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THEORETICAL AND METHODOLOGICAL PROBLEMS

Magdalena DĄBROWSKA • Anetta ZIELIŃSKA •
Grygorii MONASTYRSKYI • Mariola DROZDA

REDUCING FOOD WASTE AS A BASE OF INNOVATIVE LEAN SOCIETY PHILOSOPHY

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ABSTRACT: Due to the high level of losses and food waste nowadays, the problem become global. The main causes of food loss in households are: exceeding shelf life, excessive purchases, damage and low quality, additionally excessive portions of meals, wrong food storage, the bad taste of the product, lack of idea on how to use available ingredients, as well as reckless purchases, too large packaging. Negative effects of food loss can be grouped into three areas: environmental, economic and social, which are consistent with the basic goals of sustainable development. The aim of this article is to present an original proposal for an approach to Lean Society philosophy with respect to the problem of food loss. The authors reviewed conventional and unconventional methods of food preservation, identification of available and innovative solutions in terms of reducing food loss and indicated directions and opportunities for reducing food loss on the basis of Lean Society philosophy.

KEYWORDS: reducing food waste, Lean Society, conventional and unconventional methods of food preserving, rational food management, prevention

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The entire love of the world will not help
if there is not any food on the table.
Diane Chamberlain

Introduction

Food is the foundation of human existence and survival. The need to eat always accompanies man at every stage of his/her life and development. Food issues are very important, as indicated by their position in Maslow's hierarchy of needs. Maslow (2004) prioritised the needs and placed the need of eating in the group of physiological needs, which, if not satisfied, will predominate over all other needs and they will determine not only human survival but also his/her behaviour. Apart from food, Maslow (2004) included the need for drinking, breathing, sleeping, avoiding cold and heat or sex to physiological needs. Giving the needs of eating first degree in his hierarchy, he attributed them very important status with regard to human functioning (Forsyth & Tatar, 2004; Maslow, 1990; Miler-Zawodniak, 2012; Stelmach, 2008).

Max-Neef et al. (1991) distinguished nine groups of needs, and they included food to needs of keeping alive, which are first-order needs (Table 1).

Due to high level of losses and food waste nowadays, the problem become global. This phenomenon occurs throughout the food chain, from the production process to the consumption (Marszałek, 2018). Unfortunately there is a lack of harmonised definition of food loss and with respect to this phenomenon the name food waste was applied (Sokołowski, 2020); hence, in 2012 European Parliament (EP) proposed that food loss is „food products discarded from the agri-food chain because of economic or esthetic reasons or close to expiry date, which can be still eaten and can be consumed by people and which because lack of an alternative way of use is intended for destruction and disposal, what causes negative spill-over effects taking into consideration their influence on the environment, economic costs and loss of revenue for businesses" (Resolution, 2012).

There are many sources of food loss. They vary and depend on many factors. The main factors which determine food loss are place in the agri-food chain, the type of industry or the economic situation of the country where the presented phenomenon occurs (Kwasek, 2016).

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Table 1. Taxonomy of human needs

The need	Existence, being (qualities)	Possession (things)	Activities (actions)	Environment, system (interactions, communication, cooperation)
Keeping alive, existence	Physical and mental health	Food, shelter, work	Food, dressing, rest, work	Living environment, social, surrounding
Protection, safety	Care, adaptability – ability to adatp, autonomy	Social care, health care, work	Cooperation, planning, taking care over someone, something, help	Social environment, residential environment
Love, devotion	Respect, sense of humour, nobility, generosity, sensuality	Friendship, family, relations to nature	Sharing, caring, loving, expressing emotions	Personal space (intimate), privacy, sense of community
Comprehension, understanding	Ability to think critically, curiosity, intuition	Literature, teaching, politics, education	Analysis, studying, mediation, following	Schools, families, universities, communities
Involvement, paticipation	Openess, sensitivity,dedication, sense of humour	Responsibility, duties, work, rights	Cooperation, objection, expressing opinions	Associations, parties, churches, neighbourhood
Leisuretime, relax	Imagination, calm, spontaneity	Entertainments, meetings, peace of mind	Day-dreaming, remembering, relax, having fun	Landscape, personal spaces (intimate), places of solitary stay
Creativity, creation	Imagination, clarity, invention, curiosity	Skills, abilities, work, techniques, methods of action	Searching, building, designing, work, composing, arrangement, interpreting	Space of the expression, workshops, public meetings
Identity, identification	Sense of belonging, self-esteem, stability	Language, religion, work, customs, values, standards	Self-awareness, development, engaging	Places of our commitment, daily environment, systems
Freedom	Autonomy, passions, self-esteem, lack of prejudices	Equal rights	Various views, risk-taking, development awareness	Everywhere, wherever

Source: authors' work based on Niezabitowska (2017).

It must be clearly stressed that in a globalising world, food adulteration and lack of food authenticity are very common phenomena. This has a direct influence on increasing the amount of food loss because not-authentic food (despite it being produced) is not accepted by consumers (Śmiechowska, 2013).

In the case of industrialised countries, most of the food is wasted at the stages of distribution and consumption, which means the final stages in the agri-food chain. An inverted trend is observed in developing countries where most losses appear at the initial stages of production. It is caused by a lack of advanced agricultural technologies, a lack of effective systems and transport

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infrastructure, as well as a lack of solutions which ensure that products can last longer.

Table 2. Negative effects of food loss

The area of negative effects of food loss		
Environmental	**Economic**	**Social**
Vainuse of water	Increase in global costs	Objectives in achieving food security in starving world regions
Vainuse of soil	Cumulative costs on the entire length of food chain	Unethical practices
Vainuse of energy	Losses incurred by all supply chain operators	People's malnutrition
Vainuse of packages	Lack of possibility of introducing food marketing because of its low quality	Increased number of malnourished people
Vain use of other resources and materials used for food production and distribution and disposal of unsold products	Decrising economic value of the products	Lack of access to food for many people
Global warming	Financial losses	Increased consumption
Emission of methane	Additional costs in relations to treatment of wasted food	Lack of confidence in security of food supply
The need to manage greater mass of organic and inorganic waste	Increased investment connected with employment of people, purchase of raw materials, maintaining systems providing health security as well as maintenance of machinery equipment	
	Increasing food costs	
	Increase in the price of foodstuffs	
	Rise in the cost of production	

Source: authors' work based on Dąbrowska & Janoś-Kresło (2013); Marszałek (2018); Michalczyk & Michalczyk (2019); Sokołowski (2020); Zabłocka et al. (2016).

Taking into consideration the food industry, the causes of food loss are inadequate marketing strategy, inappropriate stock management, the inadequate target group of the product, and large-scale food disposal (Marszałek, 2018). The main causes of food loss in households are exceeding shelf life, excessive purchases, damage and low quality (Bilska et al., 2015), additionally excessive portions of meals, wrong food storage, the bad taste of the

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product, lack of idea on how to use available ingredients (Mitka, 2020) as well as reckless purchases, too large packaging (Niedek & Krajewski, 2021).

Negative effects of food loss can be grouped into three areas: environmental, economic and social, which are consistent with the basic goals of sustainable development[1] (Table 2).

This article aims to present an original proposal for an approach to Lean Society philosophy with respect to the problem of food loss. The authors reviewed conventional and unconventional methods of food preservation, identification of available and innovative solutions in terms of reducing food loss and indicated directions and opportunities for reducing food loss on the basis of Lean Society philosophy.

Legislative aspects which protect food from wastage – Polish conditions

The problem of legal issues which protect food from wastage was undertaken in many publications (e.g. Leśkiewicz, 2015; Sokołowski, 2020).

Act of 19 July 2019 on preventing food waste is an important document in Polish legislation. It implemented principles concerning dealing with food and obligations for food traders and non-governmental organisations. The aim of the act was to support charitable activities by reducing the throwing of food away and its donation to people in need.

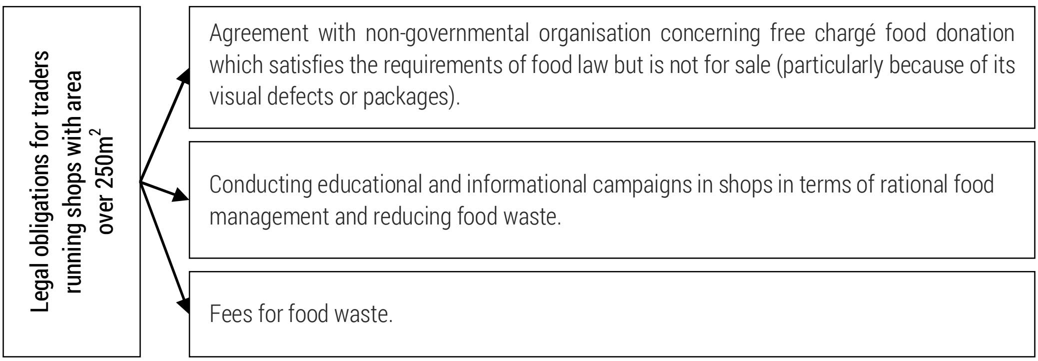

Figure 1. Legal obligations for traders running shops with area over 250 m^2

Source: authors' work based on Act (2019).

[1] The areas of sustainable development were presented in: Borys (2005); Borys (2011); Burchard-Dziubińska et al. (2014); Ciarko & Paluch-Dybek (2014); Czaja & Fiedor (2010); Gupta & Vegelin (2016); Matuszczak (2009); Papuziński (2007); Rogall (2010); Skowroński (2006); Sztumski (2006).

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In light of this act, obligations have been imposed on traders who run a shop with the area over 250 m^2 (earlier 400 m^2) (Act, 2019) (Figure 1).

It must be stressed that the act imposes obligations only on distribution business operators and does not include all parts of the food chain. The act omits the issue of food donation for non-food purposes and food which is still safe for human consumption after the date of minimum durability. It must be marked that the food loss problem should be solved in a comprehensive way, and hence implemented legal instruments cannot be limited only to distribution (Sokołowski, 2020).

Conventional and unconventional methods of food preservation

Food preservation is an action whose aim is to stop the process of food spoilage (Baryłko-Pikielna, 1995). These are also activities aimed at protecting against spoilage and delay and stopping processes which reduce food quality (Wielgosik, 2020). Very important aspect of food preservation is to extend the shelf life of food by preserving certain quality characteristics (Harasym et al., 2016).

The development of methods of food preservation corresponds with civilisation and technological progress. The necessity of food preservation is also connected with an increasing number of people on Earth who have to satisfy their needs in terms of eating. There is a huge problem due to the delivery of fresh, healthy and proper amounts of food to societies. It results from different aerodynamic conditions in different parts of the world, mainly short-term harvesting and rapid population growth in cities far away from centres of agricultural production (Molenda, 2007).

The growth of human activity has forced a greater need for food which is safe and available, allowing prepare meals in an easy way at any time and in every situation. These contributed to searching such methods of processing and preserving food products which will result in easy, fast use and preparing products (Kowalczuk, 2004). Convenience food is widely defined, but the common element which connects all definitions presented in the literature on this subject is a minimal time of meal preparation[2] (Babicz-Zielińska et al., 2010). An approach to a matter of convenience of food is connected with methods of its preservation. Evolutionarily there are three generations which refer to methods of food preservation in terms of convenience food (Table 3).

[2] Examples of convenience food definitions were presented in: Gawęcki (2002); Gawęcki & Mossor-Pietraszewska (2008); Górska-Warsewicz (2007); Janicki (1993); Janicki (2006); Świderski (2006).

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Table 3. Food preservation and generations of convenience food

Generation	Metods of food preservation	Examples
I – first	Traditional methods: - drying, - freezing, - sterilisation, - pasteurisation.	- bread, - dried fruit, - dried vegetables, - dried meat, - dried fish, - traditional sterilised tinned meat, - traditional pasteurised tinned meat.
II – second	-microwave heating, -aseptic production, -vacuum packaging, - Modified Atmosphere Packaging.	- ready-to-eat dinners, -sterilised meals, - pasteurised meals, - frozen meals, - chilled meals, - meals intended to microwaving, - concentrates of soups, - concentrates of juice, - concentrates of desserts and cakes, - breakfast cereals.
III – third	Combined methods (use of few preserving agents at the same time): - sous-vide, - cook-chill, - non-thermal processing methods, - edible casings, - natural inhibitory substances or antimicrobial substances, -sustainable packaging, - natural and biological active substances.	

Source: authors' work based on Adamczyk (2010).

Table 4 presents conventional methods of food preservation, and Table 5 presents unconventional methods of food preservation.

Table 4. Conventional methods of food preservation

GROUP OF METODS	METHOD	APPLICATION
PHYSICAL		
THERMAL METHODS	1. High temperatures	
	a) pasteurisation	destruction of pathogenic microorganisms and inactivation of vegetative forms of other microorganisms
	b) scalding	deactivation of tissue enzymes cleaning of raw material and reduction of microbiological contamination improvement of food structure especially further dehydrated
	c) sterilisation	removal or killing allmicrobes from the given environment, also spores,
	d) tyndallization (fractioned pasteurisation)	microbiological stability of fixed product in proces of production of tinned food, which extends food life for a year and milk for few weeks
	e) apertisation	for tinned food and „wek" jar containers
	f) thermisation	extending food sustainability
	2. Low temperatures	
	g) cooling	reducing speed of chemical reactions extending shelf life for raw materials, by-products and food products for further processing or eating
	h) freezing	inhibiting the development of microorganisms and activity of tissue enzymes
PROTECTIVE GASES	1. Nitrogen	propellant, for example in containers with whipped cream
	2. Argon	protection against oxidation
	3. Carbon dioxide	fizzydrinks drinking water purification dryice – cooling agent coolant
REDUCTION OF WATER ACTIVITY	1. Water removal	
	a) densification (concentration)	concentration of components of dry matter in smaller mass of product
	• equlibrum methods	
	– evaporation	used in production of juice, puree, fruit and vegetable, pulp, jam, jelly, milk
	– cryoconcentration	
	• nonequilibrum methods (osmoactive)	inactivation of microorganisms by adding to food substances which increase osmotic pressure
	– osmosis	
	– dialysis	
	– reverse osmosis	

GROUP OF METODS	METHOD	APPLICATION
REDUCTION OF WATER ACTIVITY	b) drying	reduction of the water phase in raw material stopping of enzymatic and life processes of microorganisms
	• contact drying	
	• convection drying	
	• radiant drying	
	• fluidised drying	the method is used to dry for example pea, rape, bean, cereals or berries and this process is very fast
	• drying by the use of microwaves	
	• freeze drying (liophilisation)	protects product against shrinking
	2. Osmotic substances	these include: sugar (sucrose), glucose, starch, corn syrup, glicerol, salt
PRESERVATION BY THE USE OF CHEMICAL PRESERVA-TIVES	1. Marination	fixation in vinegar marinade with addition of aromatic spices, salt and sugar
	2. Preservation	inhibits the growth of bacteria, yeats and mould inhibits development or destruction of microorganisms extending shelf life of food products preventing qualitative changes of products
PRESERVATION BY THE USE OF ORGANIC ACIDS	1. Acetic fermentation	inhibition of respiration in tissues, enzymatic, oxidative tissue processes which cause for example vitamin C oxidation or darkening of the surfaces reduction of softening and destruction of tissues and avoid-ing undesired changes in flavour and smell
	2. Lactic fermentation (lactate) – anaerobic glycolysis	inhibition of respiration in tissues, enzymatic, oxidative tissue processes which cause for example vitamin C oxidation or darkening of the surfaces reduction of softening and destruction of tissues and avoid-ing undesired changes in flavour and smell
	3. Marination	preservation in vinegar marinade with addition of aromate spices, salt and sugar
PRESERVATION BY THE USE OF INORGANIC ACIDS	1. Acidification	preservation of different cool drinks, still and fizzy drinks
SMOKING, CURING	1. Smoking	
	a) cold smoking (tempera-ture of the smoke approximately 22^{o}C)	smoking of sausages, ham, preparing of cured cold smoked meat
	b) warm smoking (tem-perature of the smoke 25-45^{o}C)	smoking sausages

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GROUP OF METODS	METHOD	APPLICATION
SMOKING, CURING	c) hot smoking (temperature of the smoke 40-80 ^{o}C)	smoking of steamedham
	d) baking (temperature of the smoke 75-90 ^{o}C)	
	Curing	
	• drycuring	
	• wet curing (immersion curing)	
	• injected curing	
BIOLOGICAL		
LACTIC ACID FERMENTATION		– pickling cucumbers, cabbage, beetroots, olives, – in dairy industry for producing fermented and dietary dairy drinks (yoghurt, kefir, sour milk, buttermilk, cream) – producing curd, matured cheese, casein, lactose – in meat industry – in baking industry
ALCOHOLIC FERMENTATION		
ACIDIFICATION (AEROBIC)		– preservation of food product – enhancing organoleptic characteristics of food products – improving pro-health properties – receiving new chemical compounds and food products by the use of biological methods
PROPIONIC FERMENTATION	Maturing of renet cheese	– food additive in baking, confectionery – storage of cereals and forage
PICKLING		– pickling cucumbers, white and red cabbages, beetroots – silage for animals (forage)

Source: authors' work based on Krzysztofik et al. (2015).

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Table 5. Unconventional methods of food preservation

METHOD	APPLICATION
IONIZING RADIATION	- sprouting inhibition in potatoes - preservation of onion - radiation disinfection of consumption grain and drying fodder - radiation preservation - destroying parasites in raw materials and food products - killing encysted larvae
NUCLEAR RADIATION	- reduction of microorganisms and their sporulated forms in food products - preventing of plant germination - extending of storage period - extending of period of fruit storage - extending of maturation period - preventing of development of fruit flies
ULTRAVIOLET RADIATION	- bactericidal activity - antiseptic effects - therapeutic effects - destruction of microflora on surfaces of meat and fish, spices, sugar used in preserved products, fruit - preventing cheese mould - sterilisation of water
SOUND AND ULTRASOUND VIBRATIONS	- destroying of microorganisms
PULSATING MAGNETIC FIELD	- preservation of food products
PULSATING ELECTRIC FIELD (PPE)	- processing of frozen products and food additives
PULSE LIGHT	- reduction of microorganisms on the Surface of meat, fish and bread - disinfection of packaging
HIGH PRESSURE	- keeping the level of vitamins and food colours - reduction of microorganisms or enzymes which reduce shelf life because of spoil
PULSE MICROWAVE FIELD	- fast heating of food without much water that limits loss of nutrients comparing to other cooking methods
USE OF ANTIBIOTICS	- prevention of development of pathogenic bacteria - reduction the amount of used chemical preservatives
ASEPTIC PACKAGING TECHNOLOGIES	
RESISTANCE WELDING	- minimising the risk of too long heat treating - minimising the risk of potential loss of nutritional characteristics
FILTRATION	
CENTRIFUGING (BACTOFUGATION)	- removing microorganisms - milk purification - separation and concentration of bacterial suspension of different origin
LESS AGGRESIVE OR NEUTRAL PRESERVATIVES	- reduction of development of microorganisms and enhancing microbiological stability of the product - extending shelf life of the product

Source: authors' work based on Krzysztofik et al. (2015).

Identification of available and innovative solutions in terms of reduction of food loss

The phenomenon of food loss is an important problem and hence American Environmental Protection Agency has developed hierarchy of prevention of food loss. Reduction of losses and wasting at their roots are priorities. Next levels are: donating food to people in need, animal feed, industrial use, composting, and at the end storage and incineration (Kołożyn-Krajewska et al., 2016) (Figure 2).

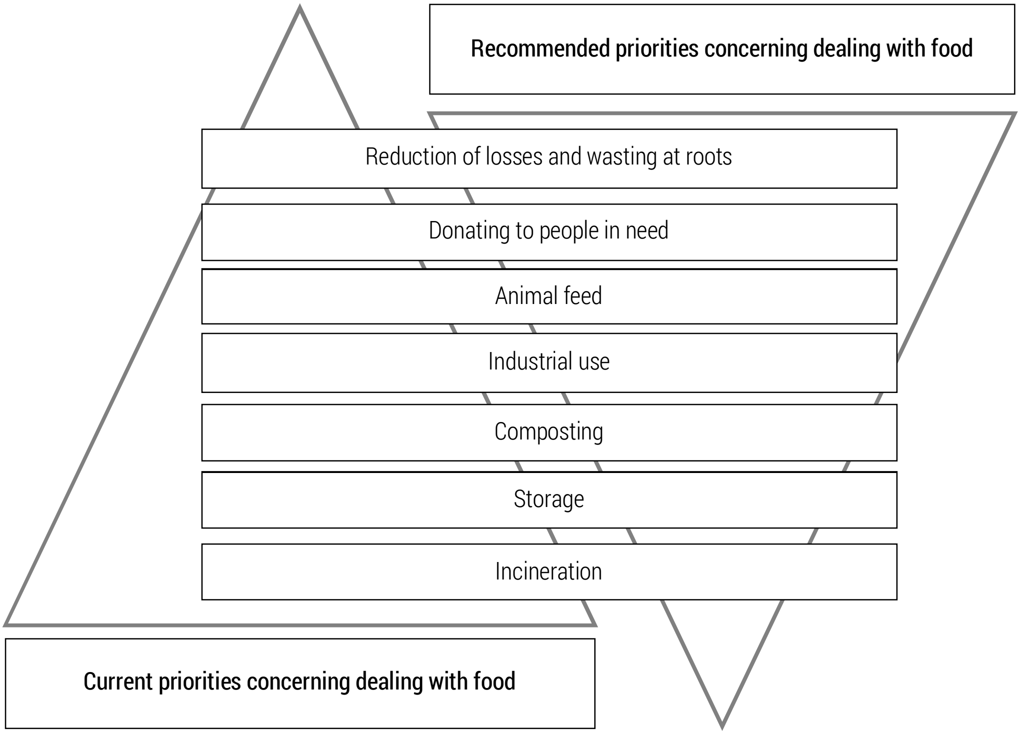

Figure 2. Current and recommended priorities concerning dealing with food
Source: authors' work based on Kołożyn-Krajewska et al. (2016).

Current solutions related to reduction of food loss can be placed in three groups of solutions: organisational, social and technical-technological (Table 6).

Table 6. Available solutions in terms of reduction of food loss

Group of solutions	Area of solutions	Examples of activities
Organisational	Legislative regulations	Regulation of the European Commission 1221/2008 – withdrawal of restrictive requirements concerning shape and size of vegetables and fruit
	Government policy	Legislation concerning necessity of segregation of wasted food (Ireland)
	Improvement of food logistics	Cooperative frames for improving supply chain (Netherlands) „Ale carte" menu (Denmark)
	Redistribution of food	Food banks Approved food (Great Britain) Buon Samaritano (Italy) Fare Share (Great Britain)
Social	Lifestyles	Foodsharing Freeganism Cocooning Smart shopping Anti-consumptionism Ecoconsumption
	Social campaigns	Love Food Hate Waste (Great Britain)
	Education, training	The art. Of not wasting (Lidl)
	Awareness	The awareness of food losses in Eurest (Sweden)
	Research projects	MOST (Poland)
Technical-technological	Mobile applications	Fooders Too Good To Go OLIO Food Rescue US Share Food43 Karma App

Source: authors' work based on Kołożyn-Krajewska et al. (2016); Kozłowski & Rutkowska (2018); Sieniecka & Kozłowska (2022).

According to the authors, the area of solutions, together with examples of actions, do not fully exhaust possibilities for the reduction of food loss. In the further part of the article, original proposals which enable a significant reduction of the amount of wasted food will be presented.

Food is an area of interest in the innovative Lean Society Philosophy

Presentation of the original definition of innovative philosophy, which is that Lean Society is: the philosophy of management of modern societies which steams from sustainable development principles and existing concepts of effective use of resources which was extended to the idea of lean thinking, eco-design, the real determination of actual needs by the support of government and society, as well as education of society, are starting point for deliberations (Dąbrowska et al., 2022).

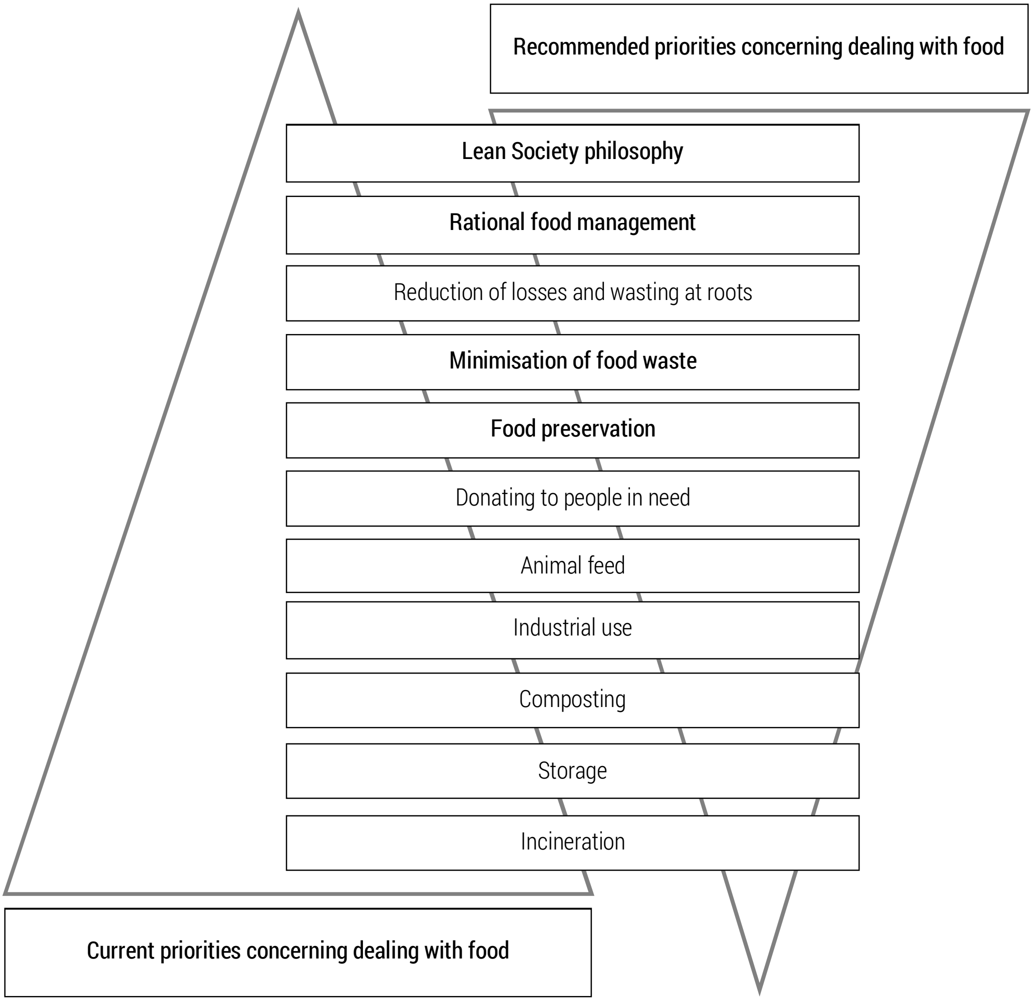

Figure 3. System actions aimed at dealing with food

With respect to Figure 2, recommended priorities concerning dealing with food should be extended to the following four activities (levels). These include food preservation, reduction of food loss, rational food management and Lean Society philosophy (Figure 3). Taking into consideration above mentioned conditions, there are postulated rules and example activities concerning rational food management, which in terms of the innovative concept of Lean Society, will reduce food loss (Figure 4, Table 7).

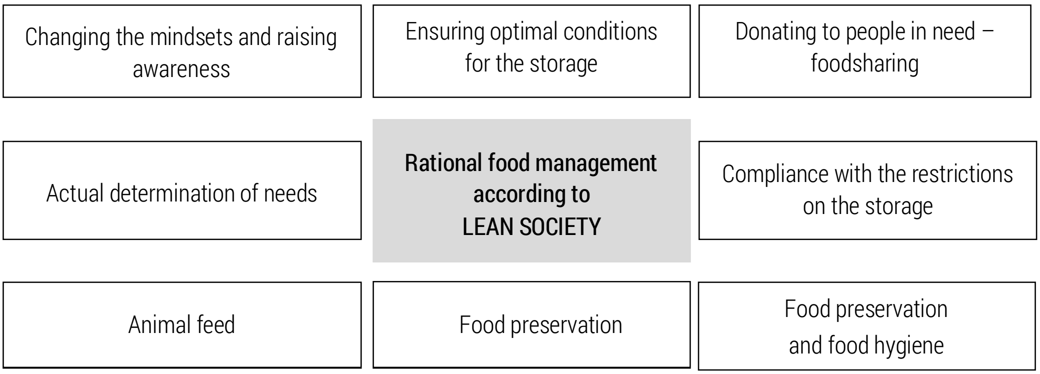

Figure 4. Rational food management according to the assumption of Lean Society Philosophy

Table 7. Supportive activities of rational food management

Principle	Activity
Changing the mindsets and rising awareness	-social campaigns, - education, - creative cooking.
Actual determination of needs	- creating shopping list, - using mobile applications, - checking of content of the fridge and pantry.
Animal feed	- feeding the birds, fish, - donating food to animal shelters.
Ensuring optimal conditions for the storage	-avoiding mistakes connected with food storage, e.g. storage of bananas next to apples, - delaying ripening, e.g. wrapping endings of bananas in cling film, - planning of arrangement of stored products, - ensuring proper storage temperature.
Food preservation	- use of conventional and unconventional methods of food preservation.
Donating to people in need – food sharing	-social fridges, - eating places.

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Principle	Activity
Compliance with the restrictions of the storage	- 7P rule (store safe, go-over, put off, rethink, recycle, tidy up, pass down), -reading of labels.
Food preservation and food hygiene	- use of vacuum containers, - use of closed containers, - proper place for food storage, for example do not put raw meat on the top shelf of the fridge, - separation of raw food from cooked food, - dividing leftovers into smaller portion.

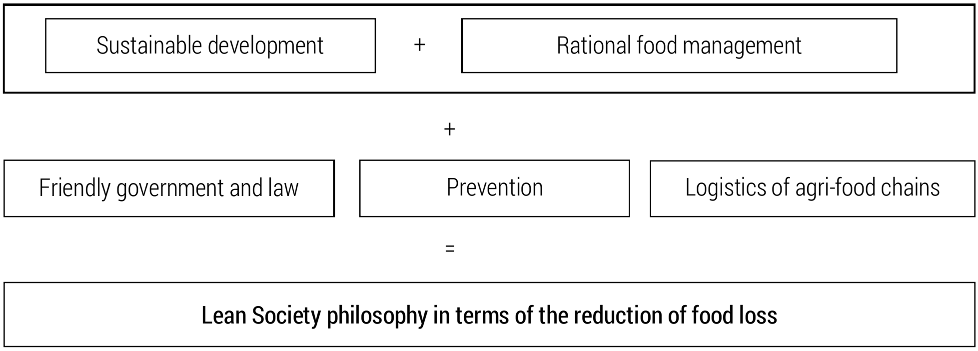

Figure 5. Pillars of Lean Society philosophy with regard to the reduction of food loss

Table 8. Proposals for actions reducing food loss with respect to pillars of Lean Society Philosophy

Pillars	Examples of activities
Sustainable development	- increase in use of biomass, - global assessment of the scale of the problem.
Rational food management	-avoiding excessive purchase and stockpiling, - reuse of safe food (freeganism), - recovery of food resources for production of animal feed.
Friendly government and law	- support in donation of unsold food as gifts to charitable bodies.
Prevention	- ongoing monitoring of situation and constant collection and analysis of data in order to better understanding of the causes of the problem and comprehensive solutions, - promoting education by e.g. social campaigns.
Logistics of agri-food chains	- promoting cross-sectoral cooperation, -commonality of agricultural policy, -strict rules for food segregation.

