; as well as Gorlice – 2nd position in 2014 and 1st in 2019. The other cities did not show any significant changes in the ranking.

On the other hand, an exciting change in the ranking in the analysed period can be noticed for the W1 indicator (Expenditure on the municipal economy and environmental protection per capita), as Gorlice and Limanowa reversed their positions from (1st) to (14th). Only Jordanów (12th) and Grybów (13th) did not change their ranking positions. Oświęcim has moved from 9th to 3rd place in the ranking, while Kraków has moved from 6th to 4th and Zakopane from 5th to 6th. The leader in the ranking for the W2 indicator (Expenditure on climate and air protection per capita) turned out to be Zakopane (1st), and the city of Krakow strengthened its position from (3rd) to (2nd place). Spending on climate and air protection is essential to sustainable development, especially in the fight against smog. Smog in Poland is a very problematic phenomenon, as the data shows. The Supreme Audit Office informed us in its report in 2015 that Poland ranks second among the EU countries with the most polluted air. The IQAir (2022) ranking from April 2022 indicates that among the most polluted cities in the world, Warsaw ranks 41st, Krakow 58th, Wroclaw 59th, and Poznan 85th. In the Małopolska province, the clear leader in this respect for many years has been the city of Krakow, due to its old buildings and unfortunate geographical location (the city lies in a valley), but also Nowy Targ, Nowy Sącz and Zakopane. The city authorities of Kraków have been taking appropriate measures to fight smog for many years, which is also confirmed by the increase in spending in this regard (2nd place in the ranking for W2 in 2019). In the ranking assessment, Nowy Targ was ranked 4th in 2019 from 11th place, and Nowy Sącz was ranked 11th from 5th place.

In conclusion, the comparative monitoring and evaluation of sustainable development indicators should constitute an essential element of the management process of municipalities (Figure 1). Determinants in the three areas of sustainable development can be stimulated or destimulated. In the case of environmental determinants, two destimulatns are visible – per capita water usage, as well as waste collected annually per capita. In the case of these two indicators, municipalities with a lower indicator value recorded the highest position in the ranking. Unfortunately, over the analysed period, the values of the indicated measures showed an upward trend. The surveyed communes received high scores in the ranking in various areas. However, the communes of Zakopane and Krakow are leaders.

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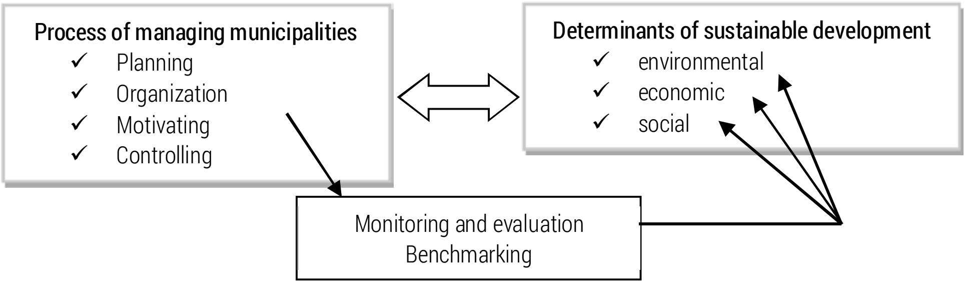

Figure 1. Sustainable development determinants in the process of managing municipalities
Source: author's work.

Benchmarking of sustainable development indicators is an essential instrument in the process of municipal management. The position of a particular determinant in the ranking in the benchmarking assessment allows for diagnosing its strengths and weaknesses. A comparison over a more extended period also indicates whether a commune has taken appropriate measures to limit its liabilities and strengthen its strengths over the years. Municipalities should strive for the best possible position in the ranking. Benchmarking helps to identify good practices, and cities should benefit from the experience of successful local government units. As the awareness of the inhabitants of communes in the field of sustainable development increases, they follow various rankings, they want to participate in the process of communal management by submitting their projects – monitoring of sustainable development indicators becomes more and more critical.

In 2021, at the turn of March and May, a questionnaire interview was conducted in the surveyed municipalities (the results will be presented in more detail in the following study). The research results in this field indicate that 100% of respondents stated monitoring sustainable development indicators as crucial in managing municipalities. All municipalities confirmed that they regularly monitor sustainable development indicators once a year.

Conclusion

Regarding the generalisation of results, three areas of sustainable development were assessed: environmental, economic and social. Six indicators from each site were selected to enable comparability of results. In a review of the literature, many authors pointed toward the limitations in the indicator assessment of sustainable development. The research limitations concern, first and foremost, the two-year delay in the publication of data in the Local Data Bank in Poland, and second, the lack of comparability of findings in var-

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ious municipalities. Therefore, only indicators that could be meaningfully compared were selected.

The indicators showing performance improvement over the study period for the 14 evaluated urban municipalities in Lesser Poland Voivodeship included: expenditure for environmental protection and municipal services management, expenditure for air and climate protection, the proportion of the population connected to a wastewater treatment plant, and the share of green areas in the total size of a city. This indicates increasing awareness of sustainable development principles among governments at a municipal level. However, analysis of the environmental indicators also revealed those showing a negative trend. These are mainly indicators of water usage and the amount of waste generated per year. No significant progress was also observed in the case of the indicator reflecting the share of urban green areas in the total size of a city. These are crucial issues concerning which urban municipalities in Lesser Poland Voivodeship should intensify their activity and adjust the management process towards a more dynamic implementation of sustainable development principles, especially in the area of environmental determinants.

In summary, along with an increase in sustainable development indicators such as expenditure on culture and art per capita, the share of the employed in the working-age population and the own revenue of municipal budgets per capita, the values of the indicators related to other aspects of sustainable development remained stable. Thus the activities of municipalities are aimed at improving these areas and increasing the level of sustainable development. All surveyed communes are identified as key in monitoring sustainable development indicators. This is because they all confirmed that they regularly assess and monitor sustainable development indicators once a year.

Benchmarking sustainability indicators is an important instrument in the municipal management process. This practice used in management consists of comparing processes and practices used by municipalities with the best ones in the analysed field. The need for a more precise analysis of municipalities' functioning results from the constantly changing environment and implementation of sustainable development principles. Therefore, benchmarking has become one of the most popular methods for improving organisations and the efficiency of their operations. Based on the results of the benchmarking assessment, strategic goals can be set, and areas for development of the municipality can be sought. Managing municipalities in terms of sustainable development should consider environmental, economic and social determinants. Tracking municipalities' ranking position for indicators in these areas should guide them in their strengths and weaknesses. Cities

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should strive for the best possible position in the ranking and benefit from the experience of the most successful local government units.

The presented research concerned the assessment of three groups of sustainable development indicators but focused primarily on benchmarking. Future research should aim towards an in-depth statistical and econometric evaluation and exploring correlations between the indicated measures.

The contribution of the authors

Conception and literature review: A. Brzozowska – 35%, J. Łukomska-Szarek – 45%, J. Imiołczyk-Sepczuk – 20%.

Acquisition of data, analysis and interpretation of data: A. Brzozowska – 35%, J. Łukomska-Szarek – 45%, J. Imiołczyk-Sepczuk – 20%.

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SUPPORTING LOCAL ECONOMIC DEVELOPMENT AS A MOTIVE FOR PURCHASING ORGANIC FOOD

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ABSTRACT: This paper aims to assess the significance of organic food purchases by consumers in Poland – motivated by supporting the local economy – against the background of other factors shaping consumer behaviour. The empirical material consists of a survey among 850 organic food consumers in Poland. The empirical material was analysed using Pearson's chi-squared test of independence and the non-parametric Mann–Whitney U test. The study shows that supporting the local economy appears to be an essential motive for its purchase for a large group of organic food consumers. The only factor significantly differentiating the two groups of consumers (motivated or not motivated by supporting the local economy) was the level of family income. The study allowed us to conclude that among consumers motivated by supporting the local economy, attitudes described as reflexive localism (the motive of supporting the local economy associated with concern for the natural environment) predominate.

KEYWORDS: organic food, purchase motives, supporting the local economy, reflexive localism

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Introduction

The organic food market has been characterised by high production and turnover dynamics for at least a dozen years. According to the works of various authors, both in the United States and in Europe, the demand for organically-farmed products is growing systematically and rapidly. As a result, organic food is the fastest-growing segment in the US agriculture and food industry (Mulder & Liu, 2017). The same is true in Europe, which is the second-largest organic food market in the world, with Germany, France, the United Kingdom, Denmark and Switzerland representing the largest market share (Ruiz de Maya et al., 2011; Ham, 2019).