The objective of developing the assumption of the initial concept of Lean Society when it comes to the reduction of food loss was the concept of sustainable development and activity in terms of rational food management. However, it should be noted that the comprehensive approach of the Lean Society philosophy in terms of reduction of food loss requires additional support in three areas. There are friendly government and law, prevention and logistics of agri-food chains (Figure 5, Table 8).

Conclusions

The problem of food loss is global and should not be solved, taking into consideration only its country or origin scale. Struggle with food loss is one of the main challenges to the modern world economy. Current activities undertaken by global and European bodies are focused on the preparation of documentation and not on designing effective systematic solutions, which will unify activities aimed at implementing real practices. It must be noted that attempts to address the issue very often are initiated by individuals or social groups and sometimes are connected with a choice of particular lifestyle (freeganism, foodsharing, smart shopping).

The aim of this article was to present the original approach to Lean Society philosophy in relation to the problem of food waste. This objective was taken by:

- presentation of the original definition of Lean Society philosophy,
- innovative approach to systematic actions in dealing with food, taking into account systemic activities in the field of food preservation, minimising food waste, rational food management and the innovative lean society philosophy,
- indication of actions which support rational food management concerning organisational, social as well as technical and technological aspects,
- identification of pillars of Lean Society philosophy in terms of the reduction of food waste and,
- proposal of actions reducing food waste with regard to pillars of the innovative concept of lean society about sustainable development, rational food management, friendly state and law, preventive measures and logistics of agri-food chains.

The contribution of the authors

Magdalena Dąbrowska – 25%, Anetta Zielińska – 25%, Grygorii Monastyrskyi – 25%, Mariola Drozda – 25%.

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ENVIRONMENTAL POLICY AND MANAGEMENT

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GOVERNANCE EFFECTIVENESS AND GREEN BONDS. AN EMPIRICAL EVALUATION

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ABSTRACT: The study aims to assess the relationship between governance effectiveness, measured by the Worldwide Governance Indicators, and the use of green bonds worldwide. We apply panel data models with random effects and a robust linear regression model that allows us to identify the impact of the family of variables on green bonds. We found a statistically significant correlation between the quality of a government, measured as government effectiveness, and the value of green bond issuances. Thus, it is advised under New Public Governance to increase the effectiveness of their functioning, which may contribute to greater investor interest in environmental projects.

KEYWORDS: world governance indicator, green bonds, government effectiveness, green financing

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Introduction

The study aims to assess the relationship between the quality of public management and the use of "green financing" instruments, thus enriching the extensive research trend on this instrument. The research relates to the growing concern of negative climate change, which will cause a deterioration in nations' quality of life and loss of material and intangible resources. Therefore, it is necessary to develop financial instruments to help reduce the adverse effects of climate change. Both public and private entities are involved in solving environmental challenges. They are looking for greener technological solutions that can help reduce global warming. To meet the ecological target of limiting global warming to 2°C, it has been estimated that almost US$ 6.9 trillion has to be spent on improving infrastructure over the next 15 years (OECD, 2017). The appearance of green bonds (GBs) in 2007 (the climate bond category) as an essential source of financing for such initiatives was a critical event in the global bond markets.

Green bonds are innovative debt instruments of sustainable financing that companies and governments use to finance environmentally friendly investments. Green bonds are issued to raise capital for financing projects that contribute to a low-emission and climate-resilient economy (Inderst et al., 2012). Green bonds differ from standard bonds because capital is only used to finance "green" projects (OECD, 2015). The allocation process includes obtaining financing, selling a financial instrument, selecting a project, and allocating funds (The World Bank). The rules for issuing green debt are the leading global standard in the green bond market. It defines green bonds as "any type of bond instrument, the proceeds of which will be used exclusively to finance or refinance part of or fully new and/or existing eligible green projects" (ICMA, 2022). These projects include renewable energy development, energy efficiency, pollution prevention and control, sustainable management of living natural resources, protection of land and aquatic biodiversity, clean transport, sustainable water management, eco-efficient products, and production technologies and processes (ICMA, 2022). Common examples of funding include low-carbon transport, recycling, energy-efficient buildings, and hydropower (Climate Bonds Initiative, 2022). Importantly, these applications cover both mitigation measures (e.g., building solar and wind installations) and measures to adapt to climate change (e.g., reforestation) (The World Bank, 2021). The Climate Bond Initiative has created a green bond taxonomy to facilitate market convergence (Climate Bonds Initiative, 2022). In addition to financing new projects, issuers can use green bonds to refinance existing debt to lower the cost of capital or raise additional financing. Green bonds are similar in structure to regular bonds, mean-

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ing that investors have direct recourse to the issuer if the issuer cannot pay the interest or par value (OECD, Green Bonds, 2015). Green bond issuers include corporations, municipalities, government entities, and international institutions. The European Investment Bank issued the first green bond in 2007 to finance renewable energy and energy efficiency projects, while Poland first issued a green state bond in December 2016 (Durand, 2016). Since then green bonds have become increasingly popular and this trend is often referred to as the "green bond boom".

The present paper aims to answer the following research question (RQ): Is there a relationship between the effectiveness of governments and the value of GB issuances? This study begins with a literature review on "impact investing" and GBs, followed by empirical analyses showing a statistical relationship between the effectiveness of governments and the value of GB issuances. It concludes with a scientific discussion based on the obtained results and research conducted so far in the area in question.

An overview of the literature

The significant increase in recent years of "impact investments" which positively impact the community and the environment, has become a key trend among the forms of implementation by public and private entities. The Global Impact Investing Network estimates that the impact investing sector grew from US$4.3 billion in 2011 to US$502 billion in 2018 (GIIN, 2019). Positive environmental changes are inextricably linked with the quality of public management. A measure of this, among others, is the World Governance Indicator (WGI). This indicator covers six key areas of governance: accountability, political stability and non-terrorism, governance performance, regulatory quality, rule of law, and the control of corruption. It is part of the wider concept of New Public Governance (NPG), which is associated with maintaining the security of the pillars of the public economy while, at the same time, increasing social welfare (Osborne, 2010). NPG has taken shape as a "self-regulating network" of stakeholders operating with or without the involvement of local governments to deliver public goods and maintain a decent quality of life (Kickert, 1993) (Rhodes, 1997). Compared to many examples of socially responsible investment projects that have been extensively researched for reputation/branding and consumption theory (McWilliams & Siegel, 2000; Lee, 2008; Campbell, 2007), little research has dealt with the relationship between NPG public management quality and the value and profitability of green bond issues as an instrument for financing impact investment projects. The growing interest in green bond issues has translated into a growing number of government initiatives in the bond market,

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both on the demand and supply side. Examples of such initiatives are not only voluntary standardization in EU countries, but also various types of subsidies or grants to cover the costs of certification as seen – for example – in Singapore. To summarise, the justification of the present research is the existence of a gap concerning the quality of public management of NPG for using "impact investing" instruments to generate positive environmental effects.

The incentives for issuing green bonds are varied and include improving market image by investing in green technologies/initiatives (Turban & Greening, 1997), improving financial performance (Nilsson, 2008; Bauer & Smeets, 2015; Hartzmark & Sussman, 2018), and risk reduction (Krüger, 2015). The value of green bond issues increased over ten times between 2014 and 2020 – from €28 billion to €230 billion (Climate Bond Initiative, 2020). Developing "green financing" instruments is necessary to achieve climate goals communicated at Glasgow's 2021 COP26 climate summit. COP26 adopted declarations that developed countries will achieve annual green investment financing at US$100 billion from 2023 (ukcop26.org).

Adverse effects related to production, consumption, and population growth have seriously impacted climate change and environmental degradation. However, developed countries can better cope with the effects of environmental change caused by industrial development (Tara et al., 2015). Ecological crises in developed countries are also perpetuated by non-compliance in developing countries. Environmental problems are much more significant in developing countries due to non-compliance with business rules that aim to protect the environment (Tu et al., 2015). As a result, the importance of green finance for developing countries has also increased. To increase the issuance of green financial instruments aimed at protecting the environment, governments must promote and regulate green financial instruments by creating incentives for introducing green technologies. Green finance is, therefore, an essential element of sustainable economic growth. Poor quality of state governance will not be conducive to the green industry and, as a result, green instruments will disappear from the market. This could contribute to the failure of economies designed to prevent climate change. Governments should strive to promote green growth by developing new technologies and environmentally friendly industries. Green bonds are one of the instruments for financing environmentally friendly projects, and government authorities should pay special attention to climate-friendly projects. Low-carbon financing fosters a low-carbon economy (Jiguang & Zhiqun, 2011) by raising capital for projects involving low-carbon production (Zhang et al., 2019). Green bonds are one of the instruments used to finance environmentally friendly projects.

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The present research aims to verify the relationship between the quality of public management and the value and profitability of global issues of the above-mentioned types of bonds. Moreover, we present a systematic review of impact investing instruments such as social impact bonds, green bonds, and sustainability bonds. We highlight this market's potential and the role of governments in developing financial instruments that increase social welfare, including environmental welfare. Assessing the relationship between the quality of government and the value and profitability of green bonds may contribute to further development of green financing instruments to better match them to the specificity of individual countries and create greater social welfare. Moreover, it may constitute a justification for specific government interventions and the use of subsidy/grant tools to stimulate the development of a green economy properly. As climate change goals are global, verifying the planned dependence may also directly support raising the level of public management under the NPG to the appropriate areas.

Previous studies linking green bonds and public management have not indicated any direct relationship between the quality of government and the value of bond issues. Nevertheless, attention should be paid to the reports of, among others, Yamahaki et al. (2020). Their research indicated the importance of structural and legislative barriers, including unstable environments, for developing GBs. In a broader context, i.e., impact investing, the vital role of governments and public institutions in coordinating relations with investors is emphasised to induce them toward making socially beneficial investments. These analyses mainly concerned the real estate market and broadly understood investments with positive social effects (Wood et al., 2013). Another analysis, this time based on a case study in Sweden, did not directly indicate the importance of the role of governments for issuers and investors in the long-term planning of a favourable climate policy. The respondents' replies were inconsistent; some considered the importance of, for example, GB government emissions for the development of the market, while others showed scepticism about the importance of public involvement in the development of the GB market (Maltais & Nykvist, 2020). It is also worth paying attention to the factors of growth of the GB market based on the experience of China (Escalante et al., 2020; Lin & Hong, 2022). The authors emphasised that one of the key determinants of the development of GB emissions was a more substantial commitment of governments to introduce standardised frameworks for reporting the environmental impact of these emissions. This would ensure a uniform methodology and provide indicators for issuers to report environmental impacts, enable the market to understand better, communicate the benefits of GBs and attract environmentally conscious investors.

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When considering green finance as a broader subject of analysis, instead of focusing solely on GBs, research on the importance of the quality of power and green finance may also be vital in answering our research question. Thus, the reports of Bhatnagar and Sharma (2022) deserve attention. The authors point out the critical importance of, among others, political stability, the development of regulatory structures of the GB market, legal regulations, and institutional involvement in the market of green instruments. In conclusion, they directly emphasised the importance of government actions in this market.

The evidence of government quality and the rule of law set the frameworks for issuance. It should be clear and publicly visible (Cheng et al., 2022). Moreover, these frameworks must require that the environmental impact is measured in both qualitative and quantitative ways (ICMA, 2022). This is in line with the assumptions of New Public Governance. Improvement in management quality should occur through the absorption of market mechanisms into the public sector, as well as management methods and techniques widely used in the private sector. Moreover, the administration should be focused on efficiency, economic efficiency, quality, and result orientation (Lapuente & Van de Walle, 2020). In this case, there is an actual translation of the investment into the quality of the natural environment.

Research methods

To answer the RQ: Is there a relationship between the effectiveness of governments and the value of GB emissions, we analysed values of GBs for 94 countries from 2014 to 2022 (thomsonreuters.com; accessed 2022) and World Governance Index (WGI) values for 169 countries (values are provided for the period 1996–2020, but since we analysed GB values from 2014, we take WGI index values from the same year, worldbank.org accessed 2021), taking common parts of these two datasets to find a relationship between both variables. We aimed to answer the RQ "Is there any significant influence of WGI on (yearly total) GB values with respect to both country and year?".

It is worth noting where the possibility of comparison between such different countries lies. We made cross-country analyses using the WGI (government effectiveness) index. It is independent of the economy's structure, geographical specificity and demographics. Efficiency is an independent factor in this case. For example, the structure of the economies of Germany and Andorra is irrelevant if we compare the effectiveness of governments in these countries and the existence of its relationship with the value of the described green finance instrument. The WGI is calculated for each of these countries according to a uniform methodology, independent of the structural specificities of the surveyed economies.

To investigate the existence of monotonic relationships between two variables, Spearman's correlation coefficient was used. This coefficient takes values from -1 to 1. A statistically significant result from Spearman's correlation coefficient substantiates the existence of monotonic dependencies between the variables. If the coefficient is positive, it means that, as one variable grows, the value of the other variable grows as well. However, if the correlation is negative, it means that, as one parameter's value increases, the other parameter's value decreases. The correlation can be low, moderate, high, or very high. It may also not be present. The following classification of the correlation strength was used (Guilford, 1965):

$|r|=0$ – no correlation,
$0<|r|\leq 0.3$ – very weak correlation,
$0.3<|r|\leq 0.5$ – weak correlation,
$0.5<|r|\leq 0.7$ – moderate correlation,
$0.7<|r|\leq 0.9$ – high correlation,
$0.9<|r|<1.0$ – very high correlation,
$|r|=1$ – full correlation.

Where applicable, a linear regression model was used to examine the relationship between the dependent and explanatory variables. Coefficient values in linear models estimate the size of the effect the independent variables have on the dependent variable. An intercept is the value the dependent variable is predicted to have, when all the independent variables are equal to zero. We also provide 95% confidence intervals for estimated coefficients. Where the assumptions of the classical linear regression model were not met, we used a robust regression model. The idea of robust regression is to weight the observations differently based on how well-behaved the observations are. Roughly speaking, it is a form of weighted and reweighted least squares regression (UCLA).

As there were too few values of total GB for an individual country in most of the cases (due to the presence of missing values), we abandoned time series models (VAR or VECM) in favour of panel data models that allowed us to identify the impact of the family of variables on GB. Despite the lack of time series models, standard approaches also have drawbacks – a pooled linear regression model does not consider heterogeneity across countries. In contrast, individual models are based on a few observations and do not consider common features of the countries (they all interact and experience the same influence of progress). Figures 1 and 2 present the phenomenon of heterogeneity across countries and across years, respectively. In the figures, dots

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represent means values for GB across countries (Figure 1) and years (Figure 2), while whiskers denote 95% confidence intervals for these means.

To allow for the country effect, we used a fixed effects model. The fixed effect assumption is that the individual-specific effects are correlated with independent variables. We introduced a dummy variable, "*Di = country*" and included it in the model along with an interaction term. Our model had the following form:

$$GB \sim A\,WGI\; + B\;Country\; + C\;WGI * Country, \tag{1}$$

where symbol * denotes the interaction term and *A, B, and C* are the estimated parameters.

We characterised statistically significant results in bold. The unique effect of the WGI is represented by everything that is multiplied by it in the model – it is equal to $A + C * Country$, where A is a coefficient corresponding to the WGI and C is a coefficient corresponding to the interaction term. Panel data models provide information on individual behaviour across individuals and over time. The basic linear panel models used in econometrics can be described through suitable restrictions of the following general model:

$$y_{it} = \alpha_{it} + \beta_{it}x_{it} + u_{it}, \tag{2}$$

where i=1,...,n is the individual (country) index, t=1,...,T is the time index, and u_{it} is a random disturbance term of mean 0.

Naturally u_{it} is not estimable with N=n×T data points. The appropriate estimation method for this model depends on the properties of the two error components. The idiosyncratic error ϵit is usually considered well-behaved and independent of both the x_{it} of the regressors and the individual error component μi. The individual component may, in turn, either be independent of the regressors or correlated. If it is correlated, the ordinary least squares (OLS) estimator of β would be inconsistent, so it is customary to treat the μi as a further set of n parameters to be estimated, as if in the general model $\alpha_{it} = \alpha_i$ for all values of t. This is called the fixed effects model, usually estimated by OLS on transformed data, and gives consistent estimates for β_{it}.

Nevertheless, the common error component over individuals induces correlation across the composite error terms, making OLS estimation inefficient, so one has to resort to some feasible generalised least squares (GLS) estimators. This is based on an estimation of the variance of the two error components, for which several different procedures are available. If the indi-

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vidual component is missing, pooled OLS is the best estimator for β. This set of assumptions is usually labelled as a "pooling model", although this refers to the errors' properties and the appropriate estimation method rather than the model itself. If one relaxes the usual hypotheses of well-behaved, white noise errors and allows the idiosyncratic error to be arbitrarily heteroskedastic and serially correlated over time, a more general kind of feasible GLS is needed (called the "unrestricted" or "general" GLS). This specification can also be augmented with individual-specific error components possibly correlated with the regressors, termed "fixed effects" GLS.

Another way of estimating unobserved effects models by removing time-invariant individual components is by first differencing the data, i.e., by lagging the model and subtracting, the time-invariant components (the intercept and the individual error component) are eliminated, and the model:

$$\Delta y_{it}=\beta\top\Delta x_{it}t+\Delta u_{it}, \tag{3}$$

where $_{it}-y_{it-1}$, $\Delta x_{it}=x_{it}-x_{it-1}$ and $\Delta u_{it}=u_{it}-u_{it-1}=\Delta\epsilon_{it}$ for t=2,...,T) can be consistently estimated by pooled OLS.

This is called the "first-difference" or "FD" estimator. Its relative efficiency, and hence the reason for choosing it against other consistent alternatives, depends on the properties of the error term. The FD estimator is usually preferred, if the errors are strongly persistent over time, because the Δu_{it} will tend to be serially uncorrelated. Finally, the "between" model, which is computed on time (group) averages of the data, discards all the information due to intragroup variability, but is consistent in some settings where the others are not (e.g., non-stationarity) and are often preferred to estimate long-run relationships. Variable coefficient model relax the assumption that $\beta_{it} = \beta$ for all values of *i* and *t*. Fixed coefficients models allow the coefficients to vary along one dimension, e.g $\beta_{it} = \beta$ for all values of *t*. Random coefficients models instead assume that coefficients vary randomly around a common average, as $\beta_{it} = \beta+n_i$ for all values of *t*, where n_{it} is a group (time) specific effect with a mean of zero.

In the case of this analysis, the level of statistical significance was set to p=0.05. However, we also separately highlighted significant results for the levels of p=0.01 and p=0.001. P-values indicating a statistically significant result are shown in bold. In cases where P<0.001, the notation "P<0.001" was used. All calculations were done in R (version 4.02).

Research results

First, we investigated the relationship between WGI and GB for each year from 2014 to 2020. As we can treat both variables as continuous variables and hence suitable to calculate Spearman's correlation coefficient, Table 1 below presents the results of calculating Spearman's correlation between these two variables for each consecutive year. In each case, there was an average positive (statistically significant) monotonic correlation between WGI and GB. We note that the results here were very similar across the years, i.e. a high consistency of mutual correlations for all successive years characterises the results. Based on the significance test of the correlation coefficient (p-value < 0.001), we reject the null hypothesis stating that there is no significant correlation between these variables each year.

Table 1. Spearman's correlation coefficients between GB and WGI (2014-2020)

Year	Correlation coefficient	p-value
2014	0.5	<0.001
2015	0.528	<0.001
2016	0.505	<0.001
2017	0.511	<0.001
2018	0.608	<0.001
2019	0.607	<0.001
2020	0.486	<0.001

Since correlation does not mean causation, we modelled the influence of WGI level on the total amount of Green Bonds (bln $) with a linear regression model. Still, as its assumptions could not be satisfied (i.e., heteroscedasticity and lack of normality of residuals), we applied a robust linear regression model, suitable when such basic assumptions are not fulfilled. Diagnostic plots verifying individual assumptions of the linear regression model for the models in each year have been included in the supplementary material (Appendix 1). Scale-Location is a type of graph used to check the homogeneity of variance of the residuals (homoscedasticity). A horizontal line with equally spread points is a good indication of homoscedasticity. We can see clearly that it does not occur in our case. Hence, we use a robust model. The results are presented in Table 2. We note that, in each case, WGI was statistically significant (p-value < 0.001). The results imply that, with an increase of WGI by one unit, the value of GB increases on average by the value of the coefficient corresponding to WGI. Every year, an increase in the value of WGI caused a simultaneous increase in the value of GB. The increasing values of

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the regression coefficients indicate that this trend has been strengthening in subsequent years. An example illustrating this situation is the increase in the value of GB by an average of 0.09 billion USD, with a one-point increase in the WGI index in 2014, whereas, in 2020, it is already an average of 1.63 billion USD. We also added the values of the coefficient of determination R^2, indicating the model's fit as the percentage of variance in GB explained by the model.

Table 2. Robust linear regression model determining the relationship between GB and WGI (2014-2020)

Year	Variable	Coefficient	2.5%	97.5%	*p*-value	R^2
2014	Intercept	0.043	-0.012	0.098	0.128	0.119
	WGI	0.09	0.042	0.139	**<0.001**	
2015	Intercept	0.046	-0.018	0.111	0.165	0.124
	WGI	0.112	0.055	0.169	**<0.001**	
2016	Intercept	0.183	0.001	0.365	0.053	0.143
	WGI	0.334	0.171	0.5	**<0.001**	
2017	Intercept	0.29	0.033	0.546	0.031	0.023
	WGI	0.439	0.211	0.667	**<0.001**	
2018	Intercept	0.2	-0.01	0.411	0.066	0.21
	WGI	0.444	0.255	0.633	**<0.001**	
2019	Intercept	0.666	-0.025	1.357	0.064	0.156
	WGI	1.515	0.887	2.142	**<0.001**	
2020	Intercept	1.103	0.295	1.911	**0.001**	0.085
	WGI	1.626	0.88	2.371	<0.001	

Figure 1 below presents the phenomenon of heterogeneity across countries. Here, dots represent mean values for GB across countries, and whiskers denote 95% confidence intervals for these means.

Similarly, we can present heterogeneity across years, as depicted in Figure 2 below.

Table 3 presents the results for the fixed model described in detail by Equation 1. We denoted statistically significant results in bold. The unique effect of WGI is represented by everything that is multiplied by it in the model – it is equal to A + C*Country, where A is a coefficient corresponding to WGI and C is a coefficient corresponding to the interaction term.

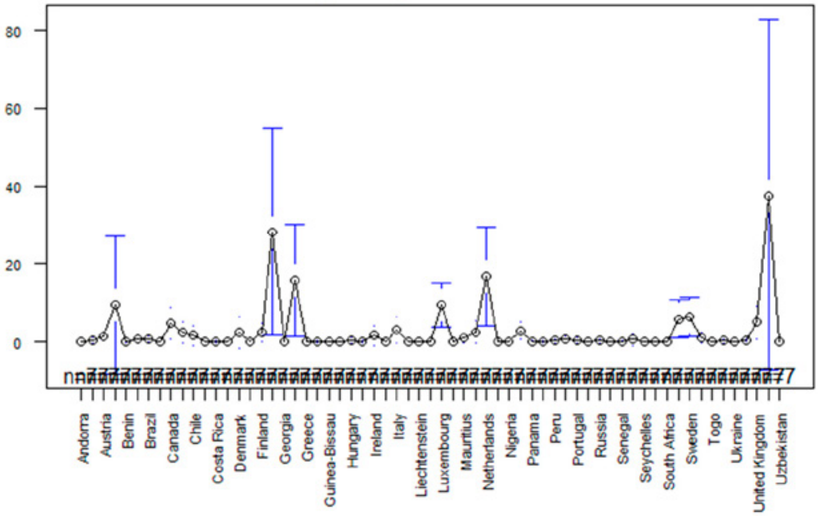
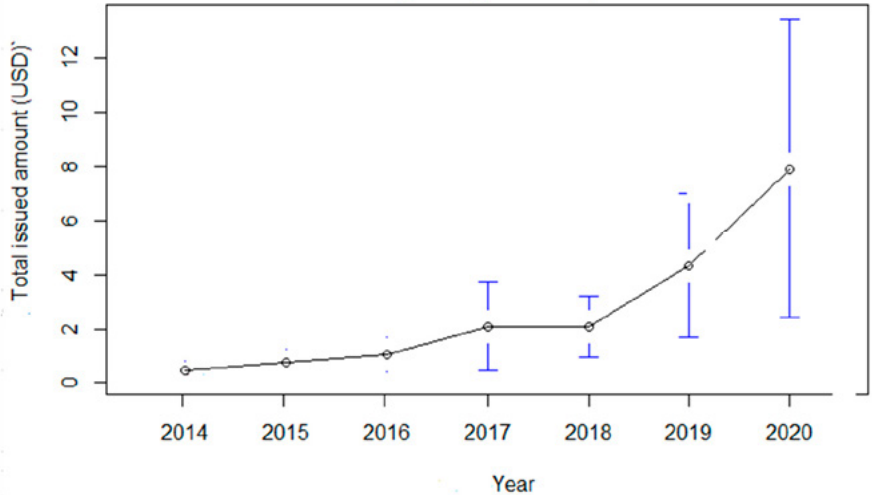


Figure 1. Heterogeneity across countries for GB (2014-2020)

Figure 2. Heterogeneity across years for GB



For example, the unique effect of WGI on GB for Austria is equal to 14.391, which means it is 14.391 stronger than the effect for Andorra. As observed here, we primarily speak of a statistically significant relationship in the case of wealthy countries with a high GDP, especially when compared to the tiny reference country of Andorra. These countries were significant factors influencing the value of GB itself and statistically significant moderators of the relationship between GB and WGI.

Table 3. Fixed effects model for the relationship between GB and WGI across countries

Variable	Coefficient	2.5%	97.5%	*p*-value
Argentina	0.032	-2.152	2.216	0.977
Austria	-20.907	-24.275	-17.540	**<0.001**
Belgium	23.180	20.870	25.489	<0.001
Benin	0.500	-1.717	2.717	0.659
Bermuda	-1.325	-3.585	0.935	0.251
Brazil	1.365	-0.827	3.558	0.223
Burkina Faso	-0.089	-2.439	2.260	0.941
Canada	125.709	122.273	129.144	**<0.001**
Cayman Islands	67.159	62.817	71.501	**<0.001**
Chile	7.276	4.510	10.042	**<0.001**
Colombia	0.031	-2.153	2.216	0.977
Costa Rica	0.085	-2.321	2.491	0.945
Czech Republic	0.000	-3.003	3.003	1.000
Denmark	-30.933	-35.399	-26.466	**<0.001**
Dominican Republic	0.000	-2.281	2.281	1.000
Finland	17.533	14.118	20.949	**<0.001**
France	543.365	540.485	546.245	**<0.001**
Georgia	-0.081	-2.298	2.136	0.943
Germany	212.836	210.294	215.377	<0.001
Greece	-0.234	-2.437	1.968	0.835
Guatemala	-0.058	-2.765	2.649	0.966
Guinea-Bissau	0.132	-2.457	2.721	0.920
Honduras	0.087	-2.167	2.342	0.940
Hungary	-0.278	-2.799	2.243	0.829
Iceland	-0.613	-4.388	3.161	0.750
Ireland	6.260	3.781	8.739	**<0.001**
Israel	0.000	-2.464	2.464	1.000
Italy	22.697	20.365	25.029	**<0.001**
Latvia	-0.154	-2.616	2.308	0.903
Liechtenstein	-0.726	-4.845	3.393	0.730
Lithuania	0.420	-2.208	3.048	0.754
Luxembourg	-64.754	-68.227	-61.282	**<0.001**
Mali	-0.542	-3.038	1.954	0.671

Variable	Coefficient	2.5%	97.5%	*p*-value
Mauritius	10.615	8.151	13.079	**<0.001**
Mexico	0.772	-1.412	2.956	0.489
Netherlands	880.355	870.750	889.959	**<0.001**
Niger	0.273	-2.135	2.681	0.824
Nigeria	0.075	-2.523	2.674	0.955
Norway	-19.457	-23.570	-15.343	<0.001
Panama	0.033	-2.153	2.219	0.976
Paraguay	0.115	-2.097	2.326	0.919
Peru	0.488	-1.710	2.687	0.664
Poland	0.563	-1.669	2.795	0.622
Portugal	0.298	-2.091	2.688	0.807
Romania	0.000	-2.184	2.184	1.000
Russia	0.022	-2.163	2.206	0.984
Saudi Arabia	0.000	-2.218	2.218	1.000
Senegal	0.100	-2.089	2.289	0.929
Serbia	0.135	-2.063	2.332	0.904
Seychelles	-0.013	-2.289	2.264	0.991
Slovenia	-0.349	-2.934	2.237	0.792
South Africa	-0.377	-2.811	2.057	0.762
Spain	60.534	58.143	62.925	**<0.001**
Sweden	-390.759	-405.954	-375.564	**<0.001**
Switzerland	31.418	26.906	35.929	<0.001
Togo	0.569	-1.683	2.820	0.621
Turkey	0.304	-1.881	2.489	0.785
Ukraine	0.000	-2.230	2.230	1.000
United Arab Emirates	-1.776	-5.082	1.530	0.293
United Kingdom	52.598	50.135	55.061	**<0.001**
United States	824.504	821.704	827.304	**<0.001**
Uzbekistan	0.000	-2.376	2.376	1.000
Government Effectiveness	0.000	-1.175	1.175	1.000
Argentina: Government Effectiveness	-0.026	-1.382	1.330	0.970
Austria: Government Effectiveness	14.391	12.348	16.435	**<0.001**
Belgium: Government Effectiveness	-15.200	-16.504	-13.897	**<0.001**
Benin: Government Effectiveness	0.866	-0.527	2.258	0.224

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Variable	Coefficient	2.5%	97.5%	*p*-value
Bermuda: Government Effectiveness	1.332	0.072	2.592	**0.039**
Brazil: Government Effectiveness	1.768	0.375	3.160	**0.013**
Burkina Faso: Government Effectiveness	-0.168	-1.992	1.657	0.857
Canada: Government Effectiveness	-69.467	-71.384	-67.549	<0.001
Cayman Islands: Government Effectiveness	-54.785	-58.176	-51.394	**<0.001**
Chile: Government Effectiveness	-6.319	-8.313	-4.326	**<0.001**
Colombia: Government Effectiveness	-0.200	-2.079	1.679	0.835
Costa Rica: Government Effectiveness	-0.191	-3.160	2.777	0.900
Czech Republic: Government Effectiveness	0.000	-2.343	2.343	1.000
Denmark: Government Effectiveness	17.269	14.852	19.686	**<0.001**
Dominican Republic: Government Effectiveness	0.000	-2.178	2.178	1.000
Finland: Government Effectiveness	-7.992	-9.767	-6.217	<0.001
France: Government Effectiveness	-369.428	-371.221	-367.636	**<0.001**
Georgia: Government Effectiveness	0.166	-1.170	1.501	0.808
Germany: Government Effectiveness	-122.158	-123.588	-120.728	**<0.001**
Greece: Government Effectiveness	1.068	-0.479	2.614	0.177
Guatemala: Government Effectiveness	-0.106	-2.748	2.536	0.937
Guinea-Bissau: Government Effectiveness	0.080	-1.390	1.550	0.915
Honduras: Government Effectiveness	0.081	-1.362	1.523	0.913
Hungary: Government Effectiveness	0.553	-2.082	3.187	0.681
Iceland: Government Effectiveness	0.427	-1.968	2.822	0.727
Ireland: Government Effectiveness	-3.905	-5.338	-2.472	**<0.001**
Israel: Government Effectiveness	0.000	-1.475	1.475	1.000
Italy: Government Effectiveness	-38.615	-40.659	-36.572	<0.001
Latvia: Government Effectiveness	0.177	-1.459	1.812	0.833
Liechtenstein: Government Effectiveness	0.435	-1.898	2.769	0.715
Lithuania: Government Effectiveness	-0.363	-2.182	1.456	0.696
Luxembourg: Government Effectiveness	42.479	40.525	44.433	<0.001
Mali: Government Effectiveness	-0.554	-2.219	1.112	0.515
Mauritius: Government Effectiveness	-10.068	-11.756	-8.380	**<0.001**
Mexico: Government Effectiveness	1.244	-0.066	2.555	0.064
Netherlands: Government Effectiveness	-468.090	-473.292	-462.888	<0.001
Nigeria: Government Effectiveness	0.043	-1.507	2.240	0.962
Norway: Government Effectiveness	11.680	-1.736	1.823	**<0.001**

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Variable	Coefficient	2.5%	97.5%	*p*-value
Panama: Government Effectiveness	-0.093	9.493	13.867	0.898
Paraguay: Government Effectiveness	0.134	-1.521	1.335	0.836
Peru: Government Effectiveness	1.649	-1.139	1.408	0.061
Poland: Government Effectiveness	-0.696	-0.073	3.371	0.333
Portugal: Government Effectiveness	-0.225	-2.103	0.710	0.760
Romania: Government Effectiveness	0.000	-1.669	1.219	1.000
Russia: Government Effectiveness	0.106	-1.368	1.368	0.883
Nigeria: Government Effectiveness	0.043	-1.298	1.510	0.962
Saudi Arabia: Government Effectiveness`	0.000	-1.972	1.972	1.000
Senegal: Government Effectiveness`	0.266	-1.027	1.558	0.687
Serbia: Government Effectiveness`	-1.286	-4.365	1.794	0.414
Seychelles: Government Effectiveness`	0.033	-1.837	1.904	0.972
Slovenia: Government Effectiveness`	0.348	-1.380	2.075	0.694
South Africa: Government Effectiveness	1.422	-2.153	4.996	0.436
Spain: Government Effectiveness	-50.403	-51.894	-48.913	**<0.001**
Sweden: Government Effectiveness	232.310	223.430	241.191	**<0.001**
Switzerland: Government Effectiveness	-14.883	-17.158	-12.609	**<0.001**
Togo: Government Effectiveness	0.502	-0.786	1.789	0.446
Turkey: Government Effectiveness	-0.976	-2.342	0.389	0.162
Ukraine: Government Effectiveness	0.000	-1.573	1.573	1.000
United Arab Emirates: Government Effectiveness	1.388	-0.723	3.498	0.198
United Kingdom: Government Effectiveness`	-31.823	-33.214	-30.431	<0.001
United States: Government Effectiveness	-524.478	-526.147	-522.809	**<0.001**
Uzbekistan: Government Effectiveness	0.000	-2.016	2.016	1.000

Reference country value: Andorra

We must emphasise that, statistically, there is no reason why the results (ratios) should not be negative. An increase in WGI may negatively impact the value of GB, especially in rich countries. However, the overall model should be taken into account here. First, the situation in the qualitative models is that we compare country results to something which is (relatively) wealthy, Andorra in this case. Second, looking at a specific country, we can see that its impact on the size of GB (the sum of the coefficients for the country and the interaction component [B + C]) is positive in the largest economies. That is,

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not so much the WGI itself, but the influence of the WGI on GB is heavily moderated by the country, in which it is tested.