The development of the organic food market provides two groups of benefits:

- organic agriculture supplying consumers with organic food has a positive impact on the natural environment, including in particular improved soil quality, reduced water and air pollution levels, and increased biodiversity (Hole et al., 2005; Mulder & Liu, 2017);
- consumers have access to food that meets their needs in a better way, especially health needs (Żakowska-Biemans, 2009; Kułyk & Michałowska, 2018).

The importance of organic farming and the need to shorten supply chains are underlined in the new European Green Deal. It is a reference to local development, production of local food, reduction of imports, and strengthening of local manufacturing and processing, which is in line with the strategy's goal of improving the resilience and competitiveness of the economy. Within the European Green Deal framework, there are the Biodiversity Strategy for 2030 and the Farm to Fork Strategy, which set out concrete actions that span the entire chain from food production to consumption, actions that also include international cooperation on sustainable food systems. An important element of these strategies is agriculture, including organic farming, which is closer to consumers by shortening supply chains. This means more goods produced and sold locally, which ultimately enables the shortening and reduction of global supply chains – the safe delivery of food to customers.

As a result, the growing production of organic food benefits farmers because it allows more efficient use of labour resources on farms and increases the income of farming families, which is related to the farming methods specific to organic farming (higher labour input than in conventional agriculture, higher prices for organic food). In turn, the benefits received by consumers include improved health and excellent taste. The production of organic food also benefits society as a whole in the form of an enhanced state of the natural environment. However, the development of

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organic farming is determined by the dynamics of the increase in demand for organic food, which in turn can be motivated by various factors (Voon et al., 2011; Urban et al., 2012; Petrescu et al., 2017; Tandon et al., 2020).

Considering the global benefits of developing local organic food markets and taking into account the decisive role of the behaviour of organic food consumers in dynamising the development of such calls (Massey et al., 2018), we decided to make an attempt to assess the importance of organic food purchases by consumers in Poland – motivated by supporting the local economy – against the background of other factors shaping consumer behaviour. The results of the study are supposed to provide answers to the questions:

1. What are the socio-demographic characteristics of organic food consumers oriented towards supporting the local economy?
2. How important is supporting the local economy among the different motives for purchasing organic food?
3. To what extent is reflexive localism taken into account in the behaviour of organic food consumers, and what is its importance in supporting the local economy?

Review of the scientific literature

As shown in the literature, factors motivating organic food purchasing are most comprehensively characterised by the theory of planned behaviours (TPB) (Dean et al., 2006; Salleh et al., 2010; Ruiz de Maya et al., 2011; Schleenbecker & Hamm, 2013; Scalco et al., 2017; Ham et al., 2018). This theory has proved its usefulness in research on sustainable and organic food consumption and is commonly used in research on consumer behaviour.

The theory of planned behaviour was developed by Ajzen (1991) and belonged to the most popular testing instruments for measuring the cognitive factors of consumers. TPB proposes that behaviour is determined by a combination of an individual intentions to engage in a certain behaviour (Al-Swidi et al., 2014). It assumes that consumer behaviour in the organic food market is a consequence of the interaction of three groups of factors. One of them is the attitude towards this type of food. The more positive consumers' attitudes toward the presence of organic food on the market, the greater interest in buying it. The positive attitude results primarily from the acceptance of such features of organic food as health properties and taste values, as well as the beneficial impact of organic food production methods on the natural environment (Rana & Paul, 2017).

The second group of factors influencing the decision to purchase organic food are social norms (SN), understood as the adoption and reproduction of the behaviour of other consumers of organic food.

DOI: 10.34659/eis.2022.81.2.444

Therefore, the tendency to imitate the behaviour of other consumers of organic food plays an essential role. Previous studies on this topic show that family and friends have the most significant influence on such behaviour in the organic food market. In contrast, other people shape such behaviour to a lesser extent. The impact of social norms on consumer behaviour in the organic food market varies between countries. While the importance of this group of motivating factors was vital in the study conducted among consumers in the Czech Republic (Zagata, 2012), social norms were much less critical among young people in India (Yadav & Pathak, 2016).

The third segment of the TPB is formed by factors that limit access to organic food (perceived behavioural control – PBC), such as high prices, an underdeveloped distribution network, or a small range of organic items (Al-Swidi et al., 2014).

According to the TPB, decisions to purchase organic food may be simultaneously influenced by different factors from each of their three segments. In doing so, some of them may influence the strength of the other factors. As an example, the results of the study by Al-Swidi et al. (2014) show that factors classified as social norms influence the formation of the relationship between the other two groups of factors (attitudes and PBC) and consumers' purchasing decisions, which means that their importance may be greater than the others. However, as the authors of this study emphasise, such a situation may be typical only for consumers in the region they study. At the same time, factors other than SN may be more important for consumer behaviour in the different areas. This finding is supported by the work of Rana and Paul (2017). Based on a broad review of the literature on consumer behaviour in the organic food market, they found that there are differences between the motives for purchasing such food between highly developed and developing countries. In the first group, demand for organic food is motivated by satisfying needs such as esteem and self-actualisation, whereas in developing countries, the need for safety is more important. In such circumstances, social norms will be of minimal importance in developed countries, while in developing countries, factors such as the opinion of others may have a much greater influence on purchasing organic food. According to the mentioned authors, it is one of those issues that requires more detailed research.

An issue that has been poorly explored so far is the importance of supporting the local economy as a motivating factor for purchasing organic food. A study by Seyfang (2006) shows that with the growing importance of global corporations and supermarkets in the food market, a growing group of organic food consumers in the UK perceive their purchasing decisions in the context of supporting and strengthening the local economy, reflecting a search for new pathways towards sustainable consumption and the development of attitudes described as 'ecological citizenship'. Several arguments

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support the need for such attitudes to become more widespread. First of all, purchasing food produced by local producers promotes local agriculture. It shortens the supply chain, which reduces distribution costs and allows for shorter transportation of food from the producer to the consumer. As a result, the scale of threats to the natural environment is also reduced due to the reduction of energy consumption by vehicles transporting agricultural raw materials and food products (Meas et al., 2015). Another important fact here is that, in contrast to the globalised food system, in the case of increasing interest in local products, the relations between consumers and producers of organic food strengthen, which is a condition for the development of ethical and social capital, as well as a source of increasing consumer knowledge about the pro-environmental significance of organic food production methods (Honkanen et al., 2006).

It appears significant to look for an answer to the degree organic food consumers are interested in its local origin. Studies conducted in Austria (Milestad et al., 2017) and Sweden (Bosona & Gebresenbet, 2018) have shown that organic food consumers exhibit a growing interest in its local origin, with the main causes being typically its high quality and support for the local economy. On the other hand, research conducted among organic food consumers in Denmark show a low interest in its local origin (Ditlevsen et al., 2020). In turn, a study from i.a. England has demonstrated that only a small portion of farmers running organic holdings was interested in placing their produce on local markets. The reason for this is the feeling that the barriers to the local market are too significant or lack sufficient population to make a predominantly local marketing strategy viable. Some farmers identified themselves as producers with neither the time, skills, nor inclination to get involved in direct marketing and prefer the relative security of selling on contract (Lobley et al., 2013). However, research from the USA (Yue & Tong, 2009) and Germany (Hempel & Hamm, 2016) has given basis to the conclusion that organic food consumers accepted the highest price for organic products, which originated from local suppliers.

Finally, the growing importance of local organic food markets contributes to sustainable rural development because it not only improves the state of the natural environment (the higher the number of organic farms, the lower the scale of environmental threats) but also contributes to improving the economic stability of organic farms because they become less dependent on large buyers. In addition, the creation of local supply chains translates into the development of the local economy by increasing the amount of money circulating locally (the money spent on organic food stays in the local market and has a much more significant multiplier effect than purchases in hypermarkets because in the latter case the money quickly flows out of the local economy) (Mitchell & Lemon, 2019; O'Hara & Pirog, 2013; Lobley et al., 2013).