To use a more systematic approach, we shall apply the panel data model with random effects (as p-value < 0.001 in Hausman's tests and p-value < -0.001 in Lagrange multiplier test imply that random effects model is better than both Ordinary Least Squares (OLS) model and fixed effects model). The parameter *index* tells us to use fixed effects based on country and year variables.

The following table presents the results of such estimation. We see that WGI is a statistically significant variable (p=0.02). The coefficient 1.908 (next to WGI) represents the average effect of WGI over GB total value, when WGI changes across time and between countries by one unit.

Table 4. Panel model for the relationship between GB and WGI (2014-2020)

Variable	Coefficient	2,5%	97,5%	*p*-value
Intercept	1.544	-0.259	3.346	0.093
WGI	1.908	0.307	3.509	0.02

Discussion, limitations, and future research

The essence of new public governance focuses on financial markets, including capital market instruments, partnership and understanding, and even co-management with private investors, instigating the measurable impact of implemented investment projects. Our results have shown that investors should consider incorporating the level of governance effectiveness indicator before issuing bonds. That is a background for creating a trade-off between public partners' aims and private investors' expectations. Such cooperation depends on the level of effectiveness of governments. If the government improves the effectiveness of its management, it can count on investors' interest in the green finance instruments market. It is typically crucial for environmental investments and financing with GB, where the investment return period is extended. Time is necessary to obtain measurable ecological effects. The effects of the investment environment financed with such instruments are usually visible within a few years from the completion of the investment. All the more so, the quality of government, public policy, and, thus, government effectiveness is crucial to ensuring the long-term stability of the financial market and economic situation. A government's effectiveness over the long term gives the creditability of stable market conditions to conduct investments. At the same time, there is a trade-off between public and

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private partners' (investors') expectations. Stable market conditions based on a credible assessment of the effectiveness of governments contribute to the achievement of the goals of investors and public authorities. Furthermore, the public partner cannot only require or commission public tasks to be performed by the private partner. "Steer not row" under NPM (Osborne, 2006) means, in our case, not only demanding specific tasks from the project's private partner, but also the appropriate efficiency level in public partner activities.

Our research widen the results from Tara (2015), confirming that developed countries with a high WGI government effectiveness index use green instruments to a greater extent, here in the example of the GB. The established relationship between the increase in WGI and the increase in GB may be a trigger for developing countries. According to Tu's (2015) studies, if these countries manage to improve the efficiency of their governments, they will be able to attract investors for environmentally friendly investments. Moreover, it is not only the promotion of green instruments by the government, as stated by the cited authors of Jiguang and Zhiqun (2011), that is important. Due to our results on the part of governments, measures are necessary to increase the efficiency of public management. Yamahaki et al. (2020) state that economic and legislative barriers affect investors' interest in using green finance instruments. The quality of governance is directly related to the transparency and stability of legislative principles. What we have proven translates directly into the value of the issued bonds.

One could argue further that there are ratings of countries' economies. They enable investors in the financial markets to assess the stability of their potential investments. However, our study points to a narrower view of the effectiveness of governments translating into a limited group of financial instruments, such as GB. Thus, such a relationship is gaining importance for a specific green finance sector. Regardless of the type of economy, the WGI efficiency index is calculated according to the same methodology. This makes it possible to analyse the impact irrespective of the broader context of the state of economies or the stage of development of financial systems.

Conclusions

These research results indicate a statistically significant correlation between the quality of a government, measured as governance effectiveness, and the value of green bond issuances. Thus, from a scientific perspective, it is recommended for developing countries under New Public Governance to increase the effectiveness of their functioning. From a practical standpoint, the presented results may contribute to greater investor interest in environ-

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mental projects and a better assessment of the quality of a government and thus promote broader access to green finance instruments, including GB.

In light of these results, public actors should take care of the quality of public management, as it may contribute to increasing interest in green finance instruments for implementing pro-ecological investments. It has rarely been highlighted that the effectiveness of governance influences green investments. Here, the concept of governance effectiveness was measured using the WGI indicator, which considers the quality of public services, public service capacity and its independence from political pressures, as well as the quality of policymaking. Thus, public entities and local authorities should be aware of the WGI Index and use this to increase the interest of green finance investors.

It is necessary to further develop science in assessing the impact on the environment of investments implemented with the use of green bonds. The implementation of this type of investment alone cannot be considered a success. It is necessary to find the right measure, the actual impact on the environment, in the shortest possible time. It is essential, e.g. for capital recipients, to obtain more favourable financial conditions for implementing projects with a positive environmental effect. Kociemska (2021) writes about indicating a simple way of assessing the impact of the investment on the local community by using social impact bonds as an incentive-compatible mechanism of *"profit write-off"* for social purposes. Here, too, the governments of individual countries should play a key role in stimulating the development of financial markets and, at the same time, developing their public management effectiveness, including the reliable assessment of the effects of this management.

Considering the limitations of this study and developing trends in the GB market, we aim to deepen our research in the future. We want to determine whether there is a relationship between GB issuances and the Human Development Index in low- and middle-income countries. We can observe that these countries are struggling with ecological stratification (Obeng-Odoom, 2020). Considering that a government's effectiveness may tempt green-finance investors, as was suggested by the results of our study, there is a need to measure if a real impact of GB issuance exists and influences social welfare, particularly in low- and middle-income countries.

The contribution of the authors

Conception, H.K.; interpretation of data, H.K. and R.P.; literature review, E.F., E.S.-P. and M.R.; analysis, R.K., P.R., R.P., K.B. and B.P.; acquisition of data, E.F., M.R. and R.P.; editing, K.B. and B.P.; presenting impications, H.K.; concluding, H.K. and E.S.-P.

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ECOSYSTEM SERVICES CONTRIBUTING TO LOCAL ECONOMIC SECTORS – CONCEPTUAL FRAMEWORK OF LINKING ECOSYSTEM SERVICES, BENEFITS AND ECONOMIC SECTORS

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ABSTRACT: The paper introduces the principles of the System of Environmental-Economic Accounting-Ecosystem Accounting. The aim of the work is to present the application of the conceptual framework of linking ecosystem services, benefits and economic sectors. The analysis relates to year 2012 and 2018. The case study area represents five municipalities that cross borders with the Ślężański Landscape Park and its buffer zone in the Lower Silesia region in Poland. Results show that cropland related ecosystem services contribute to 17% and 14% percent of all companies operating in the case study area. Direct link between agricultural benefits and five economic sectors was established. The ecosystem extent account is created, and the land cover flows analysed. The applicability of ecosystem accounting to local governance is discussed.

KEYWORDS: SEEA EA, natural capital, ecosystem accounting, ecosystem services, protected area

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Introduction

The concept of ecosystem services has gained a lot of attention as it proved to be useful in explaining complex human-environment relations and supporting local decision making. The ecosystem services (ES)' most common definition is that ES are benefits that people obtain from nature (MEA, 2005). However, as many ES have been researched, it became prominent that there any only a few ES that brings pure benefits without human intervention. Most of the time, humans enhance, support, or modify ecosystems to supply more benefits in terms of volume and diversity. Some ecosystems are highly transformed and controlled by humans, for instance, agricultural land, and the ES of food provision is highly dependent on human inputs into food production. Therefore, the definition of ES has been slightly modified into "ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activity" (United Nations, 2021a). This definition directly links ES to benefits that are used by humans in their economic activities or for their wellbeing. From this point, we can start assessing the contribution of ES to economic sectors or GDP that is in line with the System of National Accounts. However, the relationship between the environment and economy is complex and difficult to put into tables (Becla, 2013). The statistical framework for integrating biophysical information of ecosystems, the ES measuring methods, compiling biophysical and economic accounts, and linking it to human economic activities has been a challenge for many years. Recently, the attempts to accept the international statistical standard of accounting for ecosystem services have been successful. The work of international experts within the System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA) has brought significant developments in the methods concerning natural capital accounting. The System of Environmental-Economic Accounting (SEEA) is coordinated by the United Nations Statistical division as it represents a statistical system that combines environmental and economic information to describe both natural and economic capitals with the same units and measurements. The overarching aim of the system is to support decision making for sustainable development and provide more holistic information about the economic performance. The global consultation on the SEEA Ecosystem Accounting (EA) involved many scientists from around the world representing many different fields of expertise. The transdisciplinary character of the ecosystem services (Mizgajski et al., 2014) requires knowledge and skills from many scientific disciplines. The SEEA EA framework includes the following steps: first to identify ecosystem assets, their condition, then ecosystem services generated by the asset, and then the benefits and beneficiaries. The accounts created as the result of

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applying the SEEA EA are: ecosystem extent and condition accounts, ecosystem service supply and use tables both in biophysical and monetary terms and ecosystem asset accounts (United Nations, 2021b). The SEEA EA provides basic guidelines on how to measure the supply of ecosystems services and attribute it to direct use of them by economic units/sectors. The attribution of ES' contribution to a specific sector is supported by the logic chains frameworks (SEEA website), but still case studies are needed to better understand how local implications should be considered in the natural capital accounting. In this contribution, we present the application of a conceptual framework of ecosystem services, benefits and economic sectors to a case study of Ślężański Landscape Park. This case study draws from previous experiences and contributes with subregional assessment and conclusions. The ecosystem extent accounts are presented, and based on that, the potential ecosystem services and benefits are explored, and economic sectors are attributed.

This is one of the very few case studies in the scientific literature that analyse the ecosystem accounting at the subregional scale (Hein et al., 2020a). Most of the SEEA EA applications are provided at the national (Hein et al., 2020b) or international scales (Vallecillo et al., 2019a). For the European case studies, the ecosystem extent assessment can be linked to the mapping and assessment of the ES (Maes, 2016). The ecosystem condition could be described by indicators reflecting the quality of the ecosystems (Keith et al., 2020). The ecosystem extent for the European case studies is often based on the Corine Land Cover (Farrell et al., 2021; Vallecillo et al., 2019b)we present results from a catchment case study in Ireland, highlighting findings specifically in relation to the development of ecosystem extent and condition accounts. In the absence of a national ecosystem map, CORINE landcover mapping formed the basic data for extent and type of ecosystems, distinguishing woodlands and forest, peatland and heathland, grasslands and cropland and urban areas, with limited coverage of linear freshwater rivers, hedgerows and coastal ecosystems. Additional remote sensing data provided higher resolution at catchment scale, while limited site-level survey data were available. Condition data gathered for reporting under the EU Water Framework Directive were available at sub-basin level for surface waterbodies. Data were available at national level for habitats reported for the EU under the Habitats Directive (59 habitats reported as it provides data for regular time frames (2000, 2006, 2012, 2018) and enables comparisons. Ideally, national data sets (like in the Netherlands) and more precise satellite images are welcomed for the local and subregional case studies (Solon et al., 2017). However, for the case study in Lower Silesia at the time, the Corine Land Cover is the only option.

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Case study area

The case study area represents five municipalities that cross borders with the Ślężański Landscape Park and its buffer zone in the Lower Silesia region in Poland. We do not consider in this study the sixth municipality that borders the Landscape Park – Świdnica, due to the very small share of intersected land. The municipalities included are as follows: Sobótka, Marcinowice, Łagiewniki, Dierżoniów, Jordanów Śląski. The total number of inhabitants of these municipalities in 2018 was 50435. The municipalities are located at the peri-urban areas of the city of Wroclaw, which is the main economic and developmental centre of the region. Two out of five municipalities belong to the Wroclaw County. The heart of the case study area – Ślęża mountain – is located about 40 km from Wrocław.

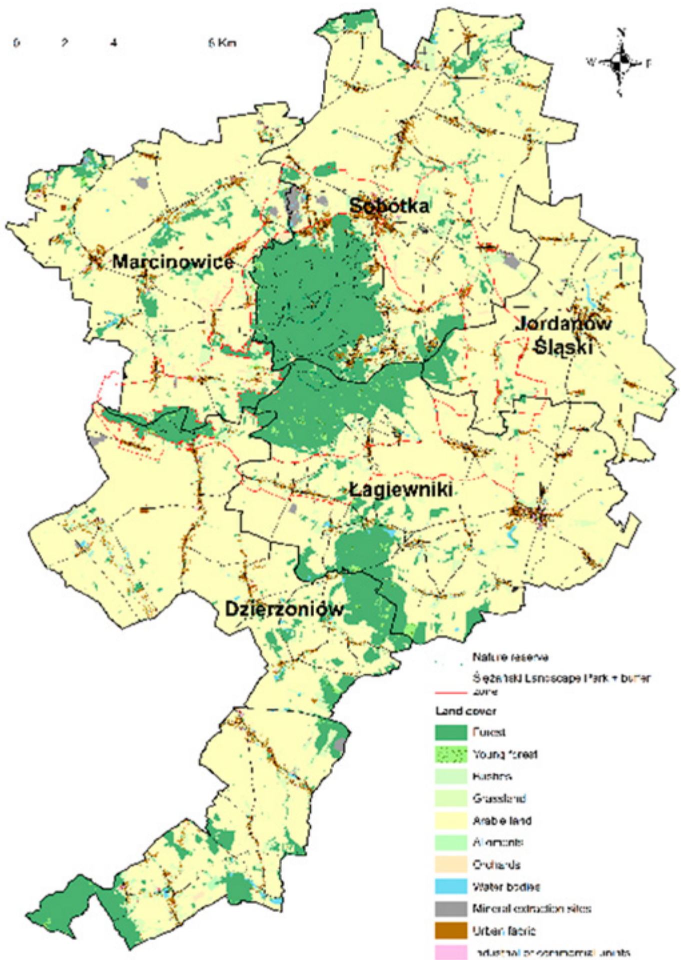

Figure 1. Case study area: land use and protected sites. For the location of the municipalities in Poland, please refer to Figure 3. Basemap: BDOT10k

Source: author's work based on geoportal.gov.pl [20-10-2022].

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The Ślężański Landscape Park was established in 1988 and covers mainly the area of the Śleża massif. The mountain Ślężą is the highest point in the landscape of the park and municipalities, reaching the height of 718 m a.s.l. There are three nature reserves within the borders of the Landscape Park: Mountain Ślężą, Radunia and Sulistrowice meadow. The Ślęża Mountain is a popular spot for one day outdoor recreation for many inhabitants of Wrocław, but it also attracts recreators from all over the Lower Silesia region and few from beyond. The landscape of the Park and municipalities is mainly agricultural, with forest covering the slopes of the main hillsides (Figure 1). The housing estates are located along roads and concentrate around bigger towns, such as Sobótka.

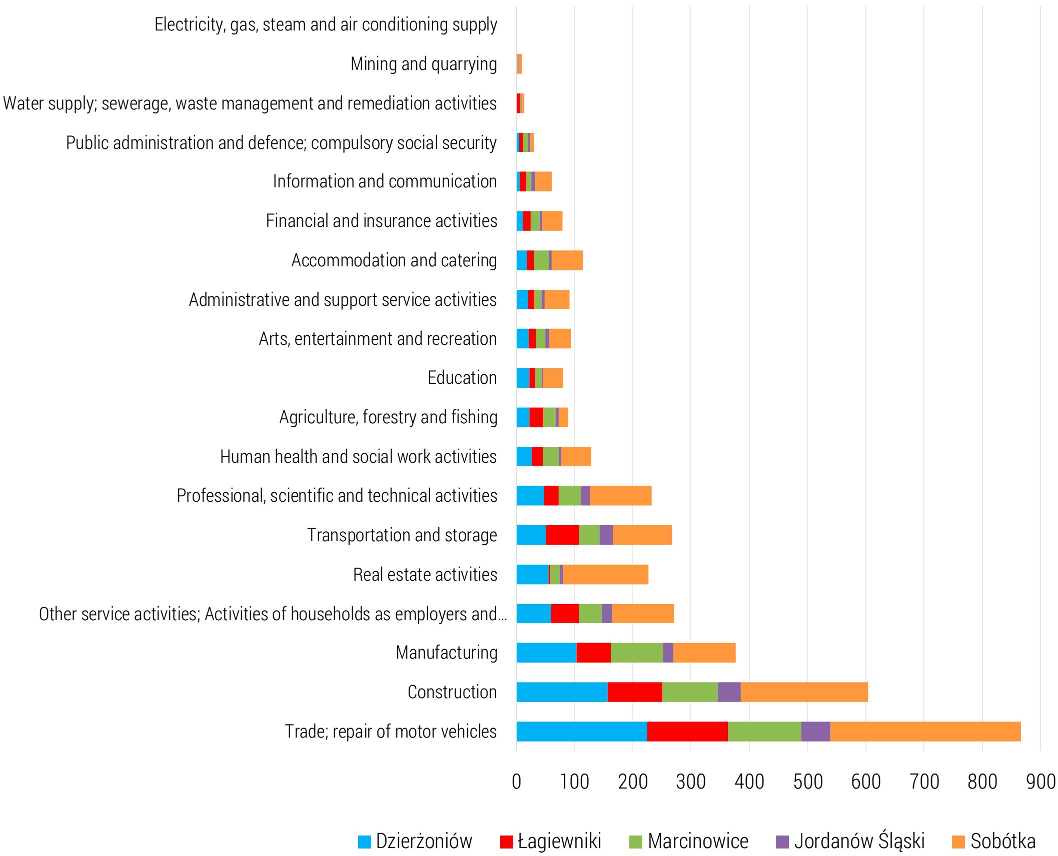

Figure 2. Number of companies by economic sectors in 2018 in case study municipalities
Source: CSO [20-10-2022].

The local economy seems to develop in the typical peri-urban way: the agricultural land is transformed into detached housing, the manufacturing outnumbers the services, and the construction sector is the strongest. In terms of the number of companies by economic sector in the case study area, there is a slight increase, however, the structure is stable. According to the International Standard Industrial Classification of economic activities, the biggest number of companies operated in 2018 within section G – trade and repair of motor vehicles, followed by section F – Construction (Figure 2) in the case study municipalities. The third most popular section was manufacturing. The biggest number of service companies operating within sections: H – transportation and storage, M – Professional, scientific and technical activities L – Real estate activities.

The economic enterprises located in the case study municipalities are mainly small companies (Table 1). About 97% of all economic entities employ less than 9 people. Most of them are single-person businesses. The Sobótka municipality hosts the biggest number of companies. The number of companies is increasing in all municipalities, which is related to the rising number of inhabitants.

Table 1. Economic entities by size classes per 1000 population total (2012 and 2018)

Municipality	0 – 9		10 – 49		50 – 249		250 – 999		>=1000	
	2012	2018	2012	2018	2012	2018	2012	2018	2012	2018
Dzierżoniów	76.7	91.9	2.1	2.2	0.1	0.1	0	0	0	0
Łagiewniki	63.5	70.9	3.2	2.7	0.3	0.3	0	0	0	0
Marcinowice	75.5	87.6	3.9	3.4	0.2	0.2	0	0	0	0
Jordanów Śląski	61.8	66.8	2.9	2.2	0	0	0	0	0	0
Sobótka	97.6	109.3	2.9	2.6	0.6	0.5	0	0	0	0

Source: CSO [20-10-2022].

Interestingly, the number of people employed in the municipalities is, except for Sobótka, lower than the number of companies, according to CSO. This is the result of the self-employment, the small size of the companies, as well as attracting employees from other municipalities.

The information about the GDP is available in Poland at the NUTS 1 (macroregions), NUTS 2 (regions) and NUTS3 levels (selected subregions – mainly biggest cities). As GDP at the municipality level is not publicly communicated, other indicators reflecting economic development could be used to assess the level of economic performance within administrative units. For this purpose, the G-index – basic tax revenue per capita of the municipality adopted for the calculation of the equalisation subvention is used. According to the Law on Income of Local Government Units, the G-index for each municipality is calculated by dividing the amount of tax revenue by the number of residents. Tax revenues of the municipality come from property tax, agricultural tax, forest tax, tax on means of transportation tax and tax on civil law activities, proceeds from stamp duty and mining fee, share in proceeds from personal income tax and share of income tax revenue from legal entities. The more taxed activities are happening within the boundaries of the municipality, the higher the G-index while keeping the number of inhabitants constant. In 2018, the case study municipalities belonged to rather less wealthy municipalities in terms of tax revenue per capita (Figure 3). The closer to the city of Wrocław, the higher the tax revenue per capita. Figure 3 illustrates the spatial influence of Wrocław on surrounding municipalities. The Ślężą Landscape Park is located further south of this influence. The further away in the southern direction, the less of the tax revenue per capita is available in the municipalities' budgets.

Table 2. Number of people employed and the total number of companies (2012 and 2018)

	Number of people employed		Number of companies	
Municipality	2012	2018	2012	2018
Dzierżoniów	640	789	738	861
Łagiewniki	462	627	505	550
Marcinowice	443	481	515	591
Jordanów Śląski	189	274	203	218
Sobótka	1581	1714	1296	1442

Source: CSO [20-10-2022].

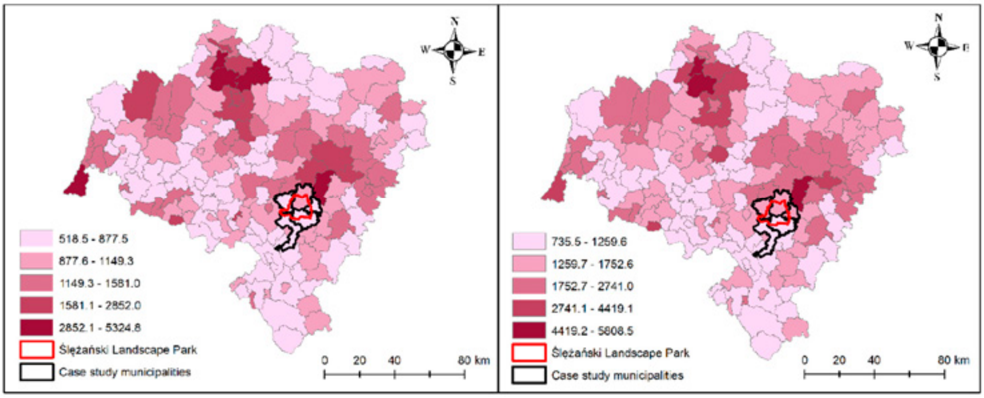

Figure 3. G-index – Tax revenue [PLN] per capita of the municipality in 2012 and 2018 for all municipalities of the Lower Silesia Region

Source: author's work based on data from the Ministry of Finance [20-10-2022].

Conceptual framework of ecosystem services, benefits and economic sectors

The conceptual framework for the assessment of the ecosystem services, benefits and beneficiaries is based on the logic chain. This framework starts from the ecosystem type that can be described by the spatial extent (e.g. in ha) and the condition (Figure 4). Very often, ecosystem type corresponds to land cover or land use. As it is described in the scientific literature by (Affek, 2018)the value of any ecosystem can be determined on the basis of its potential (capacity. various ecosystem types have the potential to provide different ecosystem services. The actual use of ecosystem service brings benefits, which could be of direct or non-direct use (Bernués et al., 2014; Häyhä et al., 2015). The benefits are enjoyed by the beneficiaries who might represent different economic units, such as governments, society or individuals and private and public companies grouped according to the type of their main activities into different economic sectors (Figure 4). One of the internationally accepted classifications is ISIC.

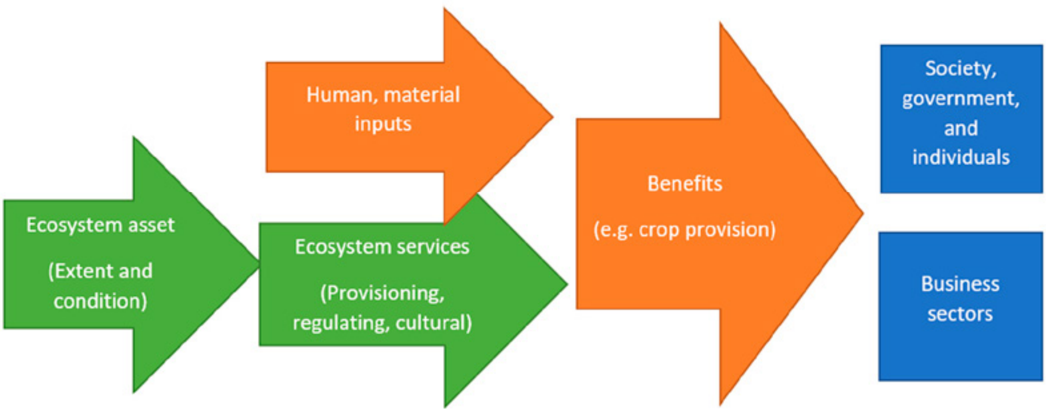

Figure 4. Conceptual framework

Source: author's work based on Keith et al. (2017).

Although the framework might seem straightforward, its practical implementation might cause difficulties (Sylla et al., 2021)its application is constrained by challenges distinct across specific implementation contexts, including those present in developing nations. In this paper, we focus on a pilot SEEA EEA application in a local-scale case study in Kyzyl Unkur, Jalal-Abad region, the Kyrgyz Republic, characterized by a unique natural walnut forest. We summarize key methodological and empirical challenges identified through collaboration with local experts and stakeholders during the compilation of Supply and Use tables for selected ecosystem services (ES. While there are a lot of guidelines in the scientific literature (Yang et al., 2021) and grey literature (Burkhard et al., 2018) about the potential of different ecosystem types to provide ecosystem services, the link between benefits and economic units remains understudied. Ecosystem accounting might contribute to explaining the connection between the environment and the economy in different ways. Firstly, the aim is to consistently report information on the environment with the same units as the metrics of GDP. Therefore, the link between benefits helps to better present the welfare of nations, both in terms of direct and indirect use values (La Notte et al., 2022). The second need refers to between assessment of risk exposure of economic activities that depend on ecosystems, e.g. because of the ecological input to production, or the removal of negative externalities, and the protection from natural hazards (La Notte et al., 2022). Although the dependency of economic capital on natural capital has been widely discussed in reference to sustainable development (King et al., 2021), the ecosystem contributions need to be clearly assessed. The third need of estimating the flow of ES in monetary terms refers to the biodiversity financial gap, which is especially useful in cost-benefit analysis (Becla et al., 2012).

Results of the research

In order to be consistent with the aims of accounting, the Corine Land Cover data was to estimate the ecosystem extent and its changes. The magnitude of landscape changes in comparison to other Landscape Parks in Poland is average (Krajewski, 2019) but the areas within the landscape park still have economic uses. Therefore, the monitoring of landscape changes within landscape parks is necessary in order to properly manage these forms of protection. The main objective of the study was to monitor the scale and nature of landscape transformations within the boundaries of landscape parks in Poland during the period 2000–2018 and to assess the possibility of using the landscape change index (LCI. The biggest flows are observed within the forest cover (245 ha) and are related to forest cuttings. The mineral extraction site was extended by 5 ha on the expense of non-irrigated arable land (Table 3). Sankey chart in Table 3 presents the source land cover type and what type it was changed into. Due to the high resolution (25m) of the data, the changes in the discontinuous urban fabric are not observed. However, the peri-urban areas experience intense housing pressures related to the process of urban sprawl.

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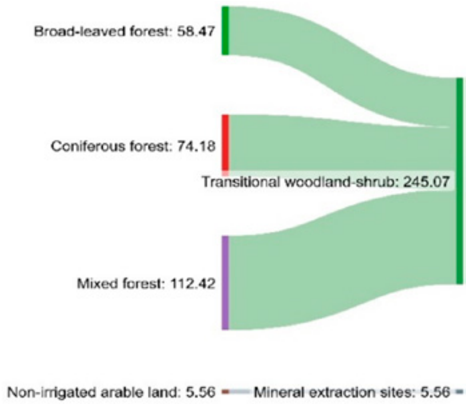
Table 3. Ecosystem extent and land cover flows between 2012 and 2018

Land cover type	2012	2018	Land cover change flows
Discontinuous urban fabric	847.020	847.020	
Mineral extraction sites	107.087	113.048	
Non-irrigated arable land	8372.413	8366.452	
Pastures	171.069	171.069	
Complex cultivation patterns	375.298	375.298	
Land principally occupied by agriculture, with significant areas of natural vegetation	784.807	784.807	
Broad-leaved forest	1269.036	1210.609	
Coniferous forest	1182.129	1107.949	
Mixed forest	2543.591	2431.166	
Transitional woodland-shrub	45.0493	290.110	



The ecosystem types have certain potentials to provide ecosystem services (Burkhard et al., 2010; Jacobs et al., 2015). As the arable land is the dominant ecosystem type in the case study are, we are going to take a closer look into the links between this ecosystem, ecosystem services and benefits, as well as beneficiaries (Table 3). Cropland ecosystem may provide various services (Power, 2010), belonging to all three types of ecosystem services: provisioning, regulating and cultural. The main provisioning service is food provision. The benefiting sectors from food provision is primarily the agricultural sector (Hełdak et al., 2022). Food is further processed, distributed, served and sold via food chains which are part of the economy. However, in order to avoid double accounting for the same benefit or product, the sector at the benefit's entry point to the economy is reported. Regulating services of arable land most often mention in the scientific literature are pest control, pollination, nutrient re/cycling, soil conservation, structure and fertility, water provision, quality and quantity and carbon sequestration. These bring benefits to the agricultural sector mainly, but also to water supply, sewage and waste management. Arable land could also provide cultural services, aesthetics being one of them (Table 4). The aesthetics are difficult to attribute to a specific sector they influence the most directly. However, based on the hedonic pricing experiences (Chwiałkowski & Zydroń, 2021; Sylla et al., 2019), we learn that aesthetic play an important role in the real estate businesses by influencing the price of housing estates. In the case study area, the aesthetics may also influence the artistic activities of small businesses which belong to the category of arts, entertainment, and recreation (Table 4).

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Recreational benefits can be linked to the sector of accommodation and catering, however, only in the part of the accommodation.

Table 4. Example of application of the theoretical framework

Ecosystem type	Ecosystem service type	Ecosystem service	Benefit	Benefiting sectors (CEIDG)
Cropland	Provisioning	Food provision	Crop provision	Agriculture
	Regulating and Maintenance	Soil retention control	Prevention of soil erosion	Agriculture
		Pollination	Crop provision	Agriculture
		Water storage	Water retention	Agriculture, water supply sewage and waste management
	Cultural	Aesthetic/ cultural	Aesthetic landscape	Real estate activities;
		Recreation	Recreation	Arts, entertainment, and recreation; Accommodation and catering

The benefiting sectors constituted 17% in 2012 and 14% in 2018 of all economic entities in the case study municipalities (Table 5). In the case study, the decrease in the contribution of the ecosystem stems from the pluming numbers of individual farmers. There is a country-wide trend of the falling number of farmers that follows that decrease in the number of small farms (Ambros & Granvik, 2020). The number of companies in the primary sector of agriculture, forestry and fishing dropped by half, and so did the percentage of all companies. Although there is a nominal increase in companies in sectors of arts, entertainment and recreation, accommodation and catering and real estate activities, their share of the economic arena has not changed between the years 2012 and 2018 (Table 5).

Table 5. Estimating the direct impacts of benefits derived from nature to benefiting sectors

Benefiting sectors (CEIDG)	Number of companies in the sector 2012	Number of companies in the sector 2018	Percentage of all companies 2012	Percentage of all companies 2018
Agriculture, forestry and fishing	179	89	5%	2%
Water supply sewage and waste management	13	14	0%	0%
Arts, entertainment and recreation	83	94	3%	3%
Accommodation and catering	92	114	3%	3%
Real estate activities	203	227	6%	6%
SUM	570	538	17%	14%

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Discussion and conclusions

The aim of this work is to present the application of the conceptual framework of linking ecosystem services, benefits and economic sectors. The framework guides the assessment in a straightforward way. It starts with the ecosystem type that can provide certain ecosystem services. Scientific literature supports the choice of ecosystem services with a rich portfolio of case studies. It is also recommended to consult stakeholders and, with their help, identify the ecosystem services and benefits (Kowalska et al., 2017). The last step is linking the benefits with benefiting sectors. The linking strategy depends on the needs of the assessment. If the need is to evaluate the contribution of ecosystems to the local economy and create the satellite environmental-economic accounts, then the direct link to sectors may be guided by the SEEA EA logic chain. However, other needs of natural capital accounting (Comte et al., 2022) could be linked to the assessment of risk exposure of economic activities that depend on ecosystems and refers mainly to regulating ecosystem services. The third need may be related to closing the gap in financing biodiversity conservation with the use of different economic instruments (Maestre et al., 2012).

The presented application may be further developed for more detailed purposes of the analysis of the ecosystem services part of natural capital. The presented example uses publicly available data; therefore, the procedure could be repeated. However, there are certain limitations that needs to be acknowledged. Firstly, the number of companies only partially presents the economic situation of the municipalities (Przybyła et al., 2022). Moreover, the value added of the companies representing diverse sectors differs significantly. The precise contribution of ecosystems to sectors can be estimated with the use of different methods, such as the production function method (Grammatikopoulou et al., 2020), input-output analysis or with a separate methodological framework (Cerilli et al., 2020).

This paper is based on the SEEA EA, which refers to the ecosystem services part of the natural capital. There are several definitions of natural capital (Czaja, 2014; Dobrzańska, 2007; Pieńkowski, 2002), but all of them include natural resource stocks. In the presented case study, the mineral extraction site would enlarge the scope of results. On the other hand, this case study has not taken into consideration the depletion of the natural capital by degradation which is caused by the mineral extraction site. What is, however, included in the ecosystem extent accounts is the depletion of the forest cover. This would influence the provision of many ES, for instance carbon sequestration or erosion control.

To conclude, ecosystem accounting has a significant potential to serve as a tool to control the levels of natural capital. The principle of SEEA EA is to use available data to create information to support better informed decisions in spatial planning and governance (Spyra et al., 2020). Because of the fact that the conceptual framework presented in this article enhances understanding of the usage and dependence of local economy on natural capital, it can be useful to measure to the realisation of the sustainable development strategy of municipalities and understanding the conflict between environmental protection and economic development (Furmankiewicz & Potocki, 2004). However, as discovered by Stępniewska et al. (2018), the drivers of the implementation of ES concept in practice in Poland are mainly academic and international, it will be the European Union's legislative that drives the implementation of natural capital accounting in the country.

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KEY ECONOMIC SECTORS FOR GREEN JOB CREATION IN POLAND – AN EMPIRICAL ANALYSIS

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ABSTRACT: In this study, we employed a stepwise empirical approach to identify economic sectors and analyze the regional potential for green job (GJ) creation in Poland. We used the operating register of economic entities (REGON) and Polish Labor Force Survey (BAEL) data for the period between 2015 and 2022. The changes in REGON reflect a proxy of changes in GJ stock in sectors of economic activity (PKD-2007) and regions. We estimated trends and spatial diversification of green employment. The results revealed that Mazowieckie, Wielkopolskie, Małopolskie, and Śląskie are the most attractive regions for GJ creation. The polarization of green employment declined during the analyzed period, but spatial disparities were still significant. Most sectors noted increases in GJ, except for agriculture, where the downward trend in employment has a significant influence on the green labor market. Our findings may be useful when formulating policy recommendations for educational institutions, employment institutions, local governments, government institutions, investors, and employers.

KEYWORDS: green jobs, regional and sectoral potential for green job creation, sections of PKD-2007, REGON, BAEL, Polish voivodeships

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Introduction

Unemployment is one of Europe's most pressing problems. More than 13 million Europeans, i.e., more than 6% of the active population, were unemployed as of December 2022. In Poland, the number of registered unemployed reached 812,300, with the unemployment rate edging toward 5.2 percent. The highest unemployment rates were recorded in Spain (13.1%) and Greece (11.6%) (Eurostat, 2023). At the same time, the climate and environmental crisis is becoming increasingly serious. Europe has been warming at a faster rate than the global average (the global 1.1°C increase is already affecting natural and human systems) (IPCC, 2022). In 2020 in the European Union (EU), 96% of the urban population was exposed to levels of fine particulate matter above the health-based guideline level set by the World Health Organization (WHO). Taking no action will generate more morbidity and healthcare costs (European Environmental Agency, 2022). Activities aimed at reducing the economy's negative impact on the natural environment have been a priority for the European Union for years. More recently, this priority has been reinforced by the European Green Deal, which adopted the goal of achieving climate neutrality by 2050 (European Commission, 2021), the COVID-19 pandemic, and the outbreak of conflict in Ukraine. These events have influenced the dynamics of the green transition (Konfederacja Lewiatan, 2022). However, the post-pandemic recovery programs emphasize the role of green investors in returning economies to a path of sustainable economic growth. There is a growing body of evidence which shows that, when optimally allocating recovery funds between emission reduction and employment creation objectives, most European countries would invest over 50% of their energy-focused green recovery packages in financing solar photovoltaics and over 10% in the onshore wind (van de Ven et al., 2022). Moreover, in May 2022 the European Commission (EC) adopted the REPowerEU Plan. The program is the EU's response to Russian aggression and an opportunity to realize the green transition. It aims to rapidly reduce dependence on Russian fossil fuels by 2027, by putting a strong emphasis on greater use of renewable energy sources and pointing out the necessity to save on energy consumption. The EC's modeling of the plan suggests a pathway to meet the targeted 45% renewable energy share in overall total final energy consumption. Accounting for all renewable energy sectors, achieving the REPowerEU aims will require the creation of over 3.5 million jobs (including GJ) by 2030 (European Commission, 2023a).

Greening the economy provides high-quality green jobs to fight unemployment, while simultaneously combating climate change and environmental decline. The UN Environment Program defines the green economy as

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low-carbon, resource-efficient, and socially inclusive (UNEP, 2011). The International Labour Organization (ILO) broadly defines a green job as any decent job that helps preserve or restore the quality of the environment, whether it is in agriculture, industry, services, or administration (UNEP, 2008). It includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high-efficiency strategies; decarbonize the economy; and minimize or altogether avoid generating all forms of waste and pollution. The U.S. Bureau of Labor Statistics (BLS) defines green occupations more specifically, but not exclusively, as jobs in businesses that produce goods or provide services that benefit the environment or conserve natural resources. They include jobs in which workers' duties involve making production processes more environmentally friendly or ones using fewer natural resources (BLS, 2023a).

The impact of green economy activities and technologies is sufficient to create the need for unique work and worker requirements, thus generating new occupations. From a broad conceptual perspective, employment will be affected in at least four ways as the economy is oriented toward greater sustainability: 1) additional jobs will be created, 2) some employment will be substituted, 3) certain jobs may be eliminated without a direct replacement, and 4) many existing jobs will be transformed and redefined as day-to-day skill sets, work methods, and profiles are greened (UNEP, 2008). Therefore, there is a growing demand for both statistical data and conceptual guidelines on measuring green jobs (in terms of the size, composition and contribution of the specific groups of workers and economic sectors to the green economy).

This paper aims to identify the key economic sectors for creating green employment and assess the regional potential for creating green jobs in Poland. We use a replicable stepwise method to accurately gauge the green economy's size and rate of growth, and to identify the jobs associated with it.

An overview of the literature

The literature on green jobs presents a broad catalog of key terms associated with the concept. Green jobs are most often associated with sustainable development (Sulich & Zema, 2018), the circular and green economies (Battaglia et al., 2018; Sulich & Sołoducho-Pelc, 2021), welfare, the labor market, and green business (Song et al., 2021; Vesere et al., 2021), the renewable energy sector, and environmental protection (Martínez-Cruz & Núñez, 2021; Dell'Anna, 2021; Kozar et al., 2022). In those studies, a tool for effectively measuring green job creation was proposed, and green human resources management was conceptualized. Questionnaire-based research was also

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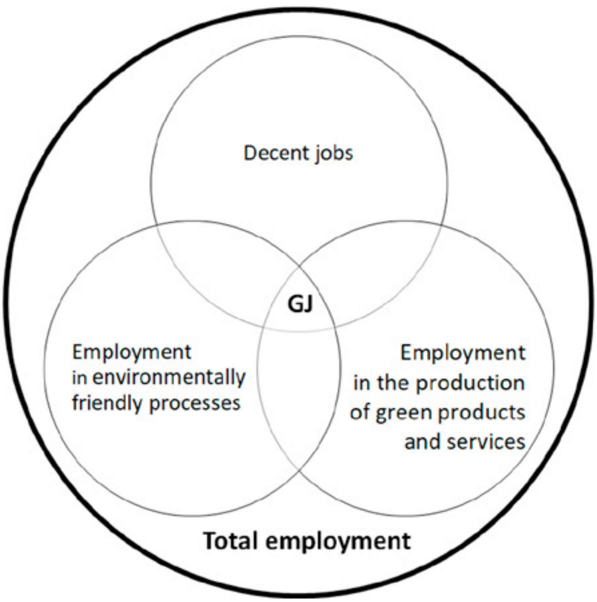
conducted to determine the barriers and socio-economic benefits that can guide policies relevant to attracting skills in green jobs and measuring the level of participation of women compared to men in green jobs (Afolabi et al., 2018).

At the academic level, the recent debate explores the ongoing green transition in selected economic sectors (Stanef-Puică et al., 2022). A fairly general discussion of the factors that influence the creation of green jobs is also discernible in the literature (Kozar et al., 2022). At the enterprise level, green jobs can produce goods or provide services that benefit the environment. They can also be distinguished by their contribution to more environmentally friendly processes (van der Ree, 2019). However, green jobs defined through production processes do not necessarily produce environmental goods or services (Sulich & Zema, 2018). Analysis of the ILO concept (ILO, 2016) of green jobs (Figure 1) which measures jobs in green economic sectors (sections) from an output perspective and job functions in all sectors from an environmentally friendly process perspective remains limited (ILO, 2022). Few researchers have investigated the Polish sectors that have the greatest potential to create green jobs.



Note: GJ – green jobs.

Figure 1. Green jobs in the ILO concept

Source: authors' work based on ILO (2016).

For example, based on the current Polish Classification of Activities (PKD) (GUS, 2023a). Sulich et al. (2020) defined the green sectors as A, C, D, E, and O therefore identifying. Possible ways in which green jobs can be used to solve youth unemployment problems in Poland, the Czech Republic and Belgium. Kryk (2014) and Kozar (2016) distinguished (sub)sections of the economy that are particularly important for creating green jobs with the PKD-2007 (Kryk: A, D, E, M, N, S and Kozar: A, C, D, E, F, H, I, M, N, P, S). However, these studies suggest theoretical case study research or actions necessary to stimulate the creation of green-collar workers.

In turn, the European Union (2016) proposed relatively general compilation methods to account for the environmental goods and services sectors (EGSS). They suggest using existing data sources to produce estimates for European countries over several years. However, their guide focuses only on the compilation approach, in particular, top-down techniques (European Union, 2016). They provide an ideal framework to collect data on employment that directly depends on the production of outputs intended to protect the environment and manage natural resources (extracted sections: A, C, D, E, F, M, O).

Identifying sectors with the greatest potential to create green jobs in Poland remains high on the list of priorities for Regional Operational Programs, for example, in the Śląskie (UMWŚ, 2015), Podlaskie (WUPB, 2012) and Warmińsko-Mazurskie voivodeships (UMWWM, 2017). The data were collected during a survey of selected entrepreneurs from green sectors and the results indicate that support for the development of qualifications of people in green jobs is particularly important from the point of view of developing these Polish regions properly.

The literature review reveals wide academic interest in defining and analyzing green jobs, both in macro and microeconomic terms. Research makes it possible to draw extremely valuable, but general conclusions for the economy. However, from the perspective of the problems that plague the Polish green labor market, it seems to be insufficient.

Research methods

After combining the aforementioned scientific discussion, EU regulations (Regulation, 2015), and ILO (2008) and BLS (Dierdorff et el., 2009) data presented in Figure 1, we suggest a detailed structural identification of selected sectors and class codes for green jobs in Polish voivodeships based on PKD-2007 (Table 1).

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Table 1. Economy codes according to PKD-2007 for green jobs in Poland

ECONOMY SECTORS	PKD 2007 – SECTIONS (S)	PKD 2007 - CLASSES (C)	DESCRIPTION
AGRICULTURE	A	AGRICULTURE, FORESTRY, HUNTING AND FISHING	
		01	crop and animal production, hunting, including service activities
		02	forestry and logging
		03	fishing and aquaculture
INDUSTRY	C	MANUFACTURING	
		26	manufacture of computer, electronic and optical prod-ucts
		27	manufacture of electrical equipment
		28	manufacture of machinery and equipment not else-where classified
		29	manufacture of motor vehicles, trailers and semi-trailers, excluding motorcycles
		33	repair, maintenance and installation of machinery and equipment
	D	ELECTRICITY, GAS, STEAM, HOT WATER AND AIR CONDITIONING MANUFACTURING AND SUPPLY	
		35	electricity, gas, steam, hot water and air conditioning manufacturing and supply
	E	WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES	
		36	water collection, treatment, and supply
		37	sewage disposal and treatment
		38	waste collection, processing, and neutralizing activities; materials recovery
		39	remediation activities and other waste management services
	F	CONSTRUCTION	
		41	construction of buildings
		42	works related to the construction of civil engineering
		43	specialized construction activities
SERVICES	I	ACCOMMODATION AND FOOD SERVICE ACTIVITIES	
		55.20	holiday and other short-stay accommodation
		56.29	other food service activities

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ECONOMY SECTORS	PKD 2007 – SECTIONS (S)	PKD 2007 - CLASSES (C)	DESCRIPTION
SERVICES	M	PROFESSIONAL, SCIENTIFIC, AND TECHNICAL ACTIVITIES	
		71	architectural and engineering activities; technical testing and analysis
		72	scientific research and development
		73.11Z	advertising agencies activities
		73.20Z	market research and public opinion polling
		75	veterinary activities
	N	ADMINISTRATIVE AND SUPPORT SERVICE ACTIVITIES	
		81.30	landscape service activities
	O	PUBLIC ADMINISTRATION AND DEFENSE; COMPULSORY SOCIAL SECURITY	
		84	public administration and defense; compulsory social security
	P	EDUCATION	
		85.31B	general upper secondary schools
		85.31C	specialized upper secondary schools
		85.32A	technical secondary schools
		85.32B	basic vocational schools
		85.32C	special job-training schools
		85.41Z	post-secondary schools
		85.42A	initial teacher training institutions and colleges of social work
		85.42B/Z	higher education institutions
	R	ARTS, ENTERTAINMENT AND RECREATION ACTIVITIES	
		91.04	botanical and zoological gardens and nature reserves activities
	S	OTHER SERVICE ACTIVITIES	
		94.99	activities of other membership organizations not elsewhere classified
		95	repair and maintenance of computers and personal and household goods

Source: authors' work based on Polish Classification of Activities (GUS, 2023a).

The approach presented in Table 1 identifies categories of green jobs. It also evaluates the volume of employment in them based on BAEL and comparable classification schemes, i.e., Statistical Classification of Economic

Activities in the European Community (NACE), Polish Classification of Activities (PKD) and the International Standard Industrial Classification of All Economic Activities (ISIC), (Figure 2). The identified sectors were also compared with the current list of occupations (existing or new) relative to the national and international occupational taxonomy (BLS, 2023b; European Commission, 2023b). Therefore, the classifications for green sections (Table 1) have established a link with the main standardized classifications for occupations of the ILO and BLS (Mannetje & Kromhout, 2003).

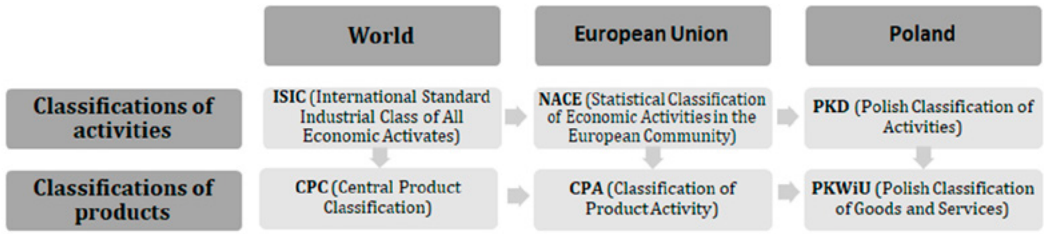

Figure 2. The system of statistical correspondence among economic classifications

Source: authors' work based on GUS (2023a).

The second stage of the empirical research was to estimate the values of green employment in the extracted classes and sectors of the economy. We based our analysis on statistics concerning the operating register of public economic entities of the national economy entered in the National Official Business Register (GUS, 2022a) classified into individual sectors and divisions (classes) of PKD-2007, as the REGON number in the sector is a direct determinant of employment (Grzywińska-Rąpca & Markowski, 2018). The employment values were extracted from the Labor Force Survey database (GUS, 2022b). We took the classification status from 1 January 2016, when there were 16 voivodeships (i.e., NUTS-2 regions) (GUS, 2023b). The volume of green jobs (GJ) in divisions and voivodeships was allocated according to the formula:

$$GJ_{c,v,t} = \frac{REGON_{c,v,t}}{REGON_{s,v,t}} \cdot E_{s,v,t}, \tag{1}$$

where: $REGON_{c,v,t}$ *and* $REGON_{s,v,t}$ are the numbers of entities in classes (c) and s (s) of PKD-2007, $E_{s,v,t}$ is the volume of employment, *index v* denotes the voivodeship, *t* is the time period.

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We conducted the research for the available period between 2015 and 2022. Employment for 2022 was estimated based on the REGON data. To compare trends in the data, we estimated the average annual least-squares growth rate (AGR) (World Bank, 2023). Finally, to take into account the uncertainty and sensitivity inherent in the analysis, robustness was checked by linking our outcomes with results from previous research using the Pearson correlation, as our data are normally distributed. To test the significance of correlation coefficients (6), we employed the t-distribution formula (Atoum, 2019). The collected data were analyzed using SPSS v. 20.

The study was based on the following research questions:

- What are the green employment trends in Poland?
- How are green jobs geographically diverse (regionalized)?
- What is the regional and sectoral potential for creating green jobs in Poland?

Answering these questions can help estimate and assess the potential for green jobs for the Polish economy from the regional and sectoral perspectives.

Research results

The average number of green employees in Poland in 2015-2022 was more than 5.5 million people, i.e., a 33.9% share of total employment (from over 16 million employed people). At the end of 2022, green sectors employed 5.55 million people (33.7%) – 74,078 fewer than in 2015. From a sectoral view, in 2015 and 2022, the greatest share of green employment was observed in sectors A (32.5% and 24.9%), F (22.2% and 24.9%), and O (19.0% and 20.3%). A decrease in employment from 2015 to 2022 was noted in sectors A, E, and P. The biggest decrease was in agriculture (7.6 pp), while the biggest rise was in construction (2.7 pp) (Figure 1).

Most sectors noted statistically significant annual increases in green job values during the period analyzed (2015-2022) and the coronavirus outbreak (2019-2022) (Table 2). Between 2015 and 2022, the strongest downward trend (AGR) in the GJ value was noted for sectors A (-3.5%) and P (-2.4%), but there was a growing positive slope in I (4.8%), S (3.5%) and D (2.8%). The highest peak in 2022 compared to 2015 was noted in I (62.8%). Agriculture and education saw the biggest drop: for A, it was -24.3%, and for P, it was -17.0%. We also observed that for the period 2019-2022, some sections (D, M, N, O, R and S) noted stronger positive changes in GJ compared to 2015-2018.

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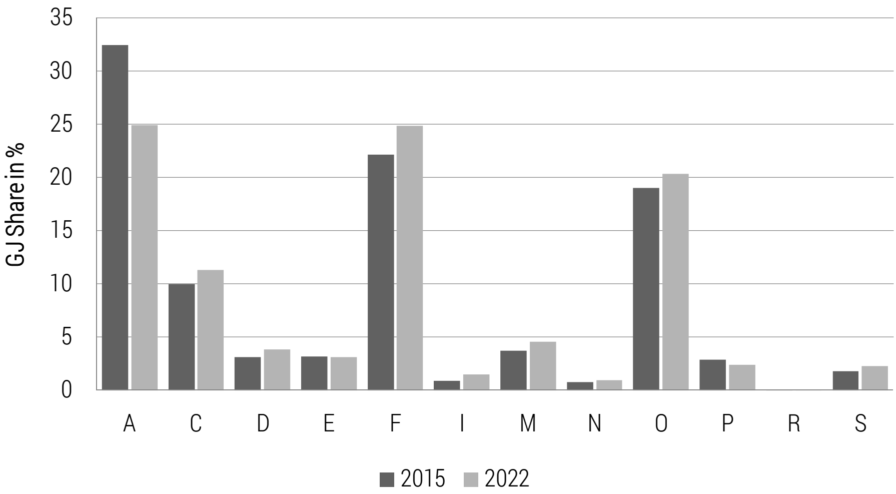


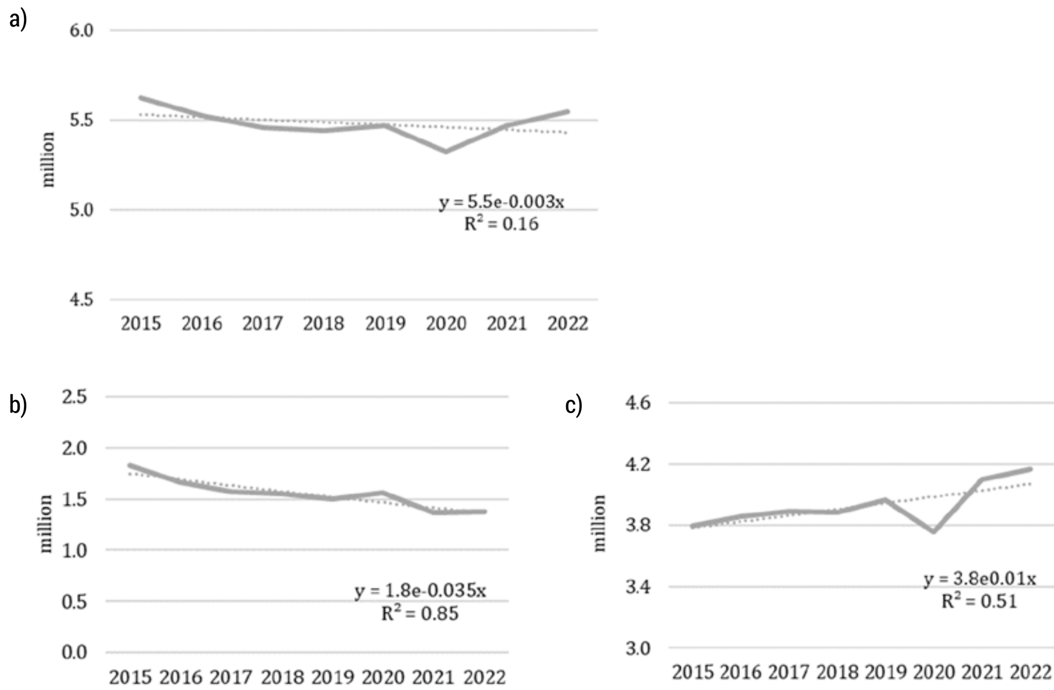
Figure 3. GJ employment shares in the economic sectors in 2015 and 2022 in %

Table 2. Sectoral changes in the number of green jobs between 2015 to 2022

Section	AGR in %		
	2015-2022	2019-2022	Change in % 2022/2015
A	-3.5***	-3.8**	-24.3
C	0.9*	1.2*	11.6
D	2.8**	9.4***	21.9
E	-0.5	-3.1***	-3.5
F	1.5**	0.6	10.7
I	4.8**	7.8*	62.8
M	2.6***	3.3***	20.7
N	2.1*	11.8***	17.2
O	0.1	4.7**	5.4
P	-2.4***	-2.2***	-17.0
R	-0.9	4.5**	2.2
S	3.5***	3.9***	25.0

Note: significance levels of the statistically significant slopes: * α = 0.10, ** α = 0.05; *** α = 0.01.

Data for the entire country show a weak downward trend (R^2=0.16) in green employment (-0.3%). However, data in Figure 3 and Table 2 indicate that the negative GJ slope is determined by a very strong, decreasing trend for the agriculture sector (R^2=0.85, AGR=-3.5%), with a much slower trend for P and R. The value of the slope for the trend without section A points to significant annual growth (1.0%) in green employment (R^2=0.51) (Figure 4).



Note: The average annual growth rate (expressed as a percentage) is the coefficient of b estimated from $y=ae^{bx}$, obtained as [exp(b)– 1]*100 (WB, 2023).

Figure 4. Green job trends in Poland, 2015-2022, in million people; a) green employment, b) green employment in section A, c) green employment without section A

The level of green jobs in Poland is spatially diverse (Figure 5). In 2015 and 2022, the highest shares of green employment were noted in Mazowieckie, Wielkopolskie, Małopolskie and Śląskie; the lowest were observed in Opolskie and Lubuskie. The regional disparities of green employment stock declined over the analyzed period, as the coefficient of variation decreased over time (from 55% in 2015 to 51% in 2022).

The highest positively growing slopes were observed in Zachodniopomorskie (2.7%), Warmińsko-Mazurskie (2.5%) and Wielkopolskie (2.1%) (Table 3). When analyzing data without section A, the strongest GJ growth trend was in Podkarpackie (4.4%). The greatest annual drop in GJ was noted in Łódzkie (with or without section A). Compared to 2015, the greatest

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increases in green jobs in 2022 were in Zachodniopomorskie (30%), Wielkopolskie (21%) and Śląskie (17%), while the highest decreases were in Łódzkie and Świętokrzyskie (-19%). During and after the COVID-19 pandemic (2019-2022), the annual decline for those years was noted in nine voivodeships, with the highest recorded in Łódzkie (including section A) and in Pomorskie, without employment in agriculture. In some regions, the pandemic diametrically changed the green employment market and determined the upward trend in GJ – positively in Lubelskie and Śląskie and negatively in Małopolskie and Podkarpackie.