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When characterising the positive effects of developing local organic food markets, Seyfang (2006) points out that it is not about closing the most developed economies to international trade (defensive localism) and creating barriers to food imports from developing countries, which would deepen the scale of economic and social inequalities. Instead, it is about reflexive dialect, meaning an openness on the part of consumers of organic food to local markets and creating networks with the global market for those products that cannot be produced in a given local environment. It is mainly about openness to purchasing organic food from developing countries, as this is one of the conditions for improving the state of the natural environment on a global scale and for stimulating the development of the economies of these countries to reduce the scale of economic and social inequalities in the world. Such an attitude is, therefore, contrary to defensive localism and favours the introduction of the principle of sustainable development not only in the local environment close to the consumers of organic food in wealthy societies but also in economically less developed countries (Winter, 2003; DuPuis & Goodman, 2005). As noted by some authors (Fonte, 2013; Spillare, 2016; Ferguson et al., 2017), it is a process that conditions the dynamisation of local development and is based on the concept of the common good and the concept of Shared Social Responsibility (SSR) and reduces the potential threats to local environments resulting from the negative effects of globalisation. As pointed out by DuPuis & Goodman (2005), localisation is not necessarily incompatible with globalisation and may be open to deployment in a neoliberal "glocal" logic. An inclusive and reflexive politics in place would understand local food systems not as local " resistance" against global capitalist "logic" but as a process in which the local and international make each other every day. Therefore, it is more appropriate to use the term "glocal reflexivity" to combine global and local contexts.

Materials and methods

The analysis leading to the formulation of answers to the research questions was conducted based on a survey among 850 organic food consumers in Poland. The research sample was selected on the basis of age, gender, education level, number of persons in the family, a form of professional activity and place of residence of the respondents. The survey was conducted in December 2020 by a specialised research agency (ABM FAST SOLUTIONS), and the survey questionnaire was developed by the authors of the study. The survey was conducted using the CAWI (Computer Assisted Web Interview) method via an online panel.

DOI: 10.34659/eis.2022.81.2.444

Based on the literature review (Dean et al., 2006; Ruiz de Maya et al., 2011; Zagata, 2012), the survey questionnaire was constructed in such a way that the analysis of empirical data was subject to the assumptions of the theory of planned behaviour.

From the perspective of the research assumptions adopted in this paper, it was important to obtain an answer to the question about the motives for purchasing organic food, using their division into three segments: attitude, social norms and perceived behavioural control. The purchase motives belonging to the first group included: caring for one's own and family's health, high-quality values of organic food, concern for the natural environment and trust in organic food. In the second group, there were two features: friends' opinions and trends for purchasing organic food. The third group of factors were: low availability of organic food, small range and high price (Al-Swidi et al., 2013; Scalco et al., 2017; Ruiz de Maya et al., 2011; Ünal et al., 2018).

To precisely explain the importance of supporting the local economy as a motive for purchasing organic food, the studied population was divided into two groups. The first group included those consumers who, when choosing the five most important motives for purchasing organic food from among a dozen, and prioritising their importance, chose to support the local economy as one of them. The second group included consumers for whom such a motive was not significant enough in buying organic food to be included among the top five. The use of such a grouping method not only made it possible to situate the position of supporting the local economy as a motive for buying organic food among the other motives but also provided an answer to the question of what the relevance of this motive is to each of the three segments described by the TPB. This approach also facilitated (at least indirectly) the assessment of the behaviour of organic food consumers motivated by supporting the local economy in the context of altruistic attitudes (when such a motive is strongly linked to concern for the natural environment) or selfish attitudes (when it shows a solid link to concern for health). In our study, this is also one of the measures indicating the role of reflexive localism as a motivating factor for supporting the local economy. Another measure used for this assessment is the percentage of consumers who mostly buy organic food directly from producers (selling at organic farms and markets) and in small neighbourhood shops (which are generally supplied by organic farmers, bypassing long supply chains).

In order to fully assess the attitudes of consumers motivated by supporting the local economy, an analysis narrowed down to this group was carried out in the further part of the study, providing an answer to the question about the links between this motive and others, especially a concern for the natural environment. It was assumed that consumers supporting the local economy

DOI: 10.34659/eis.2022.81.2.444

also recognise the need to protect the natural environment, which could indicate attitudes corresponding to the approach characteristic of reflexive localism.

The hypotheses assumed for verification in this study were that:

1. Consumers who treat the purchase of organic food as a form of supporting the local economy are, to a greater extent than others, motivated by concern for the natural environment;
2. Consumers purchasing organic food to support the local economy spend more money on organic food and buy more often because they appreciate its high quality;
3. Among consumers of organic food motivated by supporting the local economy, an attitude characteristic of reflexive localism prevails.

Justification for this hypothesis formulation is provided by recent research findings (Kushwah et al., 2019), based on a broad review of the literature, which shows that there is little work to date examining the links between organic food consumption and support for the local economy. The literature also suggests that strong relations between organic food producers and consumers, which are only possible at the local level, are an enhancing factor not only for organic food market development (Torjusen et al., 2001) but can contribute to improving the state of the natural environment and boosting rural development (Ditlevsen et al., 2020; Eagle et al., 2017). Since motives for purchasing organic food vary between countries and change over time (Essoussi & Zahaf, 2008), it is reasonable to study the specifics of consumer behaviour in the organic food market in different countries.

As the study is based on qualitative data (consumer opinions), Pearson's chi-squared test of independence and the non-parametric Mann-Whitney U test was used to achieve the stated objectives and verify the hypotheses.

Results of the research

Consumers and their socio-demographic characteristics play an important role in the development of the organic food market, as the demand for such food is growing rapidly (Dimitri & Oberholtzer, 2005; Pelletier et al., 2013). Table 1 shows the characteristics of two groups of respondents, i.e., those who support and those who do not support the local economy (respectively: 45% and 55% of respondents). Statistically significant differences between the identified groups due to the adopted characteristics were also indicated. Pearson's chi-squared test of independence was used to examine the differences. The study shows that the majority of consumers supporting the local economy are women (4% more than men), graduates of secondary schools and higher education institutions, and inhabitants of rural areas and small towns. However, the variation in this respect is small – there are no statistically significant differences.

Table 1. Characteristics of respondents are divided into those supporting and those not supporting the local economy (Pearson's chi-squared test of independence – *p<0.05)

Variables	Categories	Group I Support (n=437)	Group II No support (n=413)	P
Gender	Female	53%	47%	0.2930
	Male	49%	51%	
Education	Primary	35%	65%	0.2381
	Secondary	53%	47%	
	Higher	51%	49%	
Place of residence	Countryside	55%	45%	0.1813
	Town up to 10,000 inhabitants	65%	35%	
	Town between 10,000 and 19,900 inhabitants	47%	53%	
	Town between 20,000 and 49,900 inhabitants	51%	49%	
	Town between 50,000 and 99,900 inhabitants	51%	49%	
	Town with more than 100,000 inhabitants	47%	53%	
Professional activity	Wage work	51%	49%	0.4493
	Self-employed	53%	47%	
	Pensioner	44%	56%	
	Student	51%	49%	
	Unemployed	60%	40%	
Income per family member in EURO	Up to 175	51%	49%	0.0702*
	175-327	54%	46%	
	327-545	55%	45%	
	545-763	43%	57%	
	763 and more	46%	54%	
Age	($\bar{x}\pm\sigma$), Min; max	(38±13.6), 18;74.	(39±14.5), 18;75.	0.4666

Source: authors' work.

Consumers supporting and not supporting the local economy are differentiated by income per family member. In the first group, there is a slightly higher percentage of families with relatively low income, which indicates that for more affluent people supporting the local economy as a motive for purchasing organic food is less important.

Studies have shown that the most important motives for purchasing organic food include taking care of one's own and family's health, high quality and better taste of food, as well as concern for the natural environment. Therefore, health and environmental values play a key role in the food selection process. Caring for one's own and family's health as well as high quality and better taste of organic food were the top-rated motives by consumers for

DOI: 10.34659/eis.2022.81.2.444

purchasing such food. This is followed by concern for the natural environment. This motive for buying organic food, which is in line with the concept of sustainable development, is also an essential component of the first TPB segment. Support for the local economy, also belonging to this segment, was ranked fourth among the motives for purchasing organic food. The motives such as fashion and trends for buying organic food, which also belong to SN, were assigned minor importance and were not mentioned at all by the highest percentage of consumers surveyed (Figure 1 and Table 2).

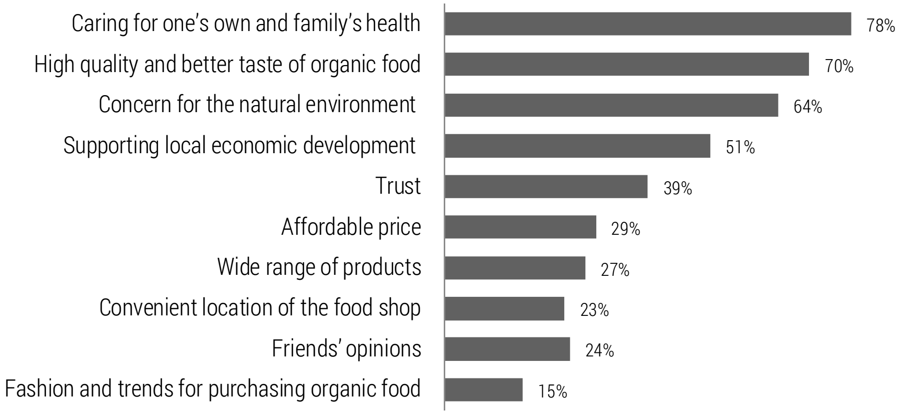

Figure 1. Motives for purchasing organic food (percentage of responses)
Source: authors' work.