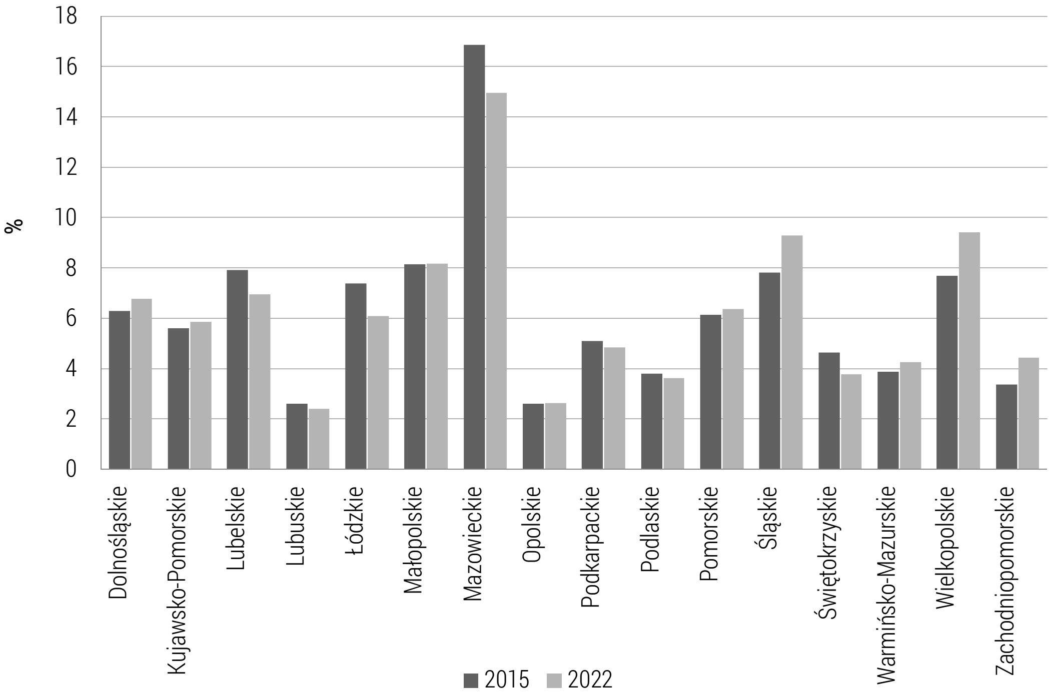

Figure 5. Share of green employment in voivodeships in 2015 and 2022, in %

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Table 3. Regional changes in values of green jobs between 2015 and 2022, in %

NUTS-2	With A sector in %			Without A sector in %		
	AGR		Change 2022/2015	AGR		Change 2022/2015
	2015-2022	2019-2022		2015-2022	2019-2022	
Dolnośląskie	0.3	1.5**	6.2	-0.2	2.4	4.3
Kujawsko-Pomorskie	0.4**	0.4*	3.0	2.0***	-0.3**	16.1
Lubelskie	-1.3*	2.7***	-13.4	-0.2	2.8*	-8.5
Lubuskie	-0.9**	-1.1*	-9.3	0.8*	1.7***	-1.6
Łódzkie	-2.6***	-4.2***	-18.5	-1.0*	1.9**	-9.2
Małopolskie	-0.3	-2.5*	-1.0	2.9***	-1.7***	25.1
Mazowieckie	-1.3*	1.3***	-12.5	-0.1	5.5**	-2.9
Opolskie	-0.2	2.8***	-0.3	0.1	2.0**	0.3
Podkarpackie	-0.9*	-2.4**	-6.1	4.4***	-1.3***	36.4
Podlaskie	-1.0**	-0.8*	-6.2	0.2	3.1**	3.1
Pomorskie	0.2	-0.1	2.2	1.3**	-1.9*	10.4
Śląskie	1.9**	4.9***	17.3	2.2**	1.3***	19.9
Świętokrzyskie	-1.5*	-1.1	-19.5	0.8	5.5*	-3.2
Warmińsko-Mazurskie	2.5**	2.5**	8.8	2.1**	2.0**	10.3
Wielkopolskie	2.1**	-1.0**	21.0	2.1*	1.9	25.9
Zachodniopomorskie	2.7**	-0.7*	29.9	3.2**	-0.1	36.0

Discussion

A detailed analysis of the results leads to interesting conclusions. The Mazowieckie region records the highest amount of green employment in Poland, confirming its leading role (especially that of Warsaw, the capital of Poland) in the domestic and regional labor market, as well as in the green employment structure (Kacprzak, 2019; Sulich et al., 2020). On the other hand, this region noted one of the steepest declines in GJ in 2022 compared to 2015 among the NUTS-2 regions. We also observed a great decrease in the value of green employment in Łódzkie, Świętokrzyskie, Lubuskie and Lubelskie. However, when excluding section A from the data, there was a growth in values of green employment in Polish regions (besides the Dolnośląskie).

The downward trend in the agriculture labor market greatly determined the volume of green employment in Podkarpackie, Świętokrzyskie, Mało-

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polskie, and Kujawsko-Pomorskie, i.e., regions with a strong concentration of agricultural production (Kopiński, 2018). The number of people working in agriculture in the total number of employed decreased dramatically in almost all voivodeships in 2022. The highest decreases were noted in Podkarpackie (-59%), Małopolskie (-57%), Lubuskie (-42%), and Świętokrzyskie (-39%). The reason for these decreases is the employment structure in Poland inherited from the times of the centrally-planned economy (Usabiaga et al., 2022). Therefore, in the context of green jobs, the employment in section A should be analyzed separately, especially due to the relatively high share of agricultural workers in total employment, the significant role of agriculture in the Polish economy and the still-small share of ecological crops (3.5%) in agricultural production compared to the EU-27 average (which is 8.5%) (Antczak, 2021).

The Polish green labor market is unevenly distributed across the voivodeships. For example, in manufacturing (C), the percentage varied between 2% in Podlaskie and 15% in Śląskie, while in section P, it varied between 2.8% in Opolskie to 17% in Śląskie and 11% and in Mazowieckie. However, the highest disparities in green employment were noted in M (professional, scientific and technical activities), from 1.6% in Lubuskie to 23% in Mazowieckie, and in I (accommodation and food service activities), from 0.9% in Opolskie to 19% in Małopolskie. This atypical polarization pattern may stem from the employment structure in Poland, but also from technical change, educational upgrading, and institutional reforms (Arendt & Gajdos, 2018). For example, the Warmińsko-Mazurskie and Podlaskie voivodeships are regions with a relatively low share of industry and the best advantageous conditions for organic production (Antczak, 2021; Podawca & Dąbkowski, 2020; Kociszewski, 2022). Meanwhile, Śląskie has a large cluster of traditionally industrial – and, therefore, environmentally harmful – industries. However, it is experiencing systematic progress in the green economy (Godlewska & Sidorczuk-Pietraszko, 2019).

In Śląskie, the green economy's efficiency has increased significantly, e.g., due to the dynamic development of the green service sector – employment in that sector is higher by 0.7 pp than the national average (UMWŚ, 2023). Moreover, in 2002, the Śląskie Ecosystem for Innovation was developed, and the Regional Innovation Strategy for 2013–2020 was adopted. Since then, the smart specializations of the Śląskie voivodeship comprise energy, medicine, information and communication technologies, green economy, and emerging industries (Pietrzykowski et al., 2022).

In turn, the Wielkopolskie, Zachodniopomorskie, and Kujawsko-Pomorskie regions have the highest total electrical capacity for renewable energy (RE) installations (Pietrzak et al., 2021). This constant possibility for further

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development of the RE sector in voivodeships generates more green jobs (Sidorczuk-Pietraszko, 2015).

The end of 2019 and the beginning of 2020 were marked by the outbreak of the COVID-19 pandemic. It had significant consequences for labor markets around the world but, simultaneously, it shaped employment policies that support a green recovery and green transition. In Poland, there was a drop in green jobs in 2020 compared to 2019, although the annual trend between 2019 and 2022 was still upward. We also noted that the impact of the COVID-19 crisis was highly heterogeneous by locality and sector. The significant downward trend of employment in Lubuskie, Łódzkie, Małopolskie, Podkarpackie, Podlaskie, and Świętokrzyskie (Table 3) was mainly determined by a very strong, negative slope for the agriculture section and a much slower trend for education, water supply, sewerage, and waste management and remediation activities. The reasons behind the collapse during the pandemic period can be attributed to disruptions in supply chains and lockdowns, which reduced the activity in sectors that require high social interaction (Rosak-Szyrocka et al., 2021). The situation could also be caused by the job market›s response to the pandemic, which manifested in a so-called reallocation shock; where some industries experienced a rapid decline, while others grew significantly. These conclusions correspond to most of the studies in Polish literature (e.g., Kaszowska-Mojsa & Włodarczyk, 2020; Kwiatkowski & Szymańska, 2022). The pandemic accelerated production automation, the digitalization of the economy and social life, as well as the implementation of new production and communication technologies (Adamowicz, 2022). Sections D and N noted an above-average upward trend in green employment from 2019 to 2022. The growth in these PKDs can be explained by the importance of services that were provided to secure the essential needs of the population and enterprises (Kwiatkowski & Szymańska, 2022).

One of the limitations of this study is that the availability of employment data collected posed a major problem. It was impossible to obtain statistical information for all analyzed sections and classes of economic activity in the NUTS-2 regions. Hence, the values of green jobs were analyzed at the most detailed level, but derived from the BAEL. We based our estimations on the assumption that the number of entities is directly related to the employment generated in a region. The Pearson correlation between labor force data and the number of entities was between 0.96*** in 2015 and 0.98*** in 2022, depending on the region and section. For this reason, changes in REGON-s explained the diversity of changes in employment. However, to account for the uncertainty and sensitivity inherent in the green employment data, we performed a robustness check by comparing our results with the outcomes from the benchmarking literature (Table 4).

Table 4. Pearson correlations between calculations of green employment by methods suggested in the scientific literature

References	Sulich et al. (2020)	Kozar (2016)	Kryk (2014)	EGSS (2016)	Arent and Gajdos (2018)
Sulich et al. (2020)	1				
Kozar (2016)	0.33	1			
Kryk (2014)	0.62**	0.80***	1		
EGSS (2016)	0.68**	0.88***	0.79***	1	
Arent and Gajdos (2018)	0.56	0.73***	0.45	0.90***	1

Based on the correlations, we noted that some green job estimations generate quantitatively similar results (e.g., EGSS (2016) and Kozar (2016), or Arent and Gajdos (2018) and EGSS (2016)). However, some could be applied to obtain diverse and case-specific falls in green employment at the regional and sectoral levels (e.g., Sulich et al. (2020) and Arent and Gajdos (2018), or Sulich et al. (2020) and Kozar (2016)). These dissimilarities depend on the definition of green jobs. The definition based on the NACE and PKD categories (Table 1) is more specific than the general concept of the EGSS.

This background serves as a basis for more refined and improved accounts based on more detailed national data sources. The outcomes allow for further assessment of the green jobs concept in Poland. As the extracted data on employment accurately approximate the real number of green jobs, these results are a starting point for a series of publications concerning empirical research using the BAEL database. We plan to quantify the green potential by extracting the green groups of occupations from BAEL, and then following a questionnaire-based approach, we will attempt to define the accurate values of green jobs in Poland.

Conclusions

The aforementioned literature mainly analyzed and defined the relevant economic sectors for creating green jobs according to a theoretical framework. Using a stepwise approach enabled us to extract the key economic sectors for creating green jobs and assess the stock of green jobs for the period between 2015 and 2022. After analyzing data from regional and temporal perspectives, this research determined the leading voivodeships and sections with future green competitiveness and green growth potential.

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The outcomes led us to interesting conclusions. Firstly, the level of green employment in Poland is spatially diverse. Mazowieckie, Wielkopolskie, Małopolskie and Śląskie are the most attractive regions for GJ creation. In contrast, the less competitive voivodeships with the lowest green employment levels are Opolskie and Lubuskie. Regional polarization of green employment declined over the analyzed period, although the spatial disparities were still significant. Therefore, geographical differences should be considered when investigating the empirical concept of green jobs in different economic sectors.

Secondly, most sectors noted statistically significant annual increases in green job values during the period analyzed and during the coronavirus outbreak, except for agriculture, education, arts, and entertainment. The strong downward trend in agricultural employment greatly determined the volume of green employment and, when section A was excluded from the data, there was growth in GJ in all NUTS-2 regions (apart from Dolnośląskie). The data for the entire country without agriculture also showed a growing trend in green employment. The disparities in employment structure by industry and region have a significant influence on labor demand and, therefore, on the green labor market development. Therefore, in this context, green jobs and employment in section A should be analyzed separately.

Thirdly, while 2020 (i.e., the onset of the COVID-19 outbreak) saw a strong decline (-2.7%) in green jobs compared to 2019, our findings show that the COVID-19 pandemic might have increased the rates of green job creation, depending on the economic sector. The outbreak had significant consequences for labor markets around the world, but simultaneously, it shaped employment policies that support a green recovery and green transition. Hence, the full impact of the pandemic on green jobs and the demand for this creation is not yet known, as COVID-19 has undoubtedly had a long-term effect on labor markets.

Identifying sectors and analyzing the regional potential for GJ creation provides a better understanding of the impact of "greening the economy" on the Polish labor market. The approach presented in this study will, at a minimum, allow a preliminary evaluation of core environment-related employment and of green jobs, clearly outlining assumptions and limitations. The results should be therefore relevant when developing national green jobs assessments and formulating strategic labor, economic and educational policies. They can be useful policy-recommendations especially for: education (e.g., new directions of education, training, and courses), employment (e.g., to identify surplus and deficit areas in terms of qualifications and professions), local governments (to verify the local potential and formulate new development directions), government institutions (to ensure that effective policy measures and tools are formulated to respond to the shift to a greener

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economy and to better set up intervention funds), investors (to assess the market potential of local economies), and for employers (to analyze labor supply in green areas). Since we suggested a stepwise approach based on real data over a fairly long period, decision-makers or researchers can test different policy scenarios which will provide an opportunity to examine the economic impacts of policy changes or other interventions to promote green jobs, including identification of which sectors are likely to "win" or "lose" under the scenarios modeled. However, policymakers should pay attention to important sectors (agriculture, construction, public administration), as the greatest changes in the number of workers may occur there, which could have a key impact on the development of Poland's green economy.

Finally, the way the methodology was carried out and described in this study means it can be replicated to identify the regional and sectoral potential of green jobs, estimate the stock of green jobs, and assess the equity issues in the labor market. The robustness check provided evidence that our estimations, based on the integrated system of international economic classifications, also present a valid approximation to evaluate and monitor green job stock and inequality in European economies.

The contribution of the authors

Conception, E.A. and A.G.; literature review, E.A. and A.G.; acquisition of data, E.A. and A.G.; analysis and interpretation of data, E.A. and A.G.

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ADMINISTRATIVE SANCTIONS FOR ENVIRONMENTAL CRIME IN SELECTED EU AREAS

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ABSTRACT: Each country in the European Union (EU) has its own legal system of environmental protection inc. rules of eco-crime fighting. The world copes environmental crime, developing better and better structures, laws and control systems. Establishing effective administrative sanction rules may help decrease environmental damage. The goal of the paper is the comparison of administrative sanctions for environmental crime in five different areas of the EU: France, Germany, Italy, Spain and Poland. The mechanisms of sanctions, fines and penalties in studied areas are based on financial fines. Although the states do their best to develop the most effective tools possible to enforce environmental protection and control its quality, it is not always possible in reality. Understanding and weighing the value of environmental destruction is difficult. It takes into account the human, economic and ecological aspects (considering the quality of the environment closest to the natural state).

KEYWORDS: environmental administrative sanctions, environmental law, environmental tools, environmental treat

Introduction

Environmental protection, in the EU legal system, is a shared competence. For non-compliance with environmental protection rules, administrative sanctions are established as various types of restrictions and cancellations (e.g. approvals, licences, permits, registrations, etc.). They include financial penalties, warnings or even closure of the business (Rao et al., 2014; This, 2020). Sanctions vary depending on the actual or anticipated impact on the environment, human health or safety. They also depend on the party's previous environmental infringement activities and breaches of regulations (Kaigorodova et al., 2020). Administrative sanctions are most appropriate for operators who undertake, i.e. such activities as unlawful hunting, use of banned chemicals, excessive pollution of particular elements of the environment or illegal waste disposal. Danilov-Danil'yan et al. (2009) writes it happens that administrative sanctions may, in many cases, overlap with criminal law, which was described by Radecki (2020) for Germany, the Czech Republic, Slovakia and Poland. According to Le and Hoang (2022), the mechanisms of sanctions, fines, and penalties allow the state to develop the most effective instruments possible to enforce environmental protection and control its quality. This makes it possible to financially compensate for the harmful effects of environmental destruction in relation to the actions of external agents and subjects. Ultimately, fines would be applied as soon as restoration is possible.

Le and Hoang (2022) explains that financial fines for environmental crimes are reasonable, as they should always balance or exceed the value of the caused damage in order to remedy previous conditions. Moreover, financial sanctions involve fewer people than a custodial sentence implementation (court, prison, police, lawyers). They are a type of payment (Fu et al., 2020). Taking all of it into consideration, the Authors have noticed the need for sanctions system comparison in several European areas. In individual countries, the value of the fine depends on the final state of the environment occurring after the environmental damage. If the offender has derived any financial benefit from this situation, the fine is also increased by this benefit (Danilov-Danil'yan et al., 2009). What is more, fines have legal deadlines.

Only failure to pay leads to other forms of punishment as imprisonment. Sanctions are applied for violations of regulations and decisions based on them. Moreover, their amount depends on the violation degree. To define them, the legislator uses different terminology, calling them fines, administrative fines or increased fees. Regardless of the terminology, the effect of financial punishment is the same. A sum of money is obliged to be paid as a reaction to illegal action. In practical use, fines are the most common sanc-

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tion for environmental offences by far, and it is extremely rare to impose a prison sentence. What is more, a fine can be extremely severe. It is imposed in daily rates, specifying their number and the amount per rate. Sanction rates vary from country to country, as studied in this paper. In the available literature, there is a lack of complete statistical data for all EU Member States on specific aspects of environmental crime: the effectiveness of its detection, investigation, prosecution, the number and nature of convictions under the law, ongoing, completed and discontinued cases, the number of financial sanctions imposed and the involvement of legal and administrative institutions and actors.

Having regard to the above, there may be noticed interesting research problem: administrative sanctions comparison in different areas in the EU individually for the countries: France, Spain, Germany, Italy and Poland. Following the establishment of Directive (2008), most Member States modified their national law on environmental offences in terms of sanctions and liability. The countries mentioned above were chosen for the assessment of sanctions because they have implemented the EU law into their internal law in different ways. France and Italy made changes to the structure of pre-existing legislation. In addition, Italy decided to tighten sanctions in case of significant negligence. Germany and Spain introduced definitions of additional crimes into the Code, which since then have been punishable. Spain, on the other hand, called institutions and companies responsible as legal entities, which could not be punished until then. Poland did not change its system of administrative sanctions at all.

Research methods

The goal of the paper is an analysis of administrative sanctions for environmental crime in five different areas of the EU: France, Germany, Italy, Spain and Poland. The first 4 are EU funders with different Gross Domestic Product (GDP), culture, freedom understanding, fight against existing crime and environment environmental awareness. The countries of the south and north are examples of a "two-speed" Europe. Germany being the core of Europe, France open to global trade with numerous remote colonies in the past, Italy struggling for years with organised crime and Spain the most touched by the historical crisis. Poland is one of the newest EU countries still compensating for differences.

Sanctioning regimes vary across EU Member States. When setting the types and levels of penalties, individual countries take into account their traditions and cultural variation. Setting a particular penalty at a particular level may be considered a deterrent in one country, and the sanctions are lower

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there, but it may not be the same in another, where the value of sanctions should be higher due to, for example, gross domestic income. When determining the overall penalties for environmental offences, it was also taken into account administrative, civil, consequential and compensatory sanctions and their relationship to criminal law. All this being said, selected analysis states have a wide range of options when determining the level of appropriate environmental system sanctions. A different implementation of environmental law, GDP and income, previous changes to nature, different ecology understanding, existing externalities, opportunities for concealment and the presence of organised crime groups were factors which showed the gap in the environmental problems in studied countries.

With a greater accent on administrative sanctions, the probability of a crime being punished increases, and the costs for potential offenders go up, and this leads to reduced environmental crime. The main difference between the penalty systems is that administrative sanctions are more convenient and cheaper to impose than criminal ones, which involve a complicated criminal procedure and high costs. The considered tools involve:

- environmental field type,
- financial sanctions for natural persons,
- financial sanctions for legal persons,
- non-financial sanctions types,
- external factors,
- definitions of sanctions,
- environmental crime prevention.

The analyses were based on the environmental presented in Table 1, legal acts, criminal codes, offence codes and other regulations defining environmental violations. Also institutions, bodies and offices are analysed which define and impose sanctions for environmental crime in the considered countries.

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Table 1. Environmental regulations in studied EU areas

	Env. fileld	France	Germany	Italy	Poland	Spain
1	Constitution	Law Constitutional No. 2005-205 Of 1 March 2005 Concerning The Environmental Charter (NOR: JUSX0300069L)	Basic Law for the Federal Republic of Germany (as amended up to Act of July 13, 2017)	The Constitution of the Italian Republic 1947	Constitution of Republic of Poland 1997	Constitución Española 1978
2	Common	Environmental Convention (1998) Directive 2008/99/EC of the European Parliament and of the Council on the protection of the environment through criminal law				
3	General environment	The French Environment Code	EU directive on environmental criminal law, 2008/99/EC	Consolidated Environmental Law (Norme in materia ambientale or Codice dell'Ambiente Legislative Decree No. 152/2006) (ECA)	Act Environment Protection Law of 27 April 2001. Nature Protection Act of 16 April 2004	Ley 6/2017 about environment protection
4	Penal code	Penal Code (Law 92-6862)	Penal Code Strafgesetzbuch (StGB)	Italian Code of Criminal Procedure 1990	Code of Conduct in Offence Cases Act of 11th Aug 2021 Penal Code of 6 June 1997	Ley Orgánica 10/1995, Penal Code (del Código Penal)
5	Environment Protection	Law 2010-788 National Commitment to Environmental Protection	Nature and landscape protection- Bundes-Naturschutzgesetz (BNatSchG)	Consolidated Environmental Law (Norme in materia ambientale or Codice dell'Ambiente Legislative Decree No. 152/2006) (ECA)	Act Environment Protection Law of 27 April 2001	Ley 6/2017 about environment protection
6	Water	Law 2006-1772 on water and the aquatic environment	Control and management of water resources – Wasserhaushaltsgesetz (WHG)	Law No. 319 of May 10, 1976 'Water protection against pollution	Act of 20 July 2017 – Water Law	Real Decreto Legislativo 1/2001, Ley from 20th Jul – Water Act La Ley 41/2010 Marine Environment Protection Act, the waters, seabed and subsoil Ley 41/2010 about Marine Environment Protection
7	GHG	Law 2001-153 on the greenhouse effect and the prevention of global warming risks (NOR: ATEX0004061L)	Emission control- the Bundes-Immissionsschutzgesetz (BImSchG)	Decree-Law no. 156/2010: ambient air quality	Act of 17 July 2009 on gases emission system management	Ley 1/2005, from 9th March about GHG emissions

	Env. fileld	France	Germany	Italy	Poland	Spain
8	Waste	Law 2020-105 on the fight against waste and the circular economy	Control, disposal and management of waste – Kreislaufwirtschaftsgesetz (KrWG)	Specific decrees concerning different types of waste i.e. Law no. 49/2014: electrical, Law no. 188/2008: batteries etc.	Waste Act of 14 December 2012 Act on management of packaging and packaging waste of 13 June 2013	Ley 7/2022 about waste. residues and contaminated soil
9	Hazards	Law 2003-699 on the prevention of technological and natural hazards and remediation of damage	The Environmental Damage Act (Umweltschadensgesetz)	Part of Consolidated Environmental Law and Env. Code	Waste Act of 14 December 2012	Local regulations
10	Environment Health & Safety	Law 2001-398 on the French Environmental Health Safety Agency	Nature and landscape protection- Bundes-Naturschutzgesetz (BNatSchG).	Part of Consolidated Environmental Law and Env. Code	Act Environment Protection Law of 27 April 2001	Ley 26/2007 from 23rd Oct about Responsibility for Environment
11	Soil	Environmental Code. Article 173	Soil protection under – Bundes-Bodenschutzgesetz (BBodSchG)	Part of Consolidated Environmental Law	Lower regulations	Ley 7/2022 about waste. residues and contaminated soil
12	EIA	Environment Code (Annex to Article R. 122-2)	Environmental impact assessment – Umweltverträglichkeitsprüfungsgesetz (UVP-G)	Environmental Impact Assessment Italian Legislative Decree 152 of 3 April 2006	Act on Environment Protection Inspection of 20 July 1991	Ley 21/2013, from 9th Dec, about environment assessment
13	Environment Information	Environment Code (Annex to Article R. 122-2)	Environmental Information Act (Umweltinformationsgesetz)	Integrated Pollution Prevention and Control Authorisation (IPPC) (Autorizzazione Integrata Ambientale) (AIA)	Act Environment Protection Law of 27 April 2001	Real Decreto 876/2014, from 10th Oct about environment protection costs
14	Specific	Local regulations	Local regulations	Presidential Decree No. 59/2013: Unified Environmental Permit (AUA)	Act on the obligations of entrepreneurmanagement of waste and product fee of 11 May 2001 Act on microorganisms and genetically modified organisms 28 January 2022.	Ley 42/2007 from13th Dec about Biodiversity Ley 33/2015, from 21st Sept about Natura 2000 in Spain Real Decreto 630/2013 from 2nd Aug about endangered species,

Results and discussion

A positively perceived environment and surroundings enhances well-being, strengthens relationships and helps to properly protect people, plants and animals. Environmental crime has a negative impact on all ambient elements: water, air, soil, habitats, human and animal health and life. It is the result of deliberate action by people mainly for financial profit. Eco-criminals know no moral, national or regional boundaries. The effects of this crime are reflected in every social and economic sector: tourism, transport, health care, agriculture, fishing, forestry, industrial production or services. Environmental crime reduces the number of plant and animal species, puts people at risk, e.g. from poisoning, spreads diseases, decreases profits for tourism, diminishes the sources of many raw materials and all of it contribute to climate change. Environmental crimes can be committed by organised crime groups and networks that operate across national and continental borders. What is more, they can even finance various mafia and terrorist activities.

Economic losses related to environmental crime in the EU are estimated at more than USD 70 billion, increasing by approximately 5% every year (DGCCRF, 2021). A large share of these profits comes from wildlife and hazardous waste trade (Percoco, 2001). This shows that environmental crime ranks at the top in terms of global crime revenue, with drug smuggling, document falsification and human trafficking. In the EU, it is estimated that the annual revenue from the illegal trafficking of flora and fauna products amounts to 25% of the income from environmental crime and 10% from waste (Garcia & Fonseca, 2018). Since the creation of the EU's borders, a significant number of environmental directives and regulations have been established. As overarching are the Convention (1998) and the Directive (2008), which was to be brought into line with the laws of individual Member States by 2010. Sectoral environmental protection and maintenance legislation should cooperate with these documents, and all administrative enforcement possibilities should be used.

The legal procedures are upgraded to better save the environment and to establish the most sustainable system meeting requirements of nature and ecology (Kaigorodova et al., 2020). Among considered countries, only Poland has waited 12 years to fully implement EU regulations. In 2022, there was adopted a new law with an increase in penalties for environmental offences.

World fights with environmental crime by developing better and better structures, laws and control systems, hoping that establishing proper sanction rules may help in environmental crime decrease. Despite some similarities, there is a number of differences between legal regulations and other rules in particular EU areas that have a significant impact on both the proce-

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dure for their application and their financial value because each country has its own legal system of environmental protection (Radecki, 2009). Although particular countries have the same goal, administrative sanctions are different in considered European countries (Kaigorodova et al., 2020). Different is also understanding system, i.e. in Spain, where the system is complicated and based on nearly one hundred regulations placed in the form of the pyramid from the Constitution on the top to laws, regulations, royal decrees, ministerial orders, autonomous orders and local regulatory provisions.

Environmental crime includes various areas: illegal pollution (ground, water, air etc.), illegal trade with protected species, waste export and disposal, but also business activities that disturb environmental conditions also belong to this group (Chen et al., 2020). It also threatens human health and life, may affect the structures of the state and inhibit sustainable development. Criminal, administrative and economic tools are used in the fight with eco-thread. These can include fines, business shutdowns or restoration of the damaged ecosystem. Danilov-Danil'yan et al. (2009) and Hering (2002) explain that some legislators, which in the past relied mainly on custodial sentences, have turned to administrative enforcement because they may be more onerous for perpetrators. Administrative sanctions are easier to impose and cheaper than criminal due to the complicated criminal procedure and high costs. Moreover, writes Gerstetter et al. (2016), criminal liability involves proving guilt, whereas administrative is irrelevant. It is sufficient to demonstrate an environmental violation has actually occurred. Therefore, fines are the most common sanction for environmental crime, and imprisonment is very rare. The legislation leads to an expectation of sanctions that should encourage the perpetrator not to repeat the actions and discourage others from doing the same.

Nowadays, France is at the forefront of European countries being condemned for its non-compliance with EU environmental directives. It has been repeatedly warned by the European Commission that it would face heavy financial penalties if it does not apply EU environmental law correctly. The French Ministry of Ecological Transition states that penalties should be modulated according to the intentionality of the perpetrator (Ouest-France, 2020). In France, environmental crime is mainly defined by case law and involves recourse to the law of civil liability. It requires the demonstration of fault, damage and causation (Law 92-6862, 1992). Areas under consideration include as for other countries water, air, waste, and noise but also illegal installations, production lines or chemical products. Italy ranks in the middle of the pack of countries in terms of the number of environmental cases. Italian legislation (EIA, lPPC, AIA) also include business activities breaking environmental rules: activities without- or with expired permits and other illegal actions violating state or regional regulations. In Italy, eco-penalties include

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monitoring of environmental pollution/disaster; trafficking and storage of radioactive materials; obstruction of control, overlooked remediation; inspection of the seabed (Rao et al., 2014). Spain is currently an EU country with particularly evident environmental violations. Gerstetter et al. (2016) report that environmental offences dealt with by the justice system here are 15% of all cases registered in Europe. As recorded by Montes and Francisco (1999) and Ruiz and Ángeles (2010), the Spanish Constitution (1978) indirectly recognises the protection and restoration of the environment as a legitimate cause for intervention. Law enforcement is mandatory. However, authorities encourage preventive action and administrative sanctions. Penal is used rarely – only where necessary. In practice, many environmental cases get away because of a lack of staff, funds and difficulties in detecting (Zapata, 2022). On the other side, Poland ranks among countries with a relatively low number of serious environmental crimes.

Financial sanctions are difficult to compare in terms of their severity for perpetrators. Usually, individual countries set them according to their national legal traditions. In the countries selected for analysis, financial sanctions vary considerably in terms of the type and level, their minimum or maximum values. In some countries, financial penalties are calculated in relation to the offender›s income or through daily loss equivalents. The way in which the different sanction regimes described by law can be combined is also different. It is worth noting that the same value of sanctions in the Member States is also not comparable to each other. For example, a certain level of sanctions may act as a deterrent in one country but not in another due to a higher level of income and a different – economic situation (Schmidt, 2013).

Values of the fines in Germany depend on the conditions of the offence, the perpetrators and the circumstances. In specific cases where the offence is committed by company management, the company is financially liable for its actions. The limits of ‘intimidation penalties ‘ can be very high so that the fine exceeds the financial benefit (or its valued equivalent) achieved by the offender (Hirschfeld et al., 2017). Nevertheless, Schäfer (2002) states that the penalty for offences contained in the KrWG usually does not reach the maximum.

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Table 2. Sanctions comparison for environmental crime in studied countries

Type of sanction	France	Germany	Italy	Poland	Spain
Max fine for individual persons	300000 EUR for wildlife offences	10800000 EUR for all included breaches of environmental law	200000 EUR illegal trade of flora and fauna	270000 EUR the same level for all offences	288000 EUR for most violations
Min fine for individual persons	75000 EUR for illegal waste management, incl.hazardous waste	No min.fine	3 000 for destruction of protected habitats	No min.fine	no fine for pollutants introduction to environment
prison sentences for individual persons	2-6 years	5-15 years	6 months to 10 years	2-8 years	1-12 years
Fines for legal persons	Depends on the offence 375000 or, 750000 or 1500000 EUR	1000000 – 10000000 EUR for intentional offences and EUR 500000 – 5,00000 EUR negligence offences	258 – 1549 EUR per offence	250 – 1250 000 EUR, but cannot exceed 3% of the annual income of the penalized company	the penalty is expressed in a number of days, with monetary value for day from 30 to 5000 EUR
Other effect for legal persons	change, suspension, removal or closure of the business correlation of the value of the charge with the economic benefit of the offender, the trade or the damage caused				
Increase/ decrease of fine	Application of accessory sanctions and confiscation	Additional fines when pollution arises in a protected or valuable areas	reductions in penalties are provided when situations are committed unintentionally	strengthening of the punishment for companies already punished	Deterrent effect is weakened because of mild sanctions or cases dismission
State authorities public institutions monitoring env. violations	OCLAESP (Central Office for Combating Attacks on the Environment and Public Health)	Federal Environment Agency – responsible for the prosecution and punishment	Italian National Institute for Environmental Protection and performs scientific, technical, research functions, assessment, monitoring, control, communication, training and education	Provincial Inspectorate for Environmental Protection – monitor, investigates and determines negative effects of the offence	Environmental Inspection Network (REDIA) – harmonizes the country and exchange good practices

Source: authors' work based on acts from Table 1 and Beine et al. (2020); Noci (2000); Marin et al. (2018); Ramos Rodríguez (2007); Zapata (2022); Guignard et al. (2019); Skiter et al. (2015); Rao et al. (2014); Schmidt (2013); Bericht (2004); Górka et al. (2001); Sina and Gerstetter (2021); Hering (2002); Kert (1999).

Financial penalties can be very severe. The French Minister of the Environment can impose an administrative penalty on an illegal waste treatment facility after one month of being summoned up to max. possible value (Guignard et al., 2019; Ouest-France, 2020). On the other hand, for Spanish companies there is established an integrated system of prevention and monitoring based on Real Decreto 1/2016 (Uriel, 2018). Interesting fact that this law applies public or private sector, but new, research or developing companies are excluded. In contrast, fines and penalties for environmental crime in Poland can be imposed repeatedly. For a subsequent repeat offence already punished, twice the amount of the last fine is imposed. The fined individual or business entity has two weeks from the date of the decision to pay the fee (Radecki, 2009). According to Radecki (2001), in Poland, penalties and sanctions should push individuals or companies breaching environmental rules to take urgent corrective action when negative changes occur, reduce impacts or prevent any damage to the environment and/or human health. Environmental penalties also aim to negate any financial benefit resulting from non-compliance.

Authorities responsible for detecting environmental crime note that the levels of sanctions are sufficient, but the problem is their practical application by state institutions (Fu at al., 2020). In the countries in question, administrative authorities, police, and courts cooperate formally or informally to detect and investigate environmental crimes. Informal cooperation often proves insufficient, as it usually depends on the attitude of those responsible and the external factors described above. There is a problem of uneven enforcement. In Spain, incompatibilities related to urban planning and zoning are considered environmental crimes (Ramos Rodríguez, 2007). Offences that actually destroy nature and are defined by a statutory list are placed in the background. In Germany, on the other hand, less attention is paid to illegal waste management (Hering, 2002).

The differences in sanctioning regimes between countries also largely depend on independent external factors that affect law enforcement. These have a strong influence on offender behaviour (Fu, 2020). One of the positive external factors is increasing public awareness and environmental education. It can lead to a reduction in environmental crime. On the other hand, external factors can also intensify environmental destruction. Easily accessible transport and intensive international trade can contribute to crime in cross-border areas. New technologies can also lead to an increase in crime. Online shops offer the possibility of placing anonymous orders anywhere in the world, which helps the illegal trade of plants and animals. The phenomenon of safe havens, i.e. places of refuge for offenders against the environment, should also be mentioned here. Offenders, to avoid punishment, in many cases, cross the borders of the countries where they committed the crime. They seek refuges that allow them to hide and escape from their punishment. This is precisely what they find in countries where there is a low rate of crime detection and a lack of effective law enforcement, where crimes are ignored or where very low penalties are imposed. Serious organised

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crime and terrorist networks play a large part in creating safe havens. They are prepared to evade effective law enforcement at all possible levels (administrative, control, police, judicial, civil, etc.). They have the resources to establish criminal cooperation. They are in possession of a large collection of data on leniency proceedings and cover-ups. The level of corruption in the state or political support should also be considered here. Only a high level of environmental awareness can cut this belt of environmental negligence (Noci, 2000; Skiter et al., 2015; Radecki, 2020).

The prevention of environmental crime and safe havens depends most heavily on the enforcement of environmental administrative law. It contains rules and protections, common standards, a licensing system, inspections, audits and other forms of control. Unfortunately, the legislation has left out some of the areas that have now become targets of environmental crime:-illegal, fishing, illegal logging and timber trade, and man-made forest fires. In addition, the internal laws of most countries have inaccurate definitions of the environmental acts committed, including legal terms such as «non-significant/significant/very significant harm», «non-significant-t/si amount», and «non -significant/significant impact», «safe/unsafe activity» or «non-significant/significant deterioration» (Directive, 2008; Decreto legislative, 2006; Environmental Protection Law, 2001; Ley 26, 2007).

The lack of definitions leads to differences in interpretation between states where this action is an offence, and in another state, it is no longer. It is also important to bear in mind the differences in interpretation between authorities in the same country resulting from a lack of environmental knowledge, understanding of the harmfulness of the act and the attribution of appropriate sanctions. As a result, this leads to inconsistent implementation of the rules and negatively affects cooperation (Soledad Arroyo Alfonso, 2018).

Summary and conclusions

The system of environmental justice and control is as effective as its execution. There is a lack of uniformity in the analysed countries as in the EU as a whole. Although every EU country should base on the same legislation, i.e. Environmental Convention and the Directive (2008), on the protection of the environment through criminal law. Sectoral environmental protection and maintenance legislation should cooperate with these documents, but in reality, every country has its own system.

Environmental crime includes various areas: illegal pollution of environmental elements (ground, water, air etc.), illegal trade with protected species, waste export and disposal, but also business activities that disturb environmental conditions. Italy considers business activities breaking environmental

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rules: activities without- or with expired permits. In France, an environmental crime includes additional illegal installations, production lines or chemical products.

In the countries selected for analysis, financial sanctions vary considerably in terms of the type and level of sanctions and their minimum or maximum values. In some countries, financial penalties are calculated in relation to the offender's income or through daily loss equivalents.

Environmental crime can be effectively controlled. There are some similarities in studied countries which conduct the punishment of legal persons. They could reach administrative decisions about business type change, cessation of economic activity, removal or total closure. There is the correlation of the charge value with the economic benefit of the offender, the trade or the damage caused.

Legal regulations in studied EU areas provide various legal and administrative tools and sanctions for both natural and legal persons. However, in Italy and Spain, these options have been underutilised or delayed in time. On the other hand, in Poland or Spain, where legal sanctions are low, may be imposed additional penalties as a deterrent, discourage or initiate criminal proceedings. In France, where individual fines can be rather low, an environmental case can be referred to the criminal court.

Of the countries assessed, the highest maximum fine can be imposed in Germany. In Spain, the penalty is expressed in terms of the number of days, which has a monetary value. In Poland, the penalty cannot exceed 3% of the annual income of the penalised entity. In France, penalties are lower in some categories, and in Italy, they are a fraction of this amount.

In Spain, the law applies public or private sector, but new, research or developing companies are excluded. In contrast, fines and penalties in Poland can be imposed repeatedly. For a subsequent repeat offence already punished, twice the amount of the last fine is imposed. The fined individual or business entity has two weeks from the date of the decision to pay the fee.

Extensive education of the public, businesses and legislators on the risks of environmental crime. There should be training and capacity-building activities provided at regional and national levels for all member countries to improve effectiveness in combating environmental crime. Group awareness of the dangers of environmental crime should be raised.

Eco-crime cannot be combated in our own backyard. The global system of inspection and police communications needs to be expanded, allowing all member countries access to criminal databases. Common and accessible tools and services should be created, and a system of notifications and alerts should be provided to law enforcement agencies around the world to share different types of eco-crime-related information.

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The contribution of the authors

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Ksymena **ROSIEK**

ANALYSIS OF OPERATOR MODELS FOR RAINWATER MANAGEMENT IN POLAND – TOWARDS THE INTEGRATED MANAGEMENT MODEL

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ABSTRACT: Over the last decade, Poland has witnessed a statutory change in the definition of rainwater. It stopped being regarded as wastewater. Municipalities in Poland have developed different models for rainwater management and various ways of financing them. The aim of the study is to identify and to describe the most important elements of rainwater management models in Poland with the use of operators. It focused not only on constitutive features of the system, but also on financial aspects, such as fees and investments (with the omission of fiscal ones). The study helped to identify three organisationally distinguishable operator models and indicated strengths and weaknesses of each of them. Such a systematic and structured analysis lays the groundwork for the assessment of these models and enables other municipalities to make a conscious decision on which model to implement.

KEYWORDS: rainwater/stormwater management

Introduction

For decades, Poland's legislation has defined rainwater as wastewater. As a result, rainwater had to be discharged to a sewage plant if it contained domestic wastewater or, otherwise, directly to surface waters. The change of Poland's Water Law regulations, alongside with the statutory change of the definition for rainwater, allowed for a different mode of management. However, it also generated numerous problems arising from the fact that there are many regulations that control rainwater issues, and that the amendment to the act did not address a significant part of them (including regulations concerning fees for discharging rainwater). At the same time, Poland's cities began to build rainwater and snowmelt management systems. Several cities started to identify issues concerning drainage infrastructure earlier than the other ones, and proceeded to implement innovative technical, as well as organisational solutions. We must note that this process primarily took part in big and middle-sized towns. We can assume, with a certain degree of concern, that the change of rainwater management and guarantee of investment means/resources for the necessary undertakings are the challenges most of cities in Poland currently face. Additionally, all of the above challenges stem from the climatic transformation. These cities learn from the experience of leaders, i.e. cities that have already undertaken such a project.

We should, therefore, ask the question why not draw on models from other European countries, or even North America. Technical solutions and general recommendations for the direction of such a change – the implementation of sustainable urban water management – are relatively easy to implement. However, on the level of specific organisational solutions, among the factors determining the whole process are the existing legal framework and available sources of financing. It is difficult to copy ready solutions from other countries, as they might be inapplicable, due to legal and, quite often, cultural differences.

Therefore, it seems extremely important to identify, analyse, and indicate weaknesses and strengths of the models for rainwater management existing in Poland. The study described in this article aims to achieve it.

The inspiration for the study was the conference presentation by W. Sumisławski, *Rainwater and snowmelt management models in Poland* (Sumisławski, 2021). However, the scope of this study has been widened, more detailed and, above all, systemised. The results have been presented in a uniform and comparable way. The names of the models, each of which contains the name of the city which has implemented it, are borrowed from the aforementioned author, but their categorisation is the contribution of the author of this article.

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The subject of the analysis are models for rainwater management in which the affiliated entity exists as the operator, or is given this role. In Poland, tasks of rainwater management can also be carried out without appointing such an entity.

The article starts with a literature review, which has been carried out from the perspective of various approaches to changing water management systems in urban areas, towards integrated water management. The author draws a parallel between the most interesting approaches: their changes in time, but also between system solutions that currently function in different regions, with references to areas in which they are most popular (chapter 1). In the part devoted to materials and methods (chapter 2), the author indicates the scope, method and time of the study and briefly refers to legal frameworks, both in the EU, and in Poland. This part of the article also describes dilemmas which arise from the ambiguity of Polish legislation in this field. Chapter 3 aims to present the study results. It describes models according to chosen analysis criteria and their graphical mapping is attempted. The author also discusses the strengths and weaknesses of each approach. The article ends with conclusions drawn on the basis of the study.

Literature overview

It seems that, in this day and age, no one needs to be persuaded that water is one of the most precious natural resources. Historically, the development of civilisation has been, and still is related to water, which often has been the cause of conflicts (Kowalczak, 2007; Kowalczak & Kundzewicz, 2011; Water Conflict Chronology, n.d.; Water, Security and Conflict, 2018). In general, we can identify several reasons for shortage of freshwater accessible to society and the environment. They include: catastrophic climate changes (AR6 Climate Change 2022, n.d.; Bates et al., 2008; Gleick, 1998; Grafton et al., 2013; Letcher, 2022; OECD, 2010, 2013; Shrestha et al., 2014; Stucker & Lopez-Gunn, 2017; Taylor et al., 2013; Tortajada et al., 2016; Whitehead et al., 2009), urban processes and other processes related to population growth (Eikenbery, 2003; Kumar, 2021; U. W. W. A. Programme, 2020; W. W. A. Programme, 2012, p. 3; WCPI Map, n.d.), as well as population growth in towns (an increase from 43% in the year 1900 up to 57% in the year 2001 on the global scale (World Bank). In the year 2007, the number of urban populations exceeded the number of rural populations (Ritchie & Roser, 2018) and, in some parts of the world, they exceed this level on average. The post-war reconstruction of Europe gave rise to many processes connected with urban modernisation, which often involved widening streets, creating city squares and closing surface waters in canals. Concrete became a synonym for a mod-

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ern, clean and modernistic city, especially in the Eastern Bloc countries (the Communist Bloc) (Hirt, 2013; Mencwel, 2020; Stanilov, 2007). Water, beyond urban park spaces, became absent from cities. According to this approach, rainwater – often regarded as a threat--was to be discharged from a city as quickly as possible. Cities became separated from their rivers by high flood embankments. Those processes were, in fact, ineffective; especially with an increase in surface sealing in cities, which accelerated ground run-off and contributed to increases in flood waves.

To put it simply, approaches to rainwater can be divided into:

- a "withdrawing water from people" approach, involving the construction of anti-flood infrastructure, which – unfortunately – leads to floodplains development,
- a "withdrawing people from water" approach, which is the next stage where efforts are made to guarantee space for water in cities.

However, the most complex approach is sustainable and integrated water management in a city, based on blue-green infrastructure and run-off delay, which also includes changes in rainwater management (Table 1). In this approach, rainwater must be treated as a resource, and not wastewater.

A perfect analysis of the changing approach to urban water has been offered by Brown and his team (Figure 1). They have indicated both social and political causes for the introduced changes. Out of necessity, the first stage is the guarantee of potable water access, the second one is the guarantee of sewerage access (public health protection), the third one is flood protection, which involves city drainage. In other stages of the approach, environmental factors, such as the elimination of pollution, especially point pollution, start to play a role. Water scarcity and water access limit are the cause of the implementation of further changes. The last stage involves the implementation of sustainable development (including intergenerational equity), introduction a concept of resilience city, which adapts to climate change, where constructed infrastructure – based on nature based solutions (NBS) and blue-green infrastructure (BGI) – is multifunctional, inhabitant-friendly, and contributes to better quality of life. It must be noted that, in different parts of the world, or even within one country, different cities will display various approaches, on different levels of development.

Analysing the scheme below (Figure 1), we must note its usefulness for planning and management processes because, once we have the awareness of undergoing processes, we can take actions to make use of the so-called lagging gap and skip stages to go towards Water Resilient City or Water Sensitive City.

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Table 1. Approaches to water management in urbanised regions

Concept	Withdrawing water from people	Withdrawing people from water – room for river	Sustainable and integrated water management
Characteristic activities	River regulation, embankment construction	Limiting construction on floodplains	Planning from the perspective of the whole catchment area
	Stream management, sewage system, surface waters regulation	Moving critical infrastructure out of floodplains	Analysis of what causes an issue, consideration of anthropogenic processes
	Fast rainwater discharge „from the cloud to the pipe”	Special technical specifications for buildings situated in regions exposed to the risk of flooding	Introduction of varied tools involving blue-green infrastructure
	City drainage, wetlands drainage	Embankment retraction, creating artificial reservoirs for rainwater or flood waves	Prevention of rainwater run-off, retention in the rainwater spot
Procedure	Point approach – performing actions in places where an issue occurs, or ones oriented towards solving a specific issue	Process approach – planning oriented towards minimizing damage	Integrated approach based on risk assessment and establishing its acceptance level by stakeholders
Idea	Water as a threat for people and their property, a solution will help to tame water	Water as a threat to people and their property, recognition of a need for a water reservoir, damage prevention	Water as an integral part of the urban environment which improves quality of life, acceptance of a specific risk level for damage occurrence
	Water away from people	Water near people	Water with people
Rainwater treatment	Fast undisturbed rainwater discharge from a city, drainage through creating expensive underground rain sewerage infrastructure that is used incidentally	Constructing retention reservoirs including dry, ground and underground ones with the purpose to catch excess rainwater and delay its run-off	Integrated rainwater management as part of sub-basin, reducing rainwater inflow into grey infrastructure through its catchment in BGI

Source: author's work based on: Bahri (2012); Krauze, & Wagner (2014); Mrowiec (2020); Rosiek (2016); Tvedt & Oestigaard (2014).

The relations between urban water, including rainwater, and quality of life, flood threat and pressure on the environment are examined worldly and in Poland. While in the USA, Low Impact Development (LID) is dominant, in Europe the approach promoted by The Economics of Ecosystems and Biodiversity concept (TEEB), as well as the use of Nature-Based Solutions (NBS) and Blue-green infrastructure (BGI) is preferred. Sustainable Urban Drainage Systems (SUDS) have been developed in Great Britain, while in Australia Water Sensitive Urban Design (WSUD) is implemented. Integrated Urban Water Management (IUWM) is widely promoted by the UN in many countries.

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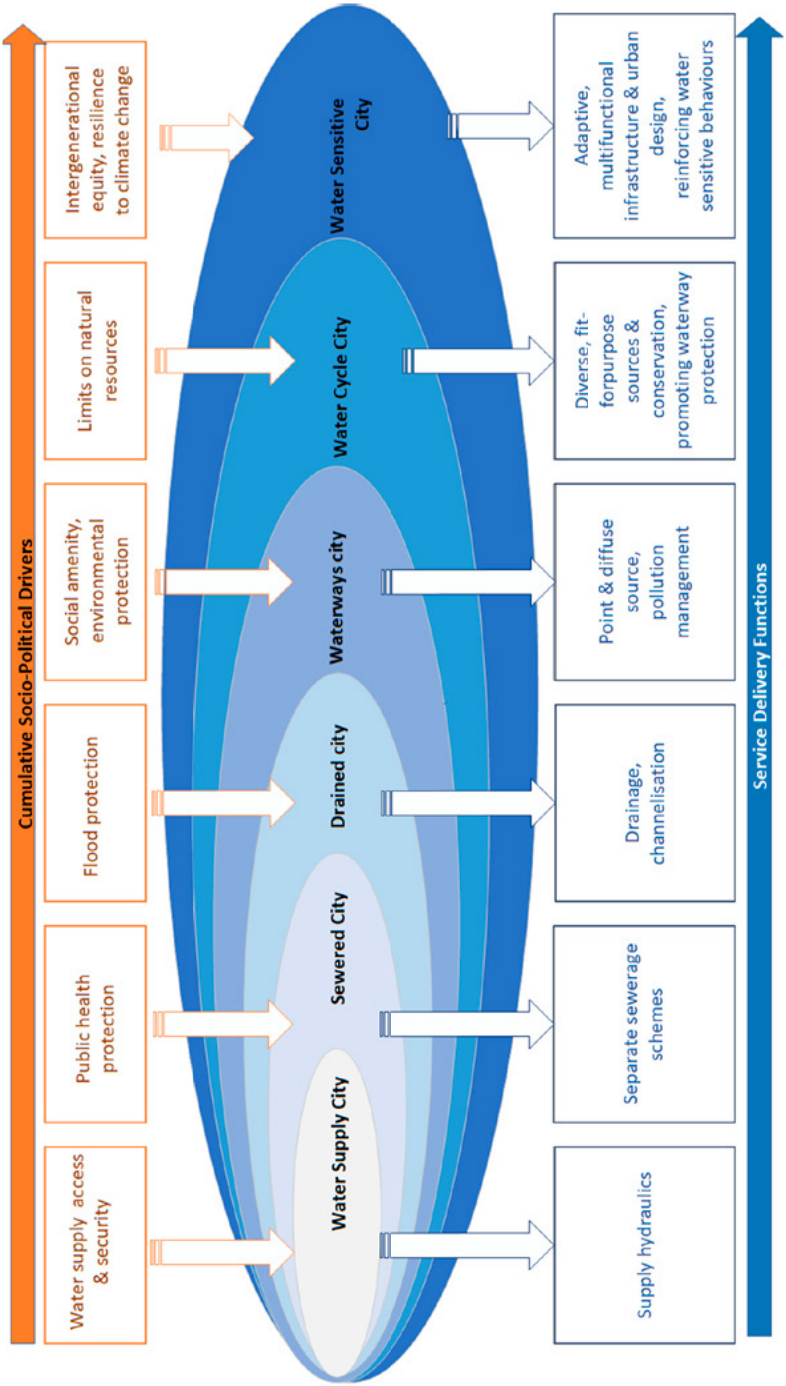

Figure 1. Urban Water Management Transition Framework

Source: Brown et al. (2008).

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The summary and comparison of the above mentioned concepts are included in Table 2.

Table 2. Chosen contemporary water management tools and concepts

Concept	Characteristic
LID – Low Impact Development	Aims at the restoration of possibly nature-like hydrological conditions with the use of: natural processes, landscape and integrated control tools, the balance of run-off volume, infiltration and evapotranspiration, achieved by „functionally equal hydrological landscape". The aim is to minimise the costs of rainwater management, while encouraging nature-based solutions. Rainwater is treated as a resource, not wastewater. (the USA, Canada, New Zealand)
WSUD – Water Sensitive Urban Design	Aims to minimise the hydrological impact of urban development on the surrounding environment. However, in practice, it is associated with rainwater management oriented towards ensuring flood risk control, improving water quality and creating opportunities for economic rainwater use. (Australia)
SUDS – Sustainable Urban Drainage Systems	Based on recreating and using natural water cycle processes, involves rainwater management solutions in a way that is more sustainable than conventional solutions. It applies to both quality and quantity. (Great Britain)
IUWM – Integrated Urban Water Management	Applies to the integrated management of all water cycle elements in a basin, combines water supply management with underground water management, city sewage and rainwater. It also deals with institutional issues and emphasises the importance of local communities in the process of creating such infrastructure. (UE, promoted by UN Department for Sustainable Development, e.g. in South America, Africa and India)
TEEB – The Economics of Ecosystems and Biodiversity	International initiative aimed to draw attention to global economic benefits offered by nature. It also emphasises the importance of biodiversity whose loss or degradation generates costs for cities. TEEB is administered by United Nations Environment Programme (UNEP), with the help from the European Commission and governments of different countries.

Source: author's work based on: Eckart et al. (2017); EPA (2007); Fletcher et al. (2015); Krauze, & Wagner (2014); Mader et al. (2011); Mrowiec (2020); Parkinson et al. (2010); US EPA (2015).

Fletcher and his team have described differences between the above tools and concepts (Figure 2). Yet, Fletcher points out that the terminology is flexible and the figure presented below should be treated as a generalisation, not a rigid classification. It should be noticed, however, that these approaches show a shift of interest: from rainwater and sewage quality improvement (in the context of water resources protection), to the approach where the primary focus is on urban water cycle restoration, possibly nature-like, with the use of BGI and NBS. We can also observe a transition from the tool approach to concept creation. Nevertheless, the figure clearly shows that the presented tools and concepts simply interface in certain areas, use the same background and similar technological and organisational solutions. Often, differences stem from the fact that they originated in different geographical regions (South America, Australia, Europe).

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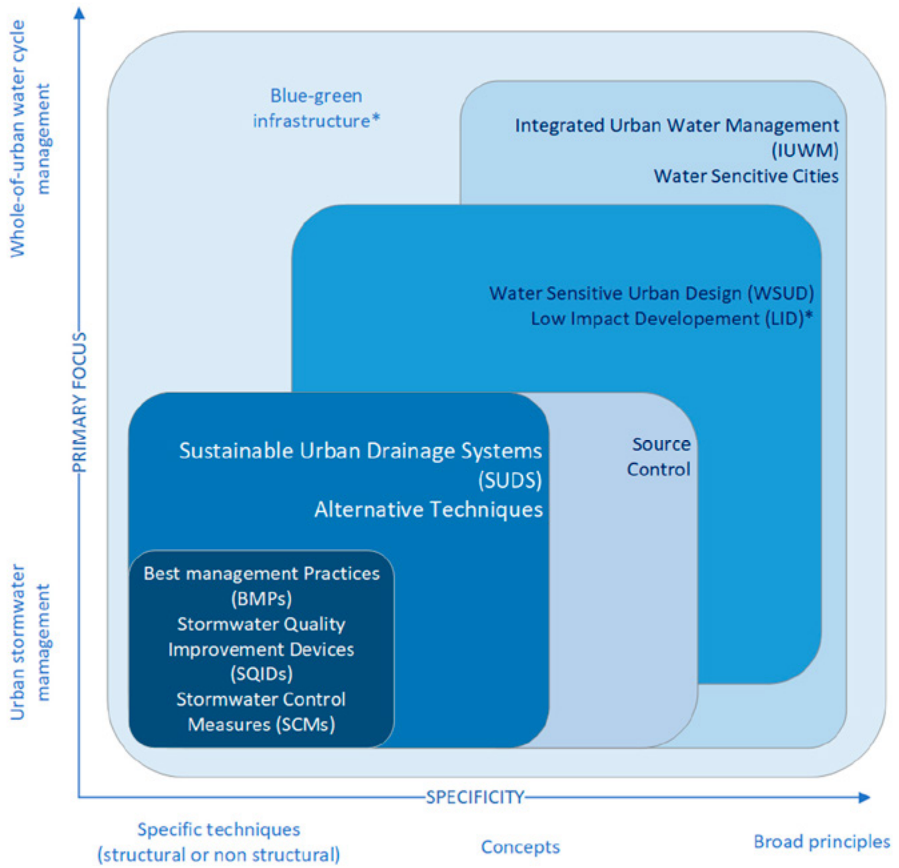

Figure 2. Dependence between different water management tools and concepts

* modified from the original

Source: Fletcher et al. (2015).

The article neither aims to decide whether all the mentioned approaches (Table 3) are identical, nor focuses on differences between them. It can be generally agreed that these approaches are to meet the same objective – water management improvement, with the purpose to protect water resources, as well as improve human quality of life and make cities more resilient and liveable in the age of the climatic disaster. Taking into consideration the fact that IUWM is the widest concept, widely promoted and recognised in the world (Furlong et al., 2017), further considerations will be based on it.

IUWM is a comprehensive approach to water management in urban and rural areas. It combines economic, social and environmental spheres with political aspects and with planning. To put it simply, the aim of IUWM implementation is the transformation of water users to water managers. It is expected to ensure better and more economical use of water resources, the improvement of their quality and accessibility, the improvement of water supply and sewage collection efficiency, the reduction of water loss, and the change of consumption habits. However, it requires the cooperation between the private sector, the public sector and the society. It also involves changes in urban development and its use. Yet, the most important change aspect is to ensure the cooperation between all water users. The differences between the traditional water management and the integrated one are presented synthetically in Table 3.

IUWM (Bahri, 2012, p. 14): "offers a set of principles that underpin better coordinated, responsive, and sustainable resource management practice. It is an approach that integrates water sources, water use sectors, water services and water management scales:

- It recognises alternative water sources.
- It differentiates between the qualities and potential uses of water sources.
- It views water storage, distribution, treatment, recycling, and disposal as part of the same resource management cycle.
- It seeks to protect, conserve and exploit water at its source.
- It accounts for nonurban users that are dependent on the same water source.
- It aligns formal institutions (organisations, legislation, and policies) and informal practices (norms and conventions) that govern water in and for cities.
- It recognises the relationships among water resources, land use, and energy.
- It simultaneously pursues economic efficiency, social equity, and environmental sustainability.
- It encourages participation by all stakeholders".

Table 3. Integrated management vs. traditional management methods

Traditional management	Integrated management
Water and wastewater systems are based on historical rainfall records*	Water and wastewater systems rely on multiple sources of data and techniques that accommodate greater degrees of uncertainty and variability*
Water follows one-way path from supply, to single use, to treatment and disposal*	Water can be reclaimed and reused multiple times, cascading from higher to lower quality*
Rainwater is a nuisance to be conveyed quickly from urban areas*	Rainwater is a resource to be harvested as a water supply and infiltrated or retained to support aquifers, waterways, and vegetation*

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Traditional management	Integrated management
Human waste is a nuisance to be treated and disposed*	Human waste is a resource to be captured, processed, and used as a fertiliser*
Linear approaches deploy discrete systems to collect, treat, use and get rid of water*	Restorative and regenerative approaches offer integrated systems to provide water, energy, and resource recovery linked with land-use design, regulation, and community health
Demand equals quantity. Infrastructure is determined by the amount of water required or produced by end-users. All supply-side water is treated to potable standards; all wastewater is collected for treatment*	Demand is multifaceted. Infrastructure matches characteristics of water required or produced for end-users in sufficient quantity, quality and level of reliability
Grey infrastructure is made of concrete, metal, or plastic*	Green infrastructure includes soil and vegetation as well as concrete, metal, and plastic*
Bigger is better; collection system and treatment plants are centralised*	Small is possible; collection systems and treatment plants may be decentralised*
Standard solutions limit complexity; water infrastructure consists of 'hard system' technologies developed by urban water professionals*	Solutions may be diverse and flexible; management strategies and technologies combine 'hard' and 'soft' systems devised by a broad range of experts*
Utilities track costs alone and focus on accounting*	Utilities evaluate the full array of benefits from investment and technology choices, and focus on value creation*
The standard is a business-as-usual toolkit*	An expanded tool kit of options includes high-tech, low-tech, and natural systems*
Institutions and regulations block innovation*	Institutions and regulations encourage innovation*
Water supply, wastewater, and rainwater systems are physically distinct. Institutional integration occurs by historical accident*	Water supply, wastewater, and rainwater systems are intentionally linked. Physical and institutional integration is sustained through coordinated management*
Collaboration equals public relations. Other agencies and public become involved only when approval of predetermined solution is required*	Collaboration equals engagement. Other agencies and public are actively involved in search for effective solutions*
Centralised planning and management	Integrated planning and management
Demand approach, taken actions equal demand	Responsive supply approach, taken actions consider resource quantity and quality and diversity of needs
Sewage, rainwater or drainage systems, as well as water supply systems are planned, constructed and managed in an independent way	Aims at interdependence, feedback loop between urban network systems, spatial planning; takes local basin conditions into consideration
Based on expert, sector model	Based on cooperation of experts from various fields as well as a social dialogue and the engagement of all stakeholders
Reactive actions (as a response to an encountered problem)	Active actions prior to potential problems
Based on sequence action, tested and fixed problem solutions	Parallel action based on good practices, pilot programmes, innovative projects

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Traditional management	Integrated management
Interaction with local authorities on a "client principle"	Cooperation between local authorities and a local community, common water resources
Based on present solutions for water and land use	Seeking alternative solutions for space use, space integration, ensuring primary water use or water reuse
Single-functional installation, e.g. rainwater discharge or collection	Multi-functional solutions integrating the issues of the environment, a community and economics
Large-scale projects are often preferred	Small and micro-scale projects are introduced „densely", which can limit the necessity for large-scale project implementation
Based on grey infrastructure	Based on blue-green infrastructure, integration with grey infrastructure and existing natural or semi-natural areas

Source: author's work based on: Furlong et al. (2016, 2017); Guthrie et al. (2020); Rosiek, (2016) and *cite from Bahri (2012).