Table 2. Supporting the local economy vs. other motives for purchasing organic food (Mann-Whitney U test results – *p<0.05; **p<0.001)

Motives	Group I Support (n=437)		Group II No support (n=413)		p-value*
		Me		Me	
Caring for one's own and family's health	2.99	4	3.03	4	0.5894
High quality and better taste of organic food	2.28	2	2.37	3	0.5661
Concern for the natural environment	2.06	2	1.82	2	0.0516*
Trust	0.76	0	1.30	0	0.0000*
Affordable price	0.52	0	1.07	0	0.0000*
Wide range of products	0.48	0	0.86	0	0.0000*
Convenient location of the food shop	0.51	0	0.76	0	0.0000*
Friends' opinions	0.35	0	0.85	0	0.0000*
Fashion and trends for purchasing organic food	0.25	0	0.50	0	0.0000*

Source: authors' work.

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The study showed that, apart from the two motives for purchasing organic food, i.e. caring for one's own and family's health as well as high quality and better taste of organic food, in the case of all the other motives analysed in the study, there are statistically significant differences between the two separated groups of consumers, i.e. supporting and not supporting the local economy (significance at the level of $p<0.001$, and in the case of concern for the natural environment $p<0.05$). Referring to the research assumptions adopted in the study and the answer to the question about the motives for buying organic food, using their division into three TPB segments, i.e., attitude, social norms and perceived behavioural control, it should be noted that with regard to the purchase motives belonging to the first segment, statistically significant differences occurred in the case of two of the four characteristics, i.e., concern for the natural environment and trust in organic food. Regarding the purchase motives belonging to the second segment, statistically, significant differences were found for features such as friends' opinions as well as fashion and trends for purchasing organic food. Regarding the purchase motives belonging to the third segment, statistically, significant differences were also found for features such as the availability of organic food and its range and price. It should be added that only concern for the natural environment – as a motive for purchasing organic food – is more associated with the group of consumers supporting the local economy. The other reasons, i.e., trust, affordable price, a wide range of products, convenient location of the food shop, friends' opinions as well as fashion and trends for such purchases, are more related to the group of consumers not supporting the local economy (Table 2).

The study showed that both consumers are supporting and not supporting the local economy list caring for their own and their family's health as the first motive for purchasing organic food, high quality and better taste of organic food as the second, and concern for the natural environment as the third. It should be added that the group of consumers supporting the local economy rated this last motive higher. Thus, it is more important to them, which confirms the first hypothesis posed in the paper, i.e. consumers treating organic food purchases as a form of supporting the local economy are more motivated by concern for the natural environment than the others. The group of consumers not supporting the local economy, on the other hand, gave higher ratings to such motives for purchasing organic food as trust, affordable price, a wide range of products, convenient shop location, friends' opinions as well as fashion and trends for such purchases (Table 2).

In addition, in order to verify the second research hypothesis, it was examined whether people who purchase organic food to support the local economy allocate more significant amounts of money to the purchase of organic food and whether they make such purchases more often because

DOI: 10.34659/eis.2022.81.2.444

they appreciate its high quality. However, the results of the Pearson's chi-squared test of independence showed that there is no statistically significant relationship either between the amount that the consumers surveyed spend on organic food or between the frequency of such purchases and the fact that they support the local economy (in the first case – $p>\alpha$, $p=0.8880$, and in the second case – $p>\alpha$, $p=0.9132$). Therefore, the conducted study did not confirm this hypothesis, so it should be rejected.

As the presented study shows, consumers of organic food motivated by supporting the local economy associate their purchasing decisions with concern for the natural environment protection more strongly than other consumers, which can be treated as a manifestation of care for the common good, and this, in turn, is a feature of the attitude characteristic of reflexive localism (Spillare, 2016).

In this context, the question of not only the presence of such behaviour among Polish consumers treating support for the local economy as a motive for purchasing organic food but also their socio-demographic characteristics is justified. In fact, the studies conducted in other countries show that consumers of such food do not treat the place of its production as an essential motive for purchase (Ham, 2019) or do not perceive a connection between organic food purchases and concern for the natural environment (Essoussi & Zahaf, 2008).

In this study, the group representing the attitude of 'reflexive localism' (RL) includes consumers supporting the local economy who – as a motive for purchasing organic food – listed concern for the natural environment as well (286 consumers). The remaining consumers declaring support for the local economy were included in the 'defensive localism' (DL) group (151 people). The results of the Pearson's chi-squared test of independence allowed us to conclude that the characteristics are significantly differentiating the two groups of consumers were: gender ($p<\alpha$, where $p=0.0042$), as women constituted 64% among those representing the RL attitude and 50% – in the DL group. Moreover, a characteristic feature of the RL group was a lower average age of consumers (37 years, while in the DL group – 40 years; $p=0.0382$), as well as a significantly higher percentage of students (12%, while in the DL group – 3%; $p=0.0376$), determining the difference in terms of professional activity. On this basis, it can be assumed that the results of the study confirmed the third hypothesis posed in the paper, assuming that among consumers of organic food motivated by supporting the local economy, an attitude characteristic of reflexive localism prevails.

However, no statistically significant differences were found in terms of education, place of residence and household income. There was also no difference when it came to the amount spent by the two groups on organic food. However, consumers with an attitude corresponding to the characteristics of

DOI: 10.34659/eis.2022.81.2.444

RL made purchases more frequently (42% made purchases several times a week compared to 31% in the DL group, while the percentage making purchases once a month was 14% for RL and 20% for DL). A significant difference in this respect is also evidenced by the p< α ratio, where p=0.0465.

In order to further determine the motives for purchasing organic food by consumers classified to the RL and DL groups, the Mann-Whitney U test was performed (Table 3).

Table 3. RL and DL attitudes and motives for purchasing organic food (Mann-Whitney U test results – *p<0.05; **p<0.001)

Motives	Attitude reflexive localism (n=286)		Attitude defensive localism (n=151)		p-value*
		Me		Me	
Caring for one's own and family's health	3.08	4	2.81	3	0.2018
High quality and better taste of organic food	2.37	3	2.11	2	0.1429
Supporting the development of the local economy	2.56	2	2.82	3	0.0472*
Trust	0.60	0	1.05	0	0.0003*
Affordable price	0.37	0	0.81	0	0.0000*
Wide range of products	0.35	0	0.73	0	0.0008*
Convenient location of the food shop	0.29	0	0.92	0	0.0000*
Friends' opinions	0.21	0	0.60	0	0.0004*
Fashion and trends for purchasing organic food	0.19	0	0.37	0	0.0166*

Source: authors' work.

The results of the Mann-Whitney U test give grounds for stating that regardless of the importance of the motive of concern for the natural environment to consumers of organic food, the most crucial reason is a concern for their own and their family's health (high average number of points for this motive in both groups on a 5-point scale). As can be seen from the data presented in Table 3, in the RL group, this is a much more important motive than supporting the local economy, while among DL consumers, both motives are rated similarly. Furthermore, consumers in the RL group rated the quality and taste of organic food slightly higher, but the differences between the two consumer groups were not significant in this respect. In both groups of consumers, the impact of the motives described by TPB as social norms was relatively weak, meaning that friends' opinions or fashion for organic food had little influence on purchasing decisions, with a completely marginal impact among RL consumers, especially against the background of motives classified in the attitude segment (health care, high-quality values, trust in organic food).

The study showed that consumers supporting the local economy tend to buy organic food either at the local market (bazaar) or at the supermarket, with this being slightly more relevant for consumers in the RL group. This is followed by a small neighbourhood shop or an organic farm (direct sale), but in the latter case, it especially concerns consumers from the DL group. On the other hand, a small percentage of consumers supporting the local economy purchase organic food in a hypermarket or via the Internet, whereas in the first case this is slightly more relevant for consumers in the RL group and in the second case for consumers in the DL group. Thus, there are no significant differences in terms of where organic food is purchased between consumers representing RL and DL attitudes, regardless of whether this place is the so-called 'local market' or a large retail chain, with a slight predominance of the second group in buying at the local market, including directly from organic farms (Figure 2).