The transition from traditional methods of urban water management to the integrated approach is, in fact, a demanding process, as it involves the engagement of many stakeholders and a change in the way of thinking about water (education). Urban water must be regarded holistically as a precious resource, including rainwater and non-potable water, i.e. re-used, treated and grey water (Figure 3).

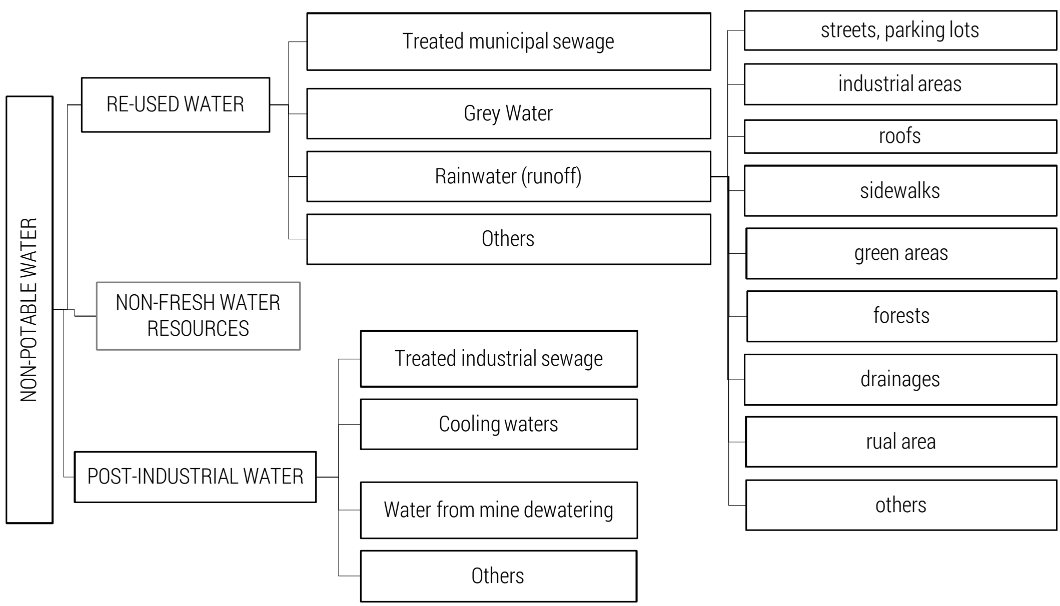

Figure 3. Rainwater, post-industrial water and re-used water

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Materials and methods

Methodology and structure of the research

A literature review and the study of documents strategic for 45 Polish cities have been carried out to identify and describe models for rainwater management in Poland and to assess the level of their integration. Between the years 2020-2022, numerous interviews with entities involved in Poland's rainwater management have also been conducted.

The study includes the cities which took part in the programme for developing urban climate adaptation plans (MPA44, 2017) and Warsaw (MPA Warszawa, 2019), where such a programme was developed within another project. These are the cities with population of more than 100 thousand and also includes several smaller cities functionally connected with the bigger ones (e.g. the Tricity agglomeration: the city of Gdańsk and the city of Gdynia meet the criteria, whereas the city of Sopot does not) or Silesia conurbation. Such a choice of the focus group was purposeful. The analysis included: a systematic overview of strategic documents and other materials (regulations adopted in cities), an analysis of the number and structure of entities engaged in rainwater management, an analysis of economic instruments being implemented, the development of specific models for the most frequently occurring structures, and an analysis of strengths and weaknesses of those models. The following analysis criteria have been chosen to research the specific models:

- constituted feature,
- infrastructure ownership,
- legal basis,
- fee rates for service,
- settlement with users,
- settlement between the operator and the local government,
- investments,
- additional financing from foreign sources,
- assets generated during an investment process.

The study do not consider tax flows.

A research frame constructed in such a manner enables drawing conclusions and comparing identified operator models for rainwater management in Poland.

Rainwater and the EU law

Water issues are managed by substantial EU legislation and are regulated by directives dedicated to the following aspects: urban waste water treatment (Directive 91/271/EEC, 1991), floods (Directive 2007/60/EC, 2007),

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bathing water (Directive 2006/7/EC, 2006), water intended for human consumption (Directive 2020/2184, 2020), groundwaters (Directive 2006/118/EC, 2006), water reuse (Directive 2020/2184, 2020, p. 741), etc. The process culminated in the year 2000 in the so-called Water Framework Directive (Directive 2000/60/EC, 2000), which aims for good qualitative status of water resources. Water Framework Directive also aims for sustainable water use and reduction of drought effects (Directive 2000/60/EC, 2000, art. 1). However, aims connected with water management, including rainwater, are also contained in a number of other documents:

- 8th General Union Environment Action Programme to 2030 (Decision 2022/591, 2022, p. 591),
- Addressing the challenge of water scarcity and droughts in the European Union (COM/2007/0414 Final, 2007),
- Blueprint to safeguard Europe's water resources in 2012 (COM/2012/0673 Final, 2012),
- Blueprint to safeguard Europe's water resources (COM/2012/0673 Final, 2012),
- Green Infrastructure (GI) – Enhancing Europe's Natural Capital (COM/2013/0249 Final, 2013),
- EU Strategy on Adaptation to Climate Change (COM/2021/82 Final, 2021),
- Strategy for Financing the Transition to a Sustainable Economy (COM/2021/390 Final, 2021),
- Circular Economy Action Plan (Resolution 2020/2077, 2021).

We can mention more documents regarding, for instance, biodiversity or urban policy, agriculture and energy production, climate change adaptation, quality and quantity of water resources and, primarily, the European Green Deal.

To systematise the data, we must emphasise that the EU water policy is developed within three pillars: EU water legislation, EU sectoral policy and regional environmental policy. However, we must remember about a significant impact of a horizontal policy, which includes climate change adaptation, transformation to a sustainable and circular economy. Waters, including rainwater, are a significant element of EU environmental and climate policy.

The scope of definitions of rainwater in Polish legislation

To explain the reasons behind the difficulties concerning rainwater management in Poland, it is essential to provide an organisational-legal background. In Poland, water management issues (including rainwater) are regulated by a number of legal acts:

- Water Law Act (Article 1566, year 2017),

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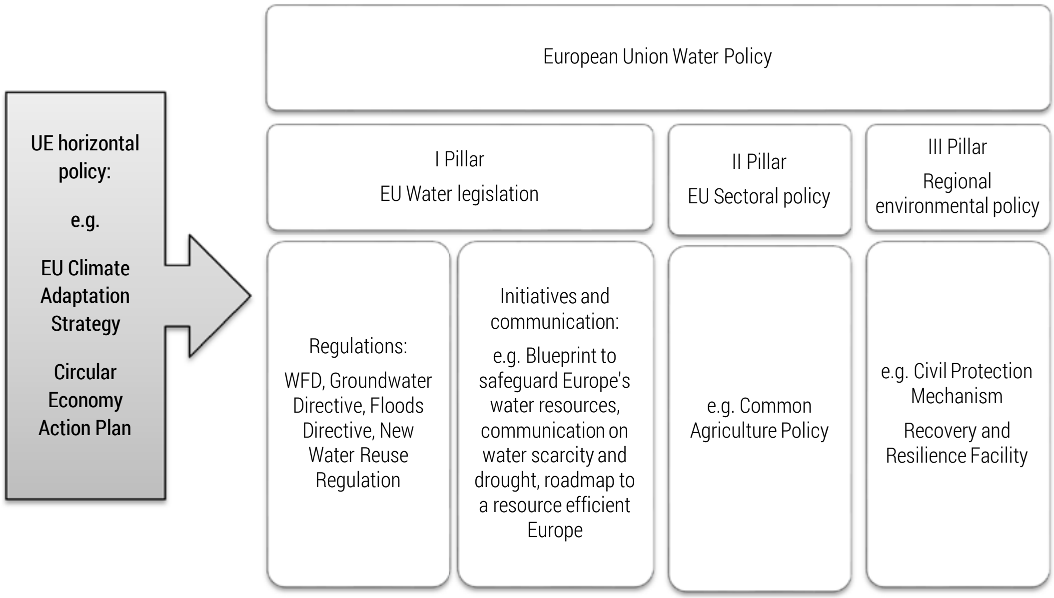

Figure 4. The EU Water policy main pillars

Source: author's work based on EEA, 2021.

- Environment Protection Law (Article 627, year 2001),
- Act on collective water supply and sewage disposal (Article 747, year 2001),
- Waste Management Act (Article 21, year 2013),
- Construction/ Building Law (Article 414, year 1994),
- Spatial Planning and Development Act (Article 717),
- Local Government Act (Dz.U. 1990, Article 95, year 1990, Article 95, year 1995),
- Municipal Services Management Act (*Article 43*, year 1997),

Regulation on disclosure on environmental information and its conservation, public participation in environmental protection and environmental impact assessment (Aricle 1227, year 2008).

Moreover, several implementing acts (in Poland called regulations) and additional norms (for instance construction/ building norms) regulate the issues.

For decades, Poland's Water Law Act defined rainwater as wastewater and, as a result, there was no other way to handle it, but to discharge it through an open or closed sewerage system. The change of Water Law Act provisions in the year 2017 was a turning point for rainwater management in Poland. This statutory change provided a new definition for rainwater and snowmelt, thus excluding it from the automatically-assigned sewage cate-

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gory. Instead, rainwater is defined as water resulting from precipitation. However, this act does not regulate whether and when rainwater/ snowmelt becomes wastewater and we must find applicable regulations in other legal acts. The regulation on substances particularly harmful for water environment (Regulation, 2014) settles the issue. It defines:

- requirements for rainwater discharge to waters or water facilities,
- the highest limit values for pollutants,
- a method for sample water examination and assessment.

The regulation defines parameters for rainwater. Once the parameters are exceeded, rainwater – from industrial areas, storage areas, transport bases, ports, airports, cities, specified national, voivodeship or district (Polish: *powiat*) roads, large parking lots, as well as petrol storage and distribution facilities – cannot be discharged to surface waters without treatment and such rainwater becomes wastewater.

Poland's Water Law Act specifies when rainwater discharge to surface waters is allowed (Article 76, Water Law Act). Rainwater which contains human waste or industrial waste becomes waste itself. The Act also specifies conditions for water discharge from storm overflows to surface waters (Article 80, Water Law Act) as well as several restrictions concerning rainwater management, e.g. a ban on direct rainwater discharge to groundwater (Article 75a, Water Law Act), a ban on snow removal or its storage close to surface waters (Article 77, Section 1, item 2, Water Law Act), a ban on the destruction of water discharge systems (Article 192, Section 1, item 1 and item 3 letter l, Water Law Act) and a ban on a change of rainwater run-off direction and intensity to the detriment of adjacent land (Article 234, Section 1, item 1 and item 2, Water Law Act).

Local plans of spatial development should deal with rainwater management (Dz.U. 2003, poz. 717.). However, current spatial development plans include only about 30% of *gminas'* area (English: *commune*) (BDL K2.G421. P2847, 2021), and many existing spatial development plans are over 10 years old. In older plans, however, a regulation concerning rainwater management only specifies that rainwater must be discharged to a combined or rain sewerage system or, if there is no such possibility, to paved areas within plot boundaries.

As laid down in Water Law Act (Dz.U. 2017 Poz. 1566, 2017 Article 1566), rainwater discharge to a closed or open sewerage system and draining areas within the administrative borders of cities is a water service. Environmental fees are also included in the service. Fees for discharging rainwater to a sewerage system is a different matter – it is a service fee (regulated by tariffs). The change of the legislation in the year 2017 allowed for rainwater management but, at the same time, hindered the collection of service fees for discharging rainwater to a sewerage system. Previously, sewage tariffs for resi-

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dents included this fee. According to the current interpretation, we can doubt whether such a charge can be levied. The Municipal Government Act (Dz.U. 1990, poz. 95, 1995, art. 7.1 pkt.3, Article 95, year 1995, Article 7.1, item 3) includes a list of the most important municipalities' tasks. "To meet the collective needs of the community is one of the municipalities' own tasks. In particular, the own tasks shall include: […] water supply, sewerage disposal and treatment of municipal wastewater, maintenance of cleanliness and order and sanitation, landfill and disposal of municipal waste, electricity and heat supply, and gas". It is worth noting that the above does not constitute a fixed catalogue. However, there is no reference made to rainwater management. A debate concerning this provision is centered around a question whether rainwater management is an example of meeting the collective needs of the community, or not. An answer to this question determines whether utility fees for discharging rainwater and snowmelt can be charged or not. Another method for the settlement of service fees is signing civil law contracts with entities that discharge water. As of the year 2020, service fees fluctuated between 1,6 and 5,7 PLN/m^3. Only three *gminas* have introduced clear discounts when rainwater is subject to retention (Godyń, 2020, p. 107). In Poland, about 40 cities have introduced service fees for discharging rainwater [Consultation on fees for rainwater, 2021 Report on the completion of project team's work dated 19 February 2021) (In Poland there are 2477 *gminas*, including 302 urban *gminas* (Polish: *gmina miejska*), 662 urban-rural *gminas* (Polish: *gmina miejsko-wiejska*) and 1513 rural *gminas* (Polish: *gmina wiejska*)].

In reality, Poland's *gminas* deal with rainwater management on their own or entrust the task to their own entity (budgetary establishments, or urban companies) or procure it to a private entity for infrastructure maintenance. A small share of *gminas* apply fees for discharging rainwater to a sewer system; most of them use their budget to cover the costs. In many *gminas*, especially the smaller ones, infrastructure for discharging water has never been inventoried, as in Poland such infrastructure can be owned by private entities.

We must note that tariffs for water supply and sewerage collection are adopted by the Council of *Gmina* and accepted by Polish Waters[1]. Rainwater fees in a combined system are settled in a sewerage tariff (which some question as unlawful) and service fees for draining rainwater to a sewerage sys-

1 The State Water Holding Polish Waters is the main entity responsible for water management in Poland (since 1st January 2018). Polish Waters have ownership rights to waters that are the property of the State Treasury. It charges water service fees, issues administrative decisions (water legal permits). Polish Waters is also a regulatory body responsible for ensuring protection of residents against unjustified increased fees for water and sewerage. It is a market regulator.

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tem are adopted by the resolution of the Council of *Gmina.* The fees are not approved by the market regulator.

We must also note that, in Poland's cities, many different entities are involved in rainwater management; the number of those entities fluctuate between 6 and more than 10, which hinders the coordination of implemented tasks.

To sum up, the legal situation concerning rainwater management in urbanised areas is not precise enough.

Results of the research

The analysis has helped to identify three main organisational-financial operator models for rainwater management in Poland. What distinguishes the identified models are financing and infrastructure ownership (Table 4). It is important whether it is the end user that pays service fees for discharging rainwater to a sewerage system, or whether the *gmina* budget covers them fully, as it can have a significant financial impact. When a *gmina* pays for, or subsidises the services provided by an operator, it is crucial to assess how the budget and settlement rates (fixed or variable) are defined. It is also important to determine who carries out infrastructure investment and whose budget is burdened with debt (which, in its turn, influences the capacity of a local government and an operator to contract debts).

The operator-public model (Table 4, Figure 5) is based on public financing, there are no fees for discharging rainwater charged to the end user; the city owns the infrastructure and the investment (which involves obtaining subsidies). There is an operator, a subsidiary company of the city itself (a water company). The city deals with all water issues, except for the issues controlled by Polish Waters and the ones handled by a water-sewage company. The City of Gdańsk has developed such a model.

The operator-market model has been developed in the city of Poznań (Table 4, Figure 6) and is relatively the latest of all the models described in this article. There is a water-sewerage company which is owned by local government units that this company operates. This company sets up a daughter company responsible for the tasks related to rainwater management. Infrastructure ownership remains in the hands of the local government, although a part of a closed sewerage system is leased from the city, so that the company can carry out the entrusted tasks. The residents pay fees for discharging rainwater under civil law contracts. The city pays for draining its properties. The company obtains funds for investment. Another entity deals with the implementation of BGI.

Table 4. Characteristics of operator models for rainwater and snowmelt management in Poland's big cities

Criteria / Model type	Operator-public Model The City of Gdańsk	Operator-market Model The City of Poznań	Operator-ownership Model The City of Bydgoszcz1
Constitutive features	Financing the operator is based on a compensation from the municipality's city budget	Financing the operator is based on fees from users	Financing the operator/ infrastructure owner is based on fees from users
Infrastructure ownership	Local government	Local government	Operator
Legal basis	Entrusting the municipality's own task	Entrusting the municipality's own task	Entrusting the municipality's own task
	Public agreement or in-house	Lease or loan agreement	Contribution of assets in-kind or by sale / long-term financing agreement
Service fee rates	-	City Council Resolution	City Council Resolution
Settlement with users	-	A service agreement with the operator	A service agreement with the operator
	-	Fees related to the exploitation of the city's infrastructure	Fees related to the exploitation of the city's water discharge infrastructure and its development or maintenance (deprecation)
Settlement between an operator and a local government	Agreement (a company) based on an investment and maintenance plan or a budget plan and its execution (a budget unit)	Investment lease payment to the municipality; optionally subsidising the operator, if fees from users do not cover the costs	The municipality's payments for draining its properties based on parameterised criteria; optionally subsidising the operator, if fees from users do not cover the costs
Investments	Local government	Local government	Operator
Foreign subsidies	Local government	Local government	Operator
Assets generated in the investment process	Balance sheet of a local government	Balance sheet of a local government unit	Balance sheet of a company
Examples	Figure 3.1	Figure 3.2	Figure 3.3

Source: author's work based on Sumisławski (2021).

The third model is called the operator-ownership model (Table 4, Figure 7) because, in this case, infrastructure has been inventoried and contributed in-kind to a water-sewerage company. The company settles with the city under parameterised indicators, but a subsidy is possible, if the residents' fees do not cover the cost of system service. The job of the company is to invest and develop, as well as provide financing for investment. The debt does not impact the city's credit rating. It is an interesting fact that the residents have received a several years' exemption from fees for discharging

Figure 5. Operator-public Model – the City of Gdańsk

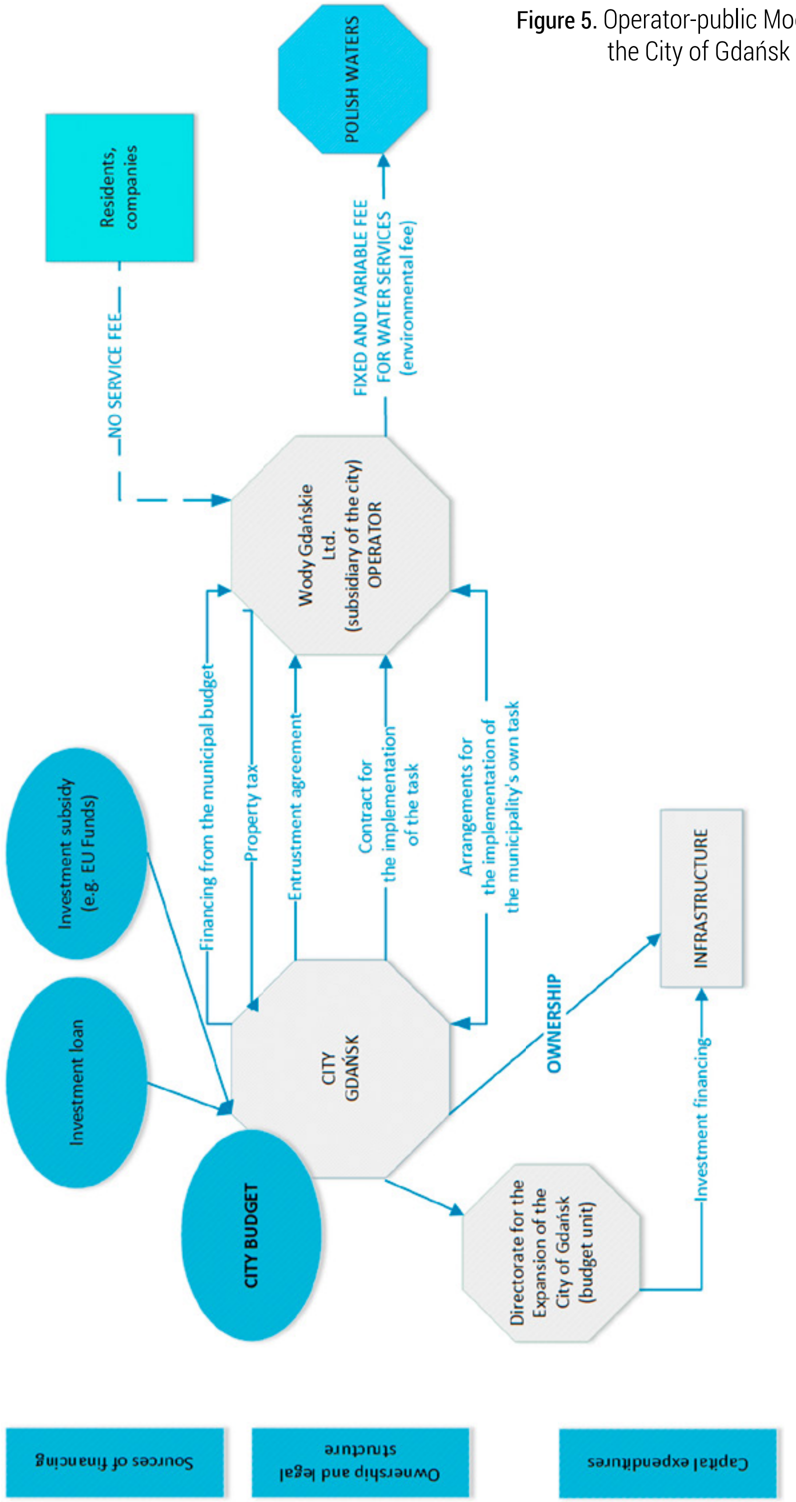


Figure 6. Operator-market Model – the City of Poznan

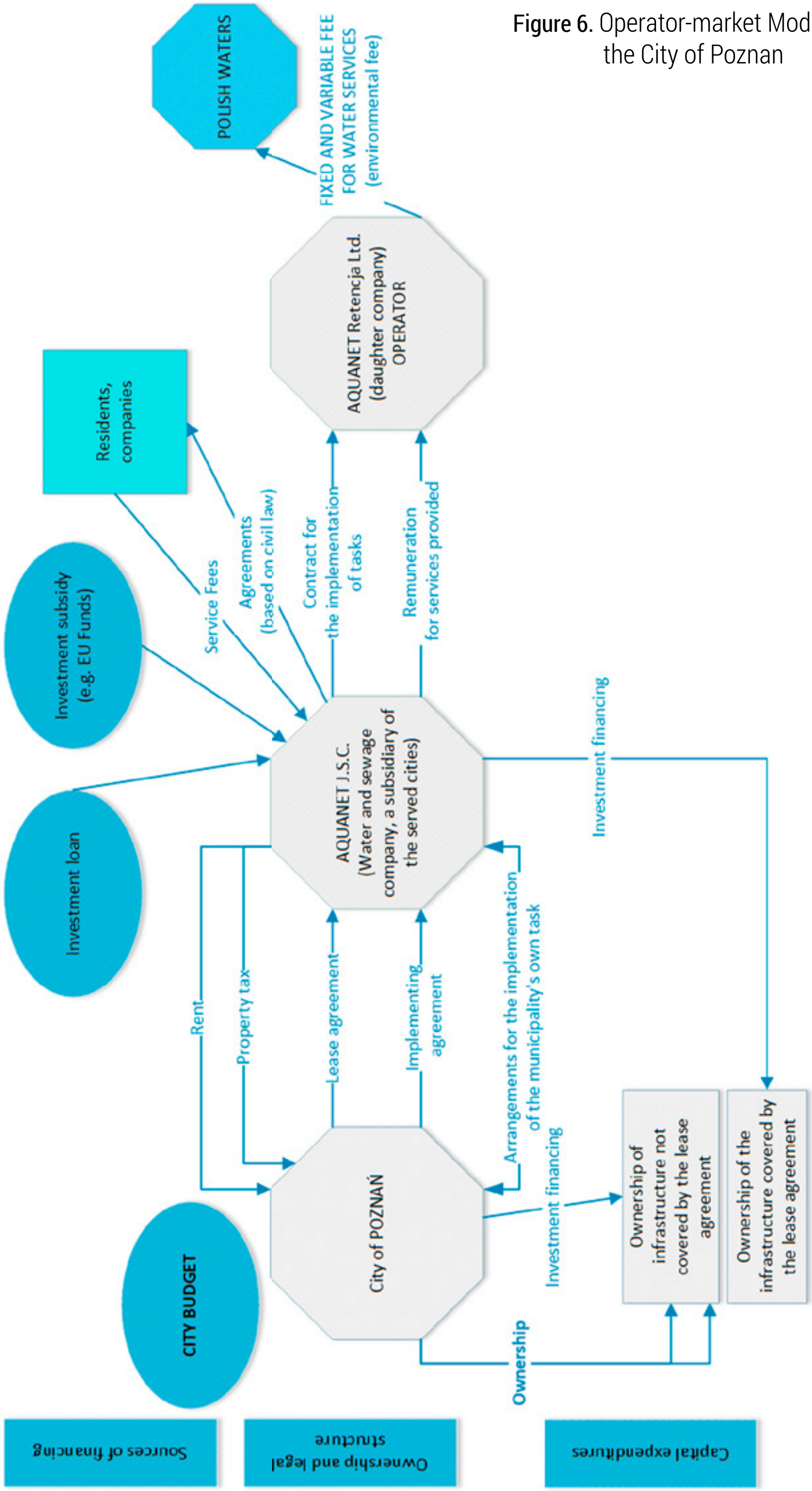
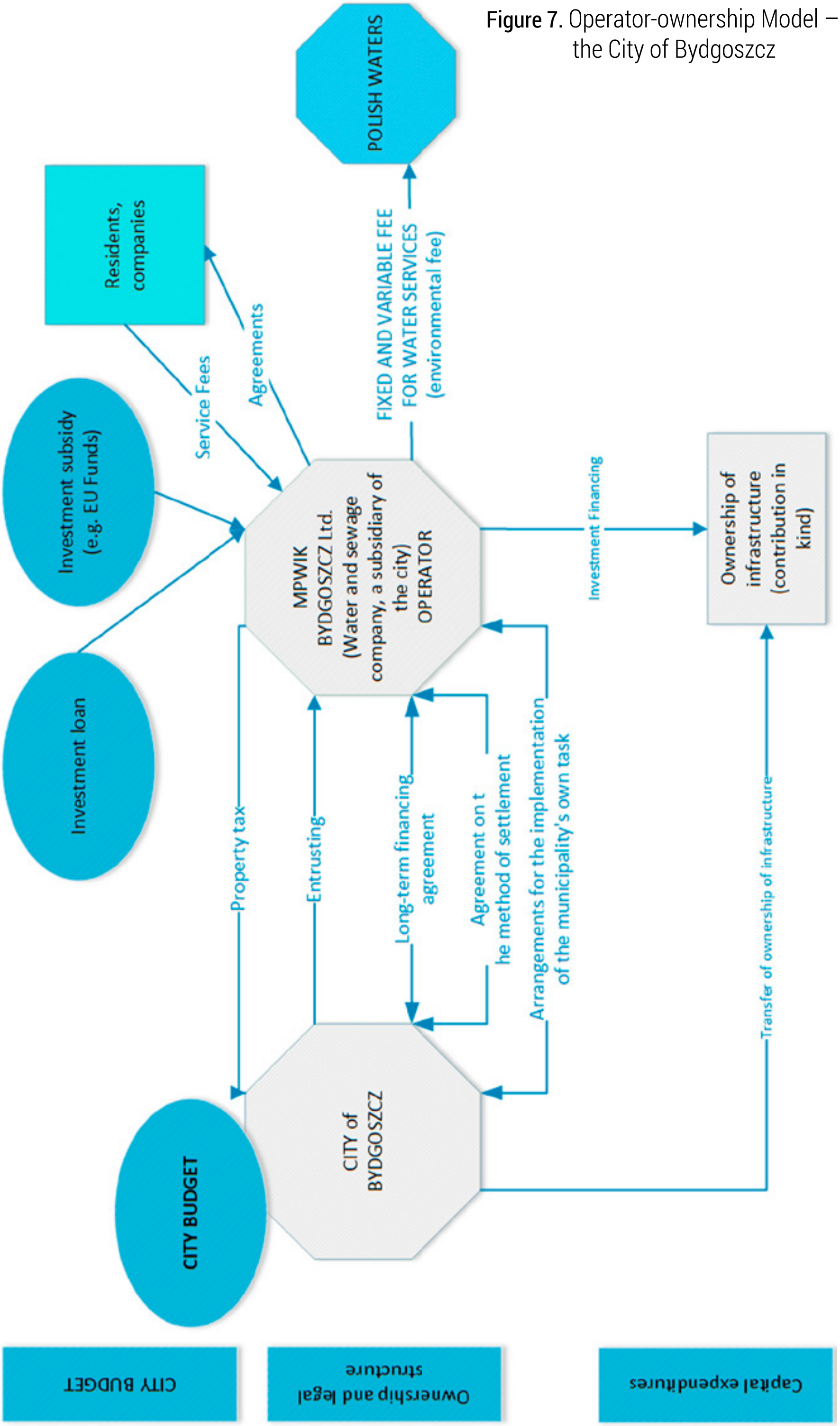


Figure 7. Operator-ownership Model – the City of Bydgoszcz



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rainwater to a sewerage system, to give the residents time for the installation of retention systems. This way, they will not have to pay the fees in the future. However, few residents have made the effort.

We must note that this study considers only the most important institutions and the relationships between them. In each of the cities, there are other institutions which are also involved in rainwater management. They remain in the structure of the city or are city-dependent entities such as *Green Spaces Management (Polish: Zarząd Zieleni Miejskiej) and sometimes Urban Forests Management*, Cemetery Management, Sports Infrastructure Management. Entities not dependent on the city may also be relevant, for example State Forests. Each of these entities is involved in rainwater management and can implement blue-grey infrastructure.

Poland's legislation, for a long time, has defined rainwater as wastewater and the main task related to its management was to quickly discharge it from a city. For two decades the situation has been changing and big cities, in particular, take actions to rationalise rainwater management. It is possible now due to the provisions which changed the definition of rainwater and defined the conditions under which it becomes wastewater. However, the provisions are not coherent and many issues remain unregulated or allow for multiple interpretations. Moreover, Poland's cities struggle with sub-urbanisation and the density of development, which results in excess surface sealing. It, in its turn, increases the risk of flooding, especially flash floods (Walczykiewicz & Skonieczna, 2020). Over the last few years, however, urban adaptation to climate change has generated more interest in rainwater management.