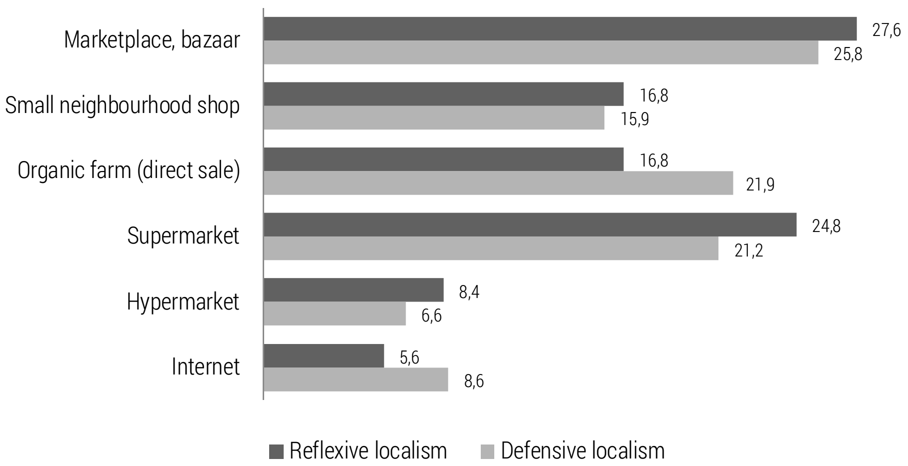

Figure 2. Place of purchasing organic food (percentage of responses)
Source: authors' work.

Thus, the presented findings support the thesis that not only the production of organic food itself is significant, but also, or perhaps above all, its processing and distribution, with direct farm sales being an essential part of the organic food distribution system. Direct sale is one of the activities related to the improvement of food quality and safety, thus having a direct impact not only on consumer health but also on supporting the local economy. It consists of the farms taking over the function of food processors and distributors, and its characteristic is shortening the route of food products between

DOI: 10.34659/eis.2022.81.2.444

farmers – organic food producers and their consumers (direct recipients), which is very important in the context of building closer and more durable mutual relations in order to not only better adjust the offer to the needs but also to reduce transport costs and thus contribute to the improvement of the natural environment protection.

Discussion

From the perspective of the EU Green Deal Strategy and determinants of sustainable development, including one of its important aspects, i.e. sustainable consumption, an important issue is the attachment of the consumer to the local product and thus to the development of the local market (Bio districts). Previous studies conducted in Poland show that consumers expressed different opinions about supporting local development through the production and marketing of organic food produced close to where they live (Nesterowicz et al., 2016; Grzybowska-Brzezińska & Grzywińska-Rąpca, 2018). Similarly, a study by Bryła (2016) among 1000 consumers in Poland shows that the most important motives for buying organic food are health properties and taste values. A lesser role is played by concern for local producers, sustainable development and identification of products with the area of their origin. All this indicates that the characteristics of organic food consumers in Poland are close to attitudes described as defensive localism, which is not confirmed by the results of our study. This may be a sign of the evolving attitudes of Polish organic food consumers in recent years.

Comparing the results of our own study with those of other authors, it can be seen that among the motives for buying organic food, consumers list health concerns in the first place. In Canada, 89% of consumers associate the choice of organic food with respect for proper nutrition and health. French consumers who buy organic food also perceive it as better for their health and the environment. Among 566 Dutch consumers of organic food, 85% indicated health, 73% environment, 65% animal welfare and taste as motives for choosing organic food (Kesse-Guyot et al., 2013). Health and quality considerations for organic food are the main motive for consumer purchases in Denmark (Hjelmar, 2011). Similarly, Polish consumers mainly justify their choice of organic food by caring for their health and by being convinced of the absence of harmful substances (Nesterowicz et al., 2016).

The results of the presented study give reason to conclude that no matter how strongly some consumers of organic food are motivated to purchase it to support the local economy or to improve the natural environment, the most crucial motive for purchase remains to care for their own and their family's health. In this context, it should be noted that the results of the study do not

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provide a basis for concluding that some consumers tend to have selfish attitudes (caring for their own health) and others altruistic attitudes (caring for the natural environment) because no matter what division was applied among consumers (supporting or not supporting the local economy; motivated by caring for the natural environment or not mentioning this motive) the primary motive for buying organic food remained caring for one's own health. In this respect, the results of this study are consistent with the conclusions formulated by other authors (Essoussi & Zahaf, 2008; Wägeli & Hamm, 2016; Krishnakumare & Niranjan, 2017; Mulder & Liu, 2017).

The study results show a high percentage of consumers motivated by supporting the local economy (51%), of whom as many as 65% listed concern for the natural environment as one of the five most important motives for buying organic food. Thus, this was the group of consumers who perceive not only personal benefits from the purchase of such food but treat such decisions as contributing to the protection of the natural environment, and such a motive is beyond the interests of the local environment. All this means that the attitude characterised by RL is quite common among the surveyed consumers of organic food in Poland and differs from the behaviour of consumers of such food in the USA, where – according to the study by Thomas and Gunden (2012) – consumers do not associate the purchase of organic food with caring for the natural environment or supporting the local economy. In contrast, consumers in Denmark perceive a link between organic food production and improving the state of the natural environment. Still, they are not guided in their purchasing decisions by the need to support the local economy (Ditlevsen et al., 2020).

Studies also confirm the variation in motives for buying organic food between countries in Europe by other authors (Bojnec et al., 2019; Thøgersen, 2009; Ruiz de Maya et al., 2011). Cultural factors that motivate consumers in some countries to buy local organic products are cited as one of the reasons (Govindasamy et al., 2010; Thomas & Gunden, 2012; Saraiva et al., 2018).

However, this raises the question of more precisely defined reasons for the different motives of consumers to buy organic food in different countries.

Conclusions

Supporting the local economy turns out to be an important motive for buying organic food by consumers in Poland. Although it is not the most important motive, as care for one's own and family's health remains the most important motive in various countries in the world, most of the surveyed consumers treat this motive as a factor significantly influencing their purchasing decisions. Consumers motivated by supporting the local economy

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have similar socio-demographic characteristics as other consumers, which means that this motive is not very related to consumers' age, education level or place of residence.

However, statistically, significant differences were visible between the two groups of consumers in terms of the importance of motives for buying organic food (with the exception of health care and assessment of food quality values), consumers declaring support for the local economy generally stressed the importance of caring for the natural environment. Their purchasing decisions were less likely to be motivated by a wide range of products, an affordable price, or a convenient location of the shop. Motives classified as social norms, i.e. fashion and friends' opinions, were much less important for this group of consumers. This can be seen as an argument demonstrating the lasting attachment of these consumers to buying organic food, built on their own knowledge of the benefits of this type of behaviour.

A more detailed analysis of the motives for purchasing organic food by consumers declaring support for the local economy showed that the reason significantly differentiates this group is the perception of such purchases in the context of concern for the natural environment. Most consumers listed both motives simultaneously, which may indicate that they perceive the purchase of organic food as benefiting not only the consumers themselves and their local community but also in a supra-local context (care for the natural environment as a common good). This is an attitude characteristic of reflexive localism.

There was also a large group of consumers for whom supporting the local economy was not associated with concern for the natural environment. This may indicate that in their purchasing decisions, they are guided by selfish motives described in the literature, which is characteristic of defensive localism (interest in their local environment and perceiving the external environment as a competitor posing a threat to the closed local group).

Further research on this issue should be directed towards analysing questions related to, but not limited to, explaining the motives driving consumers to RL-specific behaviour and limiting DL-specific behaviour.

An important limitation of this study is only a preliminary recognition of the issue concerned. It seems justified to focus further research on the issue of social relations between local producers and consumers of organic food, aiming to shorten supply chains and contribute – by reducing transport costs – to the improvement of the natural environment protection. Another critical aspect of future research in the context of the importance of RL among organic food consumers is the search for an answer to the question of the actual scale of openness of organic food consumers, motivated by supporting the local economy, to external markets offering food not produced in the local environment. Such openness would mean an acceptance of the need to

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develop not only 'my' local economy but anywhere in the world because only then it is possible to achieve the full benefits of the development of the organic food market.

The contribution of the authors

Adam Czudec: conception – 40%, literature review 80%, writing – 40%, analysis and interpretation of data – 40%, conclusions – 40%.

Teresa Miś: conception – 30%, literature review 10%, writing – 30%, analysis and interpretation of data – 30%, conclusions – 30%.

Dariusz Zając: conception – 30%, literature review 10%, writing – 30%, analysis and interpretation of data – 30%, conclusions – 30%.

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SUMMARIES IN POLISH

Danuta SZPILKO, Joanna EJDYS

EUROPEJSKI ZIELONY ŁAD – KIERUNKI BADAŃ NAUKOWYCH. SYSTEMATYCZNY PRZEGLĄD LITERATURY

STRESZCZENIE: Celem artykułu jest próba klasyfikacji badań naukowych odnoszących się do problematyki Europejskiego Zielonego Ładu (EGD), ocena ich zgodności z obszarami wskazanymi w dokumencie strategicznym EGD oraz identyfikacja pojawiających się kierunków badań. Na potrzeby badań zastosowano systematyczny przegląd literatury, oparty na analizie bibliometrycznej publikacji zawartych w dwóch bazach Scopus i Web of Science. Celem systematycznego przeglądu literatury jest identyfikacja, integracja i ocena badań, dotyczących wybranej tematyki, na podstawie jasno zdefiniowanych kryteriów. Kryteria wyszukiwania uwzględniały [TITLE-ABS-KEY ("EU" OR europ*) AND TITLE-ABS-KEY ("green deal")] w przypadku bazy Scopus oraz TS = [("EU" OR europ*) AND ("green deal")] w odniesieniu do bazy Web of Science database. Na potrzeby analiza zakwalifikowano 641 rekordów publikacyjnych. Przeprowadzona analiza bibliometryczna pozwoliła na wyodrębnienie ośmiu klastrów tematycznych i powiązanie ich z ośmioma założeniami (elementami), na których opiera się European Green Deal. Analiza bibliometryczna pozwoliła na wyodrębnienie ośmiu obszarów tematycznych międzynarodowych badań podejmowanych w związku z Europejskim Zielonym Ładem. Obejmują one różnorodne zagadnienia z zakresu nauk społecznych, inżynierii, rolnictwa, nauk ścisłych i przyrodniczych. Klastry obejmowały: energia, gospodarka cyrkularna, przemysł, budownictwo, mobilność, żywność, różnorodność biologiczna i zanieczyszczenie środowiska.

SŁOWA KLUCZOWE: Europejski Zielony Ład, energia, inteligentna zrównoważona mobilność, gospodarka cyrkularna, bioróżnorodność, żywność, zanieczyszczenia

Dorota JELONEK, Dorota WALENTEK

EGZEMPLIFIKACJA KONCEPCJI ZERO WASTE W SMART CITIES

STRESZCZENIE: W obliczu zachwianej równowagi środowiskowej naszej planety koncepcja zero waste z dnia na dzień zyskuje na znaczeniu. Szczególnie ważna jest ona w aspekcie zarządzania cyklem produkcyjno-konsumpcyjnym oraz odpowiedzialnego gospodarowania odpadami w przestrzeni miejskiej. Celem niniejszego artykułu jest egzemplifikacja metod ograniczenia ilości odpadów w smart cities zgodnych z autorskim schematem Zarządzanie Odpadami dla pokoleń, przyrody i zysków (ZO2PPZ). W pozyskiwaniu danych wykorzystano metodę wywiadu ustrukturyzowanego, zaś próbę badawczą wyselekcjonowano korzystając z Smart City Index 2020. Badanie pozwoliło na identyfikację przyjaznych środowisku i społeczeństwu oraz korzystnych z ekonomicznego punktu widzenia metod racjonalnego gospodarowania odpadami, takich jak np. kompostowanie odpadów organicznych, tworzenie podziemnych kontenerów na śmieci oraz spalanie odpadów z odzyskiem energii. Przedstawiono także konkretne sposoby ograniczenia ilości odpadów, takie jak między innymi zakaz korzystania z opakowań jednorazowych oraz pozyskiwanie energii ze źródeł odnawialnych.

SŁOWA KLUCZOWE: zero waste, zarządzanie odpadami, smart cities

Paulina BASIŃSKA, Edyta TOMCZYK

REWITALIZACJA A POLITYKA ZRÓWNOWAŻONEGO ROZWOJU – PRÓBA OCENY ZRÓWNOWAŻONEGO CHARAKTERU PROCESÓW REWITALIZACJI W POLSCE

STRESZCZENIE: Badanie wykonane na potrzeby artykułu dotyczy próby oceny stopnia osiągniętego zrównoważonego rozwoju w prowadzonych w Polsce procesach rewitalizacji. Badaniu poddano programy rewitalizacji uchwalone w miastach na prawach powiatu, w których jednocześnie cyklicznie prowadzi się monitorowanie tego procesu. Na podstawie analizy i interpretacji tych dokumentów – w oparciu o stworzoną na potrzeby badania metodologię – oceniono prowadzone procesy w kontekście zasad zrównoważonego rozwoju. Celem artykułu jest odpowiedź na pytania: (1) na ile zrealizowane projekty wpisują się w ten paradygmat, (2) w jakiej mierze przyczyniają się do jego osiągnięcia, a także (3), bardziej ogólnie, jak badać zagadnienie zrównoważonego rozwoju w procesach rewitalizacji – jest to bowiem pierwsze tego typu badanie w Polsce. Wyniki badania, świadczące o jak na razie małym zaawansowaniu i niezbyt harmonijnym prowadzeniu działań, powinny skłaniać do dalszych, bardziej pogłębionych badań na ten temat.

SŁOWA KLUCZOWE: rewitalizacja miast, rewitalizacja, zrównoważony rozwój, polityka rozwoju

Katarzyna SPADŁO, Emilia GROTOWSKA

METODY ZRÓWNOWAŻONEGO ZARZĄDZANIA PRZESTRZENIĄ W PROCESACH REWITALIZACJI – ANALIZA PORÓWNAWCZA NARZĘDZI URBANISTYKI OPERACYJNEJ STOSOWANYCH W PRAKTYCE POLSKICH MIAST

STRESZCZENIE: Artykuł podejmuje próbę analizy instrumentów urbanistyki operacyjnej stosowanych do zarządzania przestrzenią w procesach rewitalizacji prowadzonych na terenach miejskich. Analizie porównawczej poddano dokumenty planistyczne opracowywane na potrzeby wdrażania polityki rewitalizacyjnej: koncepcje urbanistyczne oraz miejscowe plany rewitalizacji. Instrumenty te zestawiono z master planami, wykorzystywanymi powszechnie w praktyce rewitalizacyjnej miast niemieckich, a także w doświadczeniach miast polskich. W artykule został przedstawiony mechanizm wpływu narzędzi urbanistyki operacyjnej na zakres i charakter procesu rewitalizacji. Ocenie została poddana skala tego wpływu, z punktu widzenia tempa realizacji celów zrównoważonego rozwoju na miejskich obszarach zdegradowanych.

SŁOWA KLUCZOWE: zrównoważony rozwój, modele planowania, polityka planowania

Mariusz KUDEŁKO

CZY UNIJNE RGULACJE ŚRODOWISKOWE SĄ ZGODNE Z KONCEPCJĄ INTERNALIZACJI KOSZTÓW ZEWNĘTRZNYCH – STUDIUM PRZYPADKU DLA POLSKIEGO SEKTORA ELEKTROENERGETYCZNEGO

STRESZCZENIE: Celem artykułu jest zbadanie, czy istniejące unijne regulacje środowiskowe wdrażane w polskim sektorze elektroenergetycznym są zgodne z koncepcją internalizacji kosztów zewnętrznych. Narzędziem wykorzystywanym w badaniach jest model równowagi cząstkowej, umożliwiający planowanie rozwoju polskiego sektora elektroenergetycznego. Analizowane były dwa scenariusze. Pierwszy scenariusz "bazowy" zakłada stopniową ndekarbonizację polskiego sektora energetycznego. W scenariuszu "int" struktura produkcji energii jest wynikiem internalizacji kosztów zewnętrznych. Zmiany strukturalne w scenariuszu "bazowym" stanowią duże wyzwanie. Elektrownie węglowe będą drastycznie wycofywane i zastępowane przez technologie odnawialne i energię jądrową. Polityka klimatyczna prowadząca do stopniowej redukcji emisji CO_2 w Polsce ma sens przy założeniu znacznie wyższych kosztów zewnętrznych emisji CO_2 (65 €/Mg CO_2) niż przyjętych w niniejszym artykule.