There are no specific provisions implying how rainwater management should be handled in Polish *gminas*. However, *gmina*s especially exposed to the risk of flash flood due to their landscape (such as Gdańsk) have started to take measures to change their urban water resources management, including urban rainwater. It is an announcement of significant changes. Consequently, various ownership-financial models for urban rainwater management have developed in Poland. This study focuses on the cities where the task of rainwater management was entrusted to the operator. The study has helped to identify three models of dependency between the city and the operator. Other entities affecting urban rainwater management are not included in the study. The focus was on financial flows and organisational aspects, ownership and responsibility. At the same time, the study concentrates on integrated urban resources management and accesses the identified models in this respect.

The three identified models: the operator-public model, the operator-market model, the operator-ownership model have been characterised and their „mapping" has been attempted (Figures 5-7). However, we must also consider the strengths and weaknesses of the models (Table 5). A signif-

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icant advantage of the operator-public model (the City of Gdańsk) is the fact that most tasks regarding urban water are entrusted to one entity. The operator's dependency on the city allows for fast communication and for the city's control over ongoing tasks. However, the total financial dependency on the city's budget may impede tasks regarding rainwater management in case the city's spending is cut. At the same time, bigger investments are implemented outside the entity and they leave the city's budget with debt burden. Still, the biggest disadvantage of the model seems to be the fact there are no fees for discharging rainwater to a sewerage system. Such a fee should be an incentive for rainwater management in the user's own area. The disadvantage can be eliminated provided the provisions are improved. A water-sewerage company is still in charge of an urban sewerage system, which hinders the integration of the whole system. Infrastructure ownership remains in the hands of the local government.

Table 5. Disadvantages and advantages of rainwater management operator models in Poland

Advantages	Disadvantages
Operator- public Model (the City of Gdańsk) – Figure 5	
All tasks regarding water in the municipality, rainwater and BGI under one entity (excluding the ones managed by Polish Waters) „fast" municipality-company communication Extensive educational action	100% financed by the budget of a local government No fees for rainwater management Bigger investment in another municipality's unit Foreign funds obtained mostly by the municipality, not by the company
Operator-market Model (the City of Poznań) – Figure 6	
A separate entity – transparent financing, prevention of cross- subsidation Fees for draining rainwater Possibility of foreign funds for investment with no burden on the municipality's budget Infrastructure remains the municipality's property (investments)	Only part of rainwater infrastructure under the company's management (closed drain system) The Council of the City sets fees, they may not cover the costs Infrastructure remains the municipality's property (investments) Another entity deals with BGI
Operator-ownership Model (the City of Bydgoszcz) – Figure 7	
Infrastructure transferred to the water-sewerage company (investment and maintenance in one hand), correctly calculated depreciation Settlement with the municipality on the basis of parameterised criteria Long-term agreement with the municipality Fees for rainwater discharge Investments do not directly burden the municipality's budget Extensive educational action	Potential risk that, in such a big entity, rainwater and BGI issues will be set The Council of the City sets fees, they may not cover the costs

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The operator-market model developed in the City of Poznań is assumed to provide transparency in financing rainwater management and to prevent cross-subsidation. At the same time, it moves away from integrated urban rainwater management as, by definition, a closed sewerage system is managed by a different entity than an open sewerage system. Still, infrastructure ownership remains in the hands of the local government.

The operator-ownership model developed in the city of Bydgoszcz is based on contribution of infrastructure ownership to the operator in kind (in this case a water-sewerage company). Such a solution requires full inventory and quoting of infrastructure for discharging water. This solution works well for the city of Bydgoszcz. However, its weakness is the fact that rainwater issues are included in the range of activities of a relatively big entity. The experience proves that they might end up being marginalised.

Commonly in Poland, a road administrator is in charge of tasks regarding rainwater management. Then, it is part of „business as usual" and the focus is on water discharge, and not on the implementation of modern, nature-based solutions.

These considerations should indicate the best model for rainwater management. However, it is not possible for certain reasons. One of the reasons is the fact that the analysis do not include complicated issues connected with tax returns, which may influence the effectiveness of the system. Even if we use an effectiveness criterion (Rosiek, 2008), the assessment of effectiveness should be based on measurable indicators, which is not possible in this case. Firstly, because the data is not collected in a coherent and precise way. Secondly, the implementation of specific solutions is connected with organisational culture in a given city.

The results of the conducted survey show organisational culture is of great significance for the development of modern water management models and, whenever cooperation between entities is well-organised and successful, a legal-organisational form is of secondary significance. This makes the models sensitive to human factors.

The possibility to apply fees influences the effectiveness of rainwater management in Poland, but not its efficiency. There are a number of possible explanations which, however, require further analysis. Among possible explanations, we could mention the lack of nationwide requirements (regulations) in the area of fees for surface sealing / retention loss (currently existing fees are facade fees), and municipalities' inability to prove the actual water retention levels allows for discounts on ecological fees for discharging rainwater [...] according to the Water Law Act.

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Conclusions

Water management, especially rainwater management in urbanised areas, appears to be the primary challenge of the climate transformation age. Despite imprecise legal provisions, many of Poland's cities--especially these exposed to the effects of river floods or flash floods--have started to implement organisational-legal changes with the purpose of finding the appropriate model for rainwater management in their area. It is a model which will reduce flood risk and drought effects while making it possible to finance this task.

The study focuses on models developed in Polish cities which use the affiliated operator for the implementation of the task. The study also focuses on formal-legal and financial issues of that relationship. However, no complete analysis on tax effects has been carried out, which should be the subject of further analysis.

On the basis of the study, we can conclude what follows:

- A literature review on the subject leads to a conclusion that integrated urban rainwater management is a direction described as the most promising;
- Integrated management process should include not only rainwater, but all kinds of non-potable waters, including grey and re-used;
- Legal framework, norms and standards for water reuse and water quality adapted to the users' needs are essential;
- The development of information ecosystem is required. It will integrate resources of all institutions and will be available to all water users;
- Despite the statutory change of rainwater definition in Poland (i.e. rainwater is not wastewater), a number of specific provisions have not been adopted, which causes chaos and hinders the implementation of reasonable solutions that would stimulate proper urban rainwater management, including economic instruments (fees, taxes);
- There are a lot of entities involved in urban water management (including rainwater management) which hinders the implementation of harmonised tasks, even with full cooperation between the entities;
- Three main operator models for rainwater management have been identified in Poland, their constitutive features being: infrastructure ownership and financing of ongoing tasks and investments;
- Identification of weaknesses and strengths of operator models for rainwater management is of significance in the context of their implementation in other cities in Poland;
- A determining factor is the issue of transferring infrastructure ownership to the operator;

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- Accepted coordination models for rainwater management influence the implementation of integrated urban water management, including rainwater; the competences for managing different types of drainage infrastructure are divided among different institutions, which may hinder the implementation of integrated urban water management;
- Poland's cities that want to implement or improve their rainwater management system are in a difficult situation, because of imprecise legal framework.

To conclude, we must note that the study outlines further research challenges, connected especially with models for water management in smaller cities not influenced by a nearby metropolis and with society's approach to fees for rainwater management.

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DOROTA **RYNIO** • HANNA **ADAMICZKA**

THE ROLE OF RIVERS IN CREATING A BLUE-GREEN CITY ECONOMY ON THE EXAMPLE OF WROCŁAW AND GDAŃSK

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ABSTRACT: The article aims to analyse and critically evaluate the use of blue-green infrastructure in the city. The study was conducted on the example of the Wrocław and Gdańsk rivers. An essential element of the analysis is to determine the possibilities of introducing and improving blue-green infrastructure by using good practices in these urban units, particularly those relating to the role of rivers. During the study, the following research questions were formulated: What megatrend of urban development is defined by current conditions, and what do urban units gain in this way? Is the blue-green potential of the examined cities effectively used? What is the state of development of blue-green zones in and around the river? The methods used to write the article are desk research, case study, analysis of the researched areas using up-to-date cartographic materials, IDI, literature, and legal status analysis. The study supports the exchange of information between cities and the management of the river in the city.

KEYWORDS: blue-green infrastructure, river, city, megatrends, development of land by the river

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Introduction

In the modern world, cities face many challenges. Urban centres, in their strategies, often emphasise the need to strive for sustainable development (Zakrzewska-Półtorak & Pluta, 2022). However, the possibilities of implementing sustainable development are different and depend on the socio-economic situation in which the urban centre is located, what resources it has, what has been achieved so far in terms of sustainable development, and what advantages it can develop (Adamiczka, 2022). Many scenarios for implementing sustainable development are considered and introduced in the literature and practice. However, in the conditions of global climate change, environmental pollution, and changes in the preferences of city dwellers, aspects related to environmental protection, securing and creating green areas, spatial order, and maintaining the environment in at least intact or better condition become a priority for the city's economy (Griffiths & Sovacool, 2020). Thus, greenery, access to water, environmental protection, and care for the climate are increasingly becoming the guidelines for strategic urban development planning. In these conditions, the aspects of cities' green areas and the presence of rivers (with the necessary infrastructure for both) and their development are becoming critical. The article aims to analyse and critically evaluate the use of blue-green infrastructure in a city. The study was conducted on the example of Wrocław and Gdańsk. The selection of research objects was made due to the river's resources and green areas in riverside spaces in both cities as well as the approach the approach to those resources in those centers. An essential element is determining the possibilities of introducing and improving blue-green infrastructure using good practices in these urban units.

During the study, the following research questions were formulated:

- What megatrend of urban development is defined by current conditions, and what do urban units gain in this way?
- Is the blue-green potential of the examined cities effectively used?
- What is the state of development of blue-green zones in and around the river? Can good blue-green infrastructure practices be transferred to other cities, and how?

The article examines Wrocław and Gdańsk – cities that have a blue-green resource, but their development scenarios are not similar, due to different conditions and resources. At the same time, both cities have been at the forefront of the Water City Index ranking for several years (Ćmielewski et al., 2021), evaluating Polish cities in crucial areas of water management in the city.

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The methods used to write the article (desk research, case study, analysis of the researched areas using up-to-date cartographic materials, IDI, literature, and legal status analysis) are described below.

An overview of the literature: blue-green development as a megatrend in the global economy

The global economy is undergoing profound changes, resulting in new challenges being created for the world. New megatrends are emerging in the economy, and the previous ones are evolving. Changes in trends are due to many factors: the use of new technologies and techniques, technical progress, faster and more effective communication, virtualisation of economic phenomena and individual areas of life, the increasing level of innovation, investment, etc. (Griffiths & Sovacool, 2020). The consequences of these factors are of two types: positive (progress, quality, etc.) and negative (climatic and environmental changes, lifestyle diseases, etc.). Megatrends are complex phenomena that occur globally, concerning various spheres, and indicate directions of potential changes. Their modelling takes place over a long period and dramatically impacts the economy and the people providing guidelines for the future. People can influence the changes taking place, enhancing or weakening their effect. Adapting to these trends is essential, allowing one to use changes to achieve success. If such adaptation does not take place, it poses a threat to the functioning of the system and the human beings in it. Correct determination of trends allows one to identify threats and select tools with which one can try to remedy the situation. The attempt at anticipation helps to understand what may happen in the future. We make decisions from a pool of various possibilities, creating a projection of the future. In this way, we gain preparation for the conceptualisation of thinking about the future in the macro dimension. However, it is not an actual picture of the future, but a potential one. Megatrends have consequences at different levels, e.g., regional and local.

The transition from the industrial economy to the information civilisation has stimulated intensive changes in both economic and social, cultural, and political aspects, as well as emerging network connections. Contemporary climate challenges, migrations, polarisation, pandemics, etc., compound this. Therefore, the currently indicated megatrends are:

- world population growth,
- increasing population migrations,
- ageing of societies in developed countries,
- growing social polarisation,
- the growing middle class,

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- increase in urbanisation,
- growing demand for energy,
- digitisation and automation of work,
- climate change,
- environmental pollution and loss of biodiversity,
- declining food security, rising international tensions,
- crisis of democracy and new models of governance (Polskie Towarzystwo Studiów nad Przyszłością, 2022).

Classifications of megatrends can be varied, and megatrends are also indicated within individual domains. The analysis of global megatrends can also be conducted from different angles. The impact of megatrends on the environment of Europe and its countries was defined by the European Environment Agency (EEA) in the methodological study "Mapping Europe's environmental future: understanding the impact of global megatrends at the national level", which, as part of issues related to ecosystems, food, water, energy, materials, and land has identified eleven global megatrends relevant to Europe (Eionet, 2017):

- the widening divergence of world population trends,
- towards a more urbanised world,
- changing disease burden and pandemic risk, ever-faster technological changes,
- steady economic growth,
- an increasingly multipolar world,
- intensifying global competition for resources,
- increasing pressure on ecosystems,
- increasingly severe effects of climate change,
- increasing environmental pollution,
- changing approach to governance (Główny Inspektorat Ochrony Środowiska, 2017).

Against the background of the classification of megatrends, the following aspects become particularly visible: environmental and climate change, which determines the concentration of actions of authorities, organisations, and people around these challenges. Therefore, the pursuit of sustainable development becomes the primary aspiration. Sustainable development is a concept defined in various ways. It refers to durability and immutability (emphasised by H.C. von Carlowitz (Lusawa, 2009)) and, according to the German school, economic benefits and ecological care (Veith, 2004). The Brundtland Report of the World Commission on Environment and Development entitled Our Common Future (United Nations, 1987) emphasises that development should meet today's needs without compromising future generations' ability to meet their needs (Morżoł, 2006). This approach is designed to ensure economic development, while maintaining social and

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environmental balance. Therefore, a traditional approach to sustainable development has been based on three pillars: economy, society, and environment. In various periods, emphasis was placed on individual pillars but, in the face of unfavourable conditions, the economy and the profits resulting from it give way to environmental goals that are to serve society. Sustainable Development Goals evolve as challenges and threats to the world grow. In 2015, the U.N. member states adopted the 2030 Agenda by a resolution of the General Assembly – a global development strategy until 2030 (Transforming our world: the 2030 Agenda for Sustainable Development), which included 17 Sustainable Development Goals, defined in 5 areas: people, planet, prosperity, peace, partnership (UN, 2015). The goals of the 2030 Agenda are the end of poverty, zero hunger, good health and quality of life, good quality education, gender equality, clean water and sanitation, clean and accessible energy, economic growth and decent work, innovation, industry, infrastructure, fewer inequalities, sustainable cities and communities, responsible consumption and production, climate action, life underwater, life on land, peace, justice, and strong institutions, and partnerships for goals (Kampania 17. Celów, 2022).

The goals indicated in the 2030 Agenda directly or indirectly demonstrate the need to implement green and blue development. The blue-green megatrend affects the creation of space in which people can live better, and in the conditions of a deepening crisis, it can contribute to sustaining life. The crisis, mainly due to climate change, leads to droughts and constant water shortages, with the possibility of floods (including flash floods), which can be catastrophic for humanity.

In cities rich in rivers, unique development opportunities are created based on this resource. The blue resource of the city provides additional opportunities to survive crises, both spatial and climate-related. (Breś, 2019; Udas-Mankikar & Driver, 2021). The blue space is a place for the development of industry, transport, entrepreneurship, real estate, tourism, culture and art, sports, as well as fauna and flora. At the same time, it is a social space integrating various social groups; it can be a place of relaxation, respite, training, etc. The basis for implementing these functions is the appropriate development of rivers, coastal areas, and their surroundings. In cities rich in river resources, blue spaces are often associated with green areas; those units usually create a common policy towards these ranges due to the overlapping challenges in the blue-green conditions of how the city functions. From this perspective, green economy is one that affects the well-being of the population, the quality of its life, and social equality. At the same time, the environmental risk and consumption of natural resources are not increased; it is a more integrated and comprehensive approach to adapting the environment into economic processes (Janiszek, 2015). Hence, green development

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assumes the economic development of the present generation without destroying the environment, without exhausting non-renewable resources, and preserving them for future generations – this means using efficient and environmentally friendly technologies and focusing on mitigating the effects of climate change. In turn, the blue economy refers to sectors related to the sea (European Commission, 2020) and, in a broader sense, also to rivers and other surface waters. Blue development of cities uses their potential to implement sustainable development. One of the elements of green and blue development is the introduction of green and blue infrastructure. Green Infrastructure (GI) is a nature-based system designed to regulate surface energy processes (achieved through evaporation, shading and emissivity regulation); it positively affects air movement and heat exchange (Almaaitah et al., 2021). Blue infrastructure (BI) consists of various types of water (natural and artificial) introduced in the city to slow down runoff, provide temporary storage, emit longwave radiation to cool surfaces, and effectively absorb short-wave radiation and release it through evaporation (Almaaitah et al., 2021). The blue-green infrastructure (BGI) is a network of areas covered with greenery and water-containing solutions based on natural functions (Sobol, 2021). These solutions positively affect the preservation of biodiversity, eliminating urban heat islands, absorbing CO2, and also enable water storage, retention and recycling (Kus & Felski, 2018; Sobol, 2021). Moreover, solutions in the field of blue-green infrastructure (such as allocating part of the land for flooding, preserving wetlands, introducing various types of urban greenery – gardens, parks, greenery on the streets, parking lots, etc., introducing green roofs and vertical gardens, rain gardens, water retention facilities and others) are aimed at preventing floods and reducing their effects (Europejska Agencja Środowiska, 2019; Pietryka, 2020).

In these conditions, it is crucial to build a blue-green infrastructure. These investments become methods of preventing consequences in terms of climate change, weather anomalies, and droughts. In addition, in many places, periods of water shortage become continuous and worsen each year. Therefore, actions that increase resistance to these negative phenomena are essential. The potential of investment in blue-green infrastructure provides the basis for indicating it as a tool for preventing and counteracting adverse climate change, which is often indicated in the literature (Januchta-Szostak, 2020; Janiszek, 2015). Therefore, implementation of blue-green development strategies in urban space becomes particularly important.

In various divisions and approaches to megatrends pertaining to cities, the tendency towards urbanisation, climate change, and health threats becomes visible. In this context, the megatrend of the blue-green economy is developing in the cities (Adamiczka, 2022). Under this megatrend, the activities undertaken by urban centres are to serve as an antidote to threats to

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those units. The green and blue development of cities is intended to lead to better air and environmental quality, improved health, creating space for rest and recreation, increased flood safety, counteracting droughts and flash floods, reducing the threats from heat waves, developing river quays and improving the quality of life (Spiller, 2020). Green and blue infrastructure should also prevent and/or reduce the likelihood of destruction of material goods, a threat to human life and health, the occurrence of strong winds and the consequences of their appearance. It could also stop the «concreting» of cities, or lead to their «un-concreting». The blue-green strategy of cities should serve as a «panacea» for climate change, inadequate spatial development, surface sealing, lack of green areas, and developing rivers and coastal areas, as well as function as a way to adapt to new weather conditions. The development of rivers and coastal areas can be multi-directional: while anti-flood measures are taken, a space for rest and recreation can also be created, which – in turn – can also be used for economic, communication, and art and culture purposes. The focus of the centres on implementing the blue-green approach is to introduce, develop and rebuild the blue-green infrastructure concerning reducing the adverse effects of heat and heavy rains in the city. These green spaces with trees, shrubs, and lawns, as well as blue spaces, e.g., water reservoirs, watercourses, and wetlands, function like a sponge and catch excess water that accompanies torrential rains; during dry periods they are a source of water for the surrounding areas. The water vapour above this surface improves the local microclimate, irrigates the vegetation, and enables water circulation in the environment. Water retention during torrential rainfall is also conducive to maintaining the ability of sewage systems to function. Concrete spaces heat up intensively, creating hot islands in the city; much cooler green areas lower the temperature and give respite to people and animals. Tall greenery, especially trees with broad crowns, provide shade, making it easier to survive periods of heat. They also shelter animals, especially birds and other organisms, creating conditions for biodiversity in urban spaces (Chmielewski et al., 2018). Trees can dissipate wind energy in their branches, serving as a protective barrier for urban buildings which can be destroyed during storms. All those elements build the resilience of cities to climate change.

Rivers are watercourses that can (and should) be a natural element of blue-green infrastructure in cities. However, their management in Poland is complex due to the division of competencies – they flow through the city managed by the local government, while being the property of the State Treasury under the management of the State Water Holding Polish Waters (Adamiczka, 2022). At the same time, comprehensive actions regarding mitigation and adaptation to climate and environmental changes are crucial for the proper functioning of modern cities.

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Research methods

The river card[1] was used to carry out the study – a tool to study river policy in the city. The first section, which was used in this study, deals with climate and environmental action and contains ten topics. According to the card's instructions, when reflecting on a given aspect, one should mark the degree of agreement with the given statement on a five-point scale where:

1 – definitely not,
2 – rather not,
3 – partially,
4 – rather yes,
5 – definitely yes.

Based on individual in-depth interviews (IDI) with representatives of Gdańskie Wody (November 23, 2022) and the desk research method (including literature studies, research of documents, source materials, and legal acts), the method of chamber work using the results of direct and detailed inventory analysis of the studied areas using current cartographic materials, the first part of the card for the city of Gdańsk was completed. Then, the results were summarised in a table with the results for Wrocław (river chart completed based on information from the coordinator for river policy in Wrocław, representatives of the Department of Water and Energy, and representatives of the Department of Safety and Crisis Management; the data was supplemented with the results of the IDI research – with Coordinator for River Policy in Wrocław of July 7, 2021, and April 21, 2022, in-depth interviews among Wrocław residents, focus group interviews among students of the Wrocław University of Economics and two online surveys) [1]. For the surveyed cities, the indicator of the use of river potential (River Potential Utilisation Index – RPUI) was calculated in the climate and environment section, using the following formula:

$$RPUI = \frac{sum\ of\ scored\ points}{sum\ of\ points\ possible\ to\ obtain}. \quad (1)$$

The card has been modified to allow for a comparison of cities. The data prepared in this way allowed the authors to conclude the possibilities of benchmarking and cooperation between Wrocław and Gdańsk to develop and improve their river policy.

[1] The river card was published in Adamiczka, H. (2022). *Wykorzystanie rzeki w kształtowaniu rozwoju społeczno-gospodarczego miasta* [Doctoral dissertation]. Uniwersytet Ekonomiczny we Wrocławiu.

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Results of the research

The objects of the study are Wrocław and Gdańsk. Wrocław is the capital of the Lower Silesia Voivodeship; its area is 292.8 km^2, and the population numbers 642.9 thousand (Urząd Statystyczny we Wrocłwiu, 2021). It is located in the south-western part of Poland, in the basin of the Middle Odra – the river Odra, together with its tributaries, forms a hydrographic network of over 100 km (LEMITOR, 2016). The main Wrocław's rivers are: Odra, Ślęza, Oława, Widawa and Bystrzyca.

Gdańsk is the capital of the Pomeranian Voivodeship; it is Poland›s principal seaport. Its area is 262 km^2, and the population numbers 470,8 thousand (Urząd Statystyczny w Gdańsku, 2021). It is located in the northern part of Poland, on the southern edge of Gdańsk Bay. Gdańsk, Gdynia, and Sopot (located close to each other) form a metropolitan area. The main Gdańsk's rivers are: Martwa Wisła, Wisła Śmiała, Motława, Kanał Raduni (called Nowa Radunia), Stara Radunia (Rada Miasta Gdańska, 2018).

In the course of the research conducted in Wrocław and Gdańsk, the following results were obtained (Table 1):

Table 1. Ratings received by Wrocław and Gdańsk in the first section of the card of river

Aspect	Wrocław	Gdańsk
The degree of flood protection is sufficient	4	4
The degree of implementation of meanders, floodplains, and wetlands is sufficient	1	4
The degree of implementation of blue-green infrastructure is sufficient	3	4
Buried rivers are being restored to the city	None of the cities in question have buried rivers.	
The water collection system is sufficiently dispersed	2	5
The city implements a rain policy appropriate to climate change	5	5
Subsidies for water-saving solutions fulfil their role	5	5
Investments related to the river (e.g., regulation, hydro-technical structures, etc.) are carried out with responsibility for the natural environment (including the ecosystem)	5	5
The condition of the natural environment of river and riverside areas (including the ecosystem) is good	4	No data
Educational campaigns related to the river are organised in the city	5	4

The blue-green megatrend is one of the primary development directions of both cities.

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The actions taken are based on age, and the scores obtained for Wrocław and Gdańsk are high.

Actions in the field of investments in flood defences aimed at protecting cities received a rating of 4, which indicates excellent progress in this area, but further work is also needed. In Gdańsk, part of the floodplains is located in built-up areas, which is the city's main problem. In Wrocław, a flood protection section was created, thanks to which protective actions are possible four days before the wave arrives.

Significant differences in the examinedcentres occurred in terms of the degree of implementation of meanders, floodplains, and wetlands is sufficient. Rating 1 for Wroclaw and 4 for Gdansk. Such a low rating of Wrocław is caused by the earlier investment process and the city's „turning its back" on rivers. In Gdańsk, the economy, in this regard, respects the river and its significant importance for the city's development. Meanders, floodplains, and wetlands are not only of importance in terms of flood protection, but they also maintain air humidity in the long term, providing a lower temperature and shelter for organisms.

The degree of implementation of blue-green infrastructure is sufficient, although these cities received different ratings (Wrocław 3; Gdańsk 4). The degree of implementation of blue-green infrastructure is better in Gdańsk than in Wrocław.

The problem of Gdańsk is the uneven distribution of greenery, which means that not all residents have comfortable pedestrian access to these areas. However, a plan is in place to equip selected allotment gardens with basic recreational infrastructure and make them available as urban spaces. A similar solution could be implemented in Wrocław, especially since allotment gardens in this city cover an area of over 1.4 thousand square metres.

In addition, blue-green infrastructure is being created in Gdańsk through a modern approach to rainwater management. The urban retention system is exceptionally developed and consists of a reservoir, field, street, household, and urban green retention. All these elements complement each other and create a blue-green infrastructure protecting against floods and droughts. Wrocław should develop a retention system, especially at home, to maintain the „blue" part of the discussed infrastructure, especially since the „green" part is being systematically expanded in this city. Despite the poor result, Wrocław's movements towards developing blue-green infrastructure can be observed. Among others, two acts of local law are in force – on rainwater management in Wrocław and on standards for planning and designing streets in the green and blue infrastructure field. New urban investments are designed considering the green and blue infrastructure, and catalogues of good rainwater management practices are available on the website. Provi-

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sions regarding green and blue infrastructure are also introduced in updated and new local plans.

In Wrocław the water collection system is insufficiently dispersed, while Gdańsk received the highest score in this area.

Both urban centres received the highest marks regarding the appropriate implementation of the rain policy to climate change, which significantly directs them to implement tasks related to green and blue development.

Care for the green and blue development of cities means that investments related to the river (e.g., regulation, hydro-technical structures, etc.) are carried out with responsibility for the natural environment (including the ecosystem) and the condition of the natural environment of river and riverside areas (including the ecosystem).

An essential element of the policy of green and blue development of Wrocław and Gdańsk are educational campaigns related to the river, which are to make city users aware of the need to have high-quality green areas and rivers along with riverside areas. Wrocław's rating in this respect is higher than Gdańsk's.

Discussion/Limitation and future research

All activities in shaping and planning blue and green infrastructure and other projects make up the city's blue-green economy. The aspects of the city's effective economy in terms of blue and green infrastructure indicated in the literature need to provide a complete picture of the challenges faced by city authorities. Triving to ensure development, they should consider that the environment is changing rapidly and anticipate the negative character of those changes. At present, these needs should be emphasised in the literature. At the same time, the literature often considers individual challenges related to the city's blue and green economy. However, it disregards other factors (which makes those studies incomplete). On the one hand, this has advantages due to the multithreading of the topic. On the other hand, such an approach to the issue of the city's blue and green economy requires a holistic view and can often lead to ignoring the effects of synergy.

Research on blue-green urban development is currently being conducted extensively. However, tools for a holistic analysis of river and riverside development have yet to be developed. The proposed tool in the form of the river card and the developed indicator of the use of river potential allow not only to carry out the following assessment, but also to make comparisons between cities. In today's conditions, city policies towards greenery and rivers should be considered as fundamental challenges, so research should be continued and extended to other cities. The conducted study is qualitative; therefore, it is necessary to conduct a quantitative study in subsequent analyses. In addition, due to various research possibilities, not all procedures performed in Wrocław (e.g. focus group study) were carried out simultaneously in Gdańsk. In further research, the research should be detailed.

Conclusions

The following conclusions were drawn from the study:

In the current global economic climate, the blue-green economy is becoming a significant development trend. About 55% of the global population already live in cities, and it is forecast that, by 2050, it will be 68% (Nosarzewska, 2021). These conditions indicate the particular importance of green and blue urban development. Cities' green areas, rivers, and riverside areas are becoming multifunctional. The investment process in the field of green and blue infrastructure is thereforenecessary.

Wrocław and Gdańsk are active in the green and blue development fields, but the effects of these activities vary.

The essential deficiencies in Wrocław concern the degree of implementation of meanders, floodplains, wetlands, the degree of implementation of the blue-green infrastructure, and the water collection system.

Gdańsk received a score not lower than 4 in all the aspects examined, indicating intensive actions taken by the authorities in the green and blue development field using the river.

Wrocław and Gdańsk should continue activities related to green and blue development, with Wrocław paying particular attention to the resource and the potential of the river.

The contribution of the authors

Concept, D.R. and H.A.; literature review, D.R.; acquisition of data, H.A.; analysis and interpretation of data, D.R. and H.A.

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Wiktor **SZYDŁO**

SUSTAINABLE DEVELOPMENT, AGENDA 2030 AND FOOD SECURITY IN HISTORICAL PERSPECTIVE

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ABSTRACT: The sustainable development (SD) concept has won substantial popularity in recent decades. At the same time, neoliberalism (the socio-economic orthodoxy since the mid-1970s) is somewhat put in the shade. The paper attempts to find out whether the SD paradigm and its recent incarnation (Agenda 2030) constitutes the decisive break from the mainstream. The second aim is to assess whether the concept of food security is adequately addressed by the Agenda 2030. The study shows that Agenda 2030, with its 17 Sustainable Development Goals, is a much broader concept than preceding MDGs, but it still cannot guarantee the attainment of food security both in the short-term (the risk of commodity price bubbles) and in the longer-term (i.e. till 2030) due to the prevalence of extreme poverty, high income inequality, structural weakness of many developing countries and inadequate global regulation.

KEYWORDS: sustainable development, neoliberalism, Agenda 2030, food security, poverty

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Introduction

Sustainable development (SD) is commonly referred to as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. SD goes along with heterodox economics in its holistic, pluralistic and interdisciplinary approach. The concept takes into account both time (i.e. present and future generations) and institutions which are often ignored by orthodoxy.

Therefore, the concept of sustainable development has won great popularity in recent decades. It is esteemed not only by popular media and academic world, but also by many environmental activists. SD is often contrasted with the mainstream focus on economic growth measured by GDP dynamics (which represents a proxy of short term performance) and the level of GDP per capita (the proxy of the standard of living and/or wealth of a country or a society). The SD concept (sometimes referred to as paradigm), however, often focuses on two pillars (i.e. economic and environmental). The third social pillar of the SD paradigm has been neglected in popular discourse. Mainstream economics aspired to be positive economics (i.e. value-free). That is the reason why the debates about income and wealth inequality or about social security and employment contracts were sporadic. The main goal was to safeguard economic growth via market mechanisms. These tendencies were further strengthened after the collapse of the communist Eastern Bloc. Hence, the so-called Washington Consensus reinforced free market imperialism. Capitalism (to be more precise, its neoliberal incarnation) was portrayed as the only viable socio-economic system. Hence, the popularity of the acronym TINA (there is no alternative). The free market was portrayed as a smoothly functioning mechanism