SŁOWA KLUCZOWE: sector energetyczny, koszty zewnętrzne, miks energetyczny, model

Malwina LEMKOWSKA, Dorota WIŚNIEWSKA

UBEZPIECZENIA ŚRODOWISKOWE A SYSTEMY ZARZĄDZANIA ŚRODOWISKOWEGO ISO 14001 – ANALIZA SKŁONNOŚCI DO WDRAŻANIA ISTOTNYCH UBEZPIECZENIOWO ROZWIĄZAŃ SYSTEMOWYCH

STRESZCZENIE: Pierwszym celem badania była ocena zależności pomiędzy skłonnością decydentów organizacji zarządzanych według ISO 14001 do wdrożenia istotnych ubezpieczeniowo rozwiązań systemowych a atrybutami tej organizacji (systemowymi, świadomościowymi i organizacyjnymi). Drugim celem była identyfikacja motywatorów, które skłaniają decydentów do wdrożenia dodatkowych elementów systemu. Wcześniejsze badania sugerują konieczność zmodyfikowania struktury obecnie wdrożonych SZŚ według ISO 14001 w celu zwiększenia ich przydatności dla procesu świadczenia ochrony ubezpieczeniowej. Problem badawczy rozwiązano w oparciu o dane pozyskane w drodze ankiety zrealizowanej online wśród organizacji, które wdrożyły i certyfikowały SZŚ ISO 14001 w Polsce. W zależności od rodzaju zmiennych do analizy wykorzystano m.in. test niezależności chi-kwadrat, test U-Manna-Whitneya, współczynnik korelacji rang Spearmana. Wyniki badań mogą być przydatne do budowania zintegrowanych narzędzi zarządzania ryzykiem środowiskowym. Wskazują na zasadność stosowania pozaubezpieczeniowych motywatorów (np. obniżenie opłat z tytułu korzystania ze środowiska) w celu osiągnięcia pożądanej – z punktu widzenia ubezpieczycieli – struktury SZŚ w organizacji. Jednocześnie akcentują konieczność budowania świadomości ryzyka środowiskowego (w tym m.in. ryzyka odpowiedzialności za szkody środowiskowe, ciężaru tej odpowiedzialności) dla osiągnięcia powyższego.

SŁOWA KLUCZOWE: ubezpieczenia środowiskowe, system zarządzania środowiskowego ISO 14001

Edyta SIDORCZUK-PIETRASZKO, Anna MATEL, Tomasz POSKROBKO,
Dariusz ANDREJUK

JAK WIDOK LASU ODDZIAŁUJE NA GOTOWOŚĆ DO ZAPŁATY ZA JEGO ZACHOWANIE WŚRÓD UŻYTKOWNIKÓW I NIEUŻYTKOWNIKÓW W METODZIE WYCENY WARUNKOWEJ?

STRESZCZENIE: W badaniach metodą wyceny warunkowej użytkownicy zazwyczaj deklarują gotowość do zapłaty (willingness to pay, WTP) wyższą niż nieużytkownicy. W niniejszym opracowaniu podjęto próbę zbadania, czy widok wycenianego dobra w czasie badania oddziałuje jednakowo na użytkowników i nieużytkowników. Przeprowadzono eksperyment terenowy, w którym użytkownicy i nieużytkownicy byli badani w dwóch lokalizacjach – jednej z widokiem na las, a drugiej bez niego. Badanie pokazało, że WTP użytkowników było znacząco wyższe niż nieużytkowników jedynie wtedy, kiedy respondenci nie widzieli lasu w czasie badania. Jednakże, gdy badanie zostało przeprowadzone w miejscu, gdzie respondenci widzieli las – różnica ta zniknęła. Wyniki wskazują również, że związek między deklarowaną WTP a statusem społeczno-demograficznym respondentów oraz ich postawami ekologicznymi był słabszy wśród respondentów badanych w miejscu z widokiem na las. Sądzimy, że wzrost WTP osób nie korzystających z lasu jest przejściowy i stanowi pewnego rodzaju błąd poznawczy. To z kolei może mieć znaczenie w projektowaniu badań CVM.

SŁOWA KLUCZOWE: metoda wyceny warunkowej, wycena lasu, gotowość do zapłaty, status użytkownika, widok dobra

Karol KOCISZEWSKI

PERSPEKTYWY ROZWOJU POLSKIEGO ROLNICTWA EKOLOGICZNEGO W ASPEKCIE EUROPEJSKIEGO ZIELONEGO ŁADU

STRESZCZENIE: Celem artykułu jest określenie uwarunkowań rozwoju rolnictwa ekologicznego w Polsce w warunkach członkostwa w Unii Europejskiej (UE). Badania opierały się na analizach źródeł wtórnych oraz na ogólnopolskim badaniu wśród rolników ekologicznych. Rolnictwo ekologiczne w UE podlega rozwojowi pod wpływem strategii związanych z Europejskim Zielonym Ładem. Polskie rolnictwo ekologiczne rozwijało się dynamicznie po przystąpieniu do UE, jednak proces ten odwrócił się od 2013 roku ze względu na niestabilną krajową politykę wsparcia. Barierami są słabe połączenia między rolnikami i dystrybutorami, procedury biurokratyczne i niska rentowność. Istotną szansą na rozwój jest oczekiwany wzrost popytu. Najważniejsze czynniki zachęcające rolników związane były z aspektami środowiskowymi i wykorzystaniem siły roboczej. Dalszy rozwój uwarunkowany jest lepiej zorganizowaną polityką polskich organizacji zaangażowanych w politykę rolną.

SŁOWA KLUCZOWE: rolnictwo zrównoważone; rolnictwo ekologiczne; rynki produktów ekologicznych

Katarzyna SMĘDZIK-AMBROŻY, Sebastian STĘPIEŃ, Anna MATUSZCZAK, Aleksandra TOSOVIC-STEVANOVIC

DROBNOTOWAROWE GOSPODARSTWA ROLNE W ZRÓWNOWAŻENIU ŚRODOWISKOWYM OBSZARÓW WIEJSKICH. OPINIE ROLNIKÓW Z POLSKI, RUMUNII I LITWY

STRESZCZENIE: Celem artykułu jest ocena zrównoważenia środowiskowego w rolnictwie drobnotowarowym. Autorzy starali się poznać subiektywne opinii rolników, ich sposób myślenia, postawy i determinanty działań środowiskowych. Zastosowanie wywiadów pogłębionych było szansą na wyciągnięcie rzetelnych i trafnych wniosków oraz zarejestrowanie wielu elementów, które mogłyby zostać pominięte przy zastosowaniu metod ilościowych. Tym samym praca stanowi komplementarną część badań nad zrównoważonym rozwojem gospodarstw drobnotowarowych, co jest jej główną wartością dodaną publikacji. Ponadto, wykorzystanie danych z trzech państw członkowskich UE – Polski, Rumunii i Litwy – dało podstawę do analizy porównawczej. Wnioski dowodzą, że małe gospodarstwa rolne pełnią ważne funkcje środowiskowe na obszarach wiejskich. Wynika to z samej istoty tego typu gospodarstw, opartej na kultywowaniu tradycji i doświadczeń przekazywanych z pokolenia na pokolenie, a także z rodzinnego charakteru tych jednostek.

SŁOWA KLUCZOWE: gospodarstwa drobnotowarowe, środowisko, zrównoważenie, wywiady, opinie producentów

Artur ZAJKOWSKI, Łukasz WYSOCKI, Piotr TUZ, Izabela BARTKOWSKA, Wojciech KRUSZYŃSKI

WYKORZYSTANIE MODELU HYDRAULICZNEGO W REDUKCJI RZECZYWISTYCH STRAT WODY ORAZ REDUKCJA KOSZTÓW EKSPLOATACJI SIECI WODOCIĄGOWEJ

STRESZCZENIE: Większość małych przedsiębiorstw wodociągowych boryka się z problemamibudżetowymi. Mogą mieć one wiele źródeł – obłsuga niewielkiej ilości odbiorców, wysoki poziom strat, konieczność zakupu wody z zewnętrznych źródeł. Czynniki te sprawiają, że wymagane nakłady na modernizacje sieci niejednokrotnie przewyższają możliwości finansowe przedsiębiorstwa. Jednym ze sposobów redukcji rzeczywistych strat wody jest obniżenie średniego ciśnienia w sieci. Dzięki nowym metodom obliczeniowym i symulacjom komputerowym dobór urządzeń redukujących ciśnienie i wybór lokalizacji ich montażu są znacznie ułatwione. W pracy skupiono się na ocenie możliwości wykorzystania modelowania komputerowego podczas wdrażania systemu zarządzania ciśnieniem w sieci wodociągowej.

SŁOWA KLUCZOWE: modelowanie hydrauliczne, straty wody, wycieki, koszt eksploatacji, redukcja strat

Izabela BARTKOWSKA, Dariusz WAWRENTOWICZ, Lech DZIENIS

ANALIZA KONCEPCJI AEROBOWEGO ORAZ ANAEROBOWEGO UNIESZKODLIWIANIA OSADÓW ŚCIEKOWYCH

STRESZCZENIE: Celem artykułu była analiza koncepcji modernizacji gospodarki osadowej opracowanych dla przykładowej oczyszczalni ścieków. Omówiono cztery warianty rozwiązań, oparte na różnych procesach, tlenowych, beztlenowych czy tlenowo-beztlenowych. W artykule przedstawiono charakterystykę istotnych elementów proponowanych rozwiązań. Wyeksponowane zostały parametry techniczno-technologiczne każdego z wariantów. Zaprezentowano przewidywane nakłady inwestycyjne i podstawowe koszty eksploatacyjne. Wykonana została również analiza efektywności kosztowej wariantów.Analizowane procesy technologiczne zapewniają otrzymywanie bezpiecznych pod względem higieniczno-sanitarnym produktów końcowych. W znacznym stopniu przyczyniają się do minimalizacji ilości osadów ściekowych. Najbardziej efektywnym pod względem ekonomicznym, charakteryzującym się najniższymi średniorocznymi kosztami, jest wariant z zastosowaniem beztlenowej termofilowo-mezofilowej stabilizacji osadów. Najwyższe średnioroczne koszty uzyskano w przypadku wariantu z suszeniem i spalaniem osadów.

SŁOWA KLUCZOWE: osady ściekowe, przetwarzanie osadów ściekowych, zagospodarowanie osadów ściekowych, nakłady inwestycyjne, koszty eksploatacyjne

Waldemar KOZŁOWSKI

ROZWÓJ INSTRUMENTÓW POLITYKI EKOLOGICZNEJ GMIN DOTYCZĄCYCH ODNAWIALNYCH ŹRÓDEŁ ENERGII

STRESZCZENIE: Wzrost udziału energii odnawialnej w całkowitym zużyciu energii jest jednym z priorytetów Unii Europejskiej. Polska powinna była osiągnąć poziom 21% energetyki odnawialnej do 2030 r. Problemy badawcze omówione w artykule: brak badań w gminach dotyczących kompleksowej oceny niewykorzystanych zasobów energii z OZE; brak analiz dotyczących kosztów pozyskania i wykorzystania energii ze źródeł odnawialnych, brak jasnej wizji gmin jako podmiotów w polityce klimatyczno-energetycznej. Biorąc pod uwagę te problemy badawcze, w artykule dokonano analizy stosowanych przez gminy instrumentów wsparcia wytwarzania energii ze źródeł odnawialnych. Badaniem objęto sto gmin w województwie warmińsko-mazurskim. W kontekście metodologicznym można postawić następującą hipotezę: poziom wykorzystania energii odnawialnej w gminie zależy od dużej ilości podejmowania działań i działań i inicjatywy.

SŁOWA KLUCZOWE: rozwój, energia odnawialna, gmina, instrumenty

Robert GRYGO, Kevin BUJNAROWSKI, Jolanta Anna PRUSIEL

ANALIZA MOŻLIWOŚCI WYKORZYSTANIA PLASTIKOWYCH ODPADÓW POPRODUKCYJNYCH W BUDOWNICTWIE

STRESZCZENIE: W artykule przedstawiono możliwość zagospodarowania plastikowych odpadów poprodukcyjnych, tj. folii zwykłej oraz termokurczliwej, w sektorze budowlanym. W tym celu wyprodukowano według własnej technologii dwa rodzaje kruszywa lekkiego o frakcji 16 mm z tworzyw sztucznych, tj. politereftalan etylenu (PET) oraz mieszanki tworzyw PET/PVC/OPS (MIX). Surowiec pochodził z odpadów poprodukcyjnych wytwarzanych podczas produkcji etykiet w postaci folii. Omówiono wyniki badań doświadczalnych właściwości kruszyw z recyklingu tworzywa sztucznego (gęstość nasypowa, gęstość ziarn, nasiąkliwość, wytrzymałość na miażdżenie). W artykule porównano właściwości fizyczne i mechaniczne wytworzonych kruszyw sztucznych i znanych kruszyw lekkich (Certyd i Keramzyt) stosowanych w budownictwie. Ponadto przeanalizowano efektywność finansową produkcji kruszywa lekkiego z surowców ubocznych produkcji etykiet plastikowych. Analiza ekonomiczna wykazała, że wykorzystanie odpadów z tworzyw sztucznych do produkcji kruszywa lekkiego jest racjonalne nie tylko ze względu na ochronę środowiska, ale również przynosi korzyści finansowe dla firm wytwarzających znaczne ilości odpadów plastikowych.

SŁOWA KLUCZOWE: kruszywo z odpadów PET, recykling, lekkie kruszywa sztuczne, analiza ekonomiczna

Anna BRZOZOWSKA, Justyna ŁUKOMSKA-SZAREK, Justyna IMIOŁCZYK-SEPCZUK

ŚRODOWISKOWE DETERMINANTY ZRÓWNOWAŻONEGO ROZWOJU W PROCESIE ZARZĄDZANIA GMINAMI MIEJSKIMI NA PRZYKŁADZIE WOJEWÓDZTWA MAŁOPOLSKIEGO

STRESZCZENIE: W dobie zmian klimatycznych, narastających negatywnych czynników rozwoju aglomeracji miejskich na środowisko implementacja zasad zrównoważonego rozwoju w procesie zarządzania gminami miejskimi nabiera coraz większego znaczenia. Trzy obszary zrównoważonego rozwoju: społeczny, gospodarczy i środowiskowy stanowią istotny zakres eksploracji badań naukowych na przestrzeni ostatnich lat. W niniejszym opracowaniu skoncentrowano się przede wszystkim na determinantach środowiskowych zrównoważonego rozwoju. Badaniu poddano 6 wskaźników środowiskowych, ekonomicznych i społecznych zrównoważonego rozwoju dla 14 gmin miejskich zlokalizowanych w województwie małopolskim. Ocenie poddano tylko wybraną grupę wskaźników ze wskazanych obszarów ze względu na ograniczoną dostępność danych. Z badanych obszarów silną korelację według współczynnika rang Spearmana wykazywały w większości miary z obszaru socjalnego i ekonomicznego. W oparciu o zebrany materiał badawczy opracowano benchmarking dla ocenianych jednostek, wskazując, że miasto Kraków na przestrzeni lat 2014-2019 generowało średnio najwyższą lokatę w rankingu w zakresie analizowanych miar gmin miejskich województwa małopolskiego.

SŁOWA KLUCZOWE: środowisko, czynniki zrównoważonego rozwoju, zarządzanie, gminy

Adam CZUDEC, Teresa MIŚ, Dariusz ZAJĄC

WSPIERANIE ROZWOJU LOKALNEJ GOSPODARKI JAKO MOTYW ZAKUPU ŻYWNOŚCI EKOLOGICZNEJ

STRESZCZENIE: Celem pracy jest ocena znaczenia zakupów żywności ekologicznej przez konsumentów w Polsce – motywowanych wspieraniem lokalnej gospodarki – na tle innych czynników kształtujących zachowania konsumentów. Materiał empiryczny stanowią wyniki badań ankietowych wśród 850 konsumentów żywności ekologicznej w Polsce. Analizę materiału empirycznego przeprowadzono z wykorzystaniem testu niezależności chi-kwadrat Pearsona i testu nieparametrycznego U-Manna-Whitneya. Z badań wynika, że dla dużej grupy konsumentów żywności ekologicznej wspieranie lokalnej gospodarki okazuje się ważnym motywem jej zakupu. Jedynym czynnikiem znacząco różnicującym obie grupy konsumentów (motywowani bądź nie wspieraniem lokalnej gospodarki), był poziom dochodów rodziny. Badania pozwoliły stwierdzić, że wśród konsumentów motywowanych wspieraniem lokalnej gospodarki dominują postawy określane jako reflexive localism (motyw wspierania lokalnej gospodarki powiązany z dbałością o środowisko przyrodnicze). Niezależnie jednak od tego jak ważne znaczenie w podejmowaniu decyzji o zakupie żywności ekologicznej miały oba z wymienionych motywów, najważniejszym motywem pozostawała troska o zdrowie, natomiast marginalne oddziaływanie miały moda i opinie znajomych.

SŁOWA KLUCZOWE: żywność ekologiczna, motywy zakupu, wspieranie lokalnej gospodarki, reflexive localism, defensive localism

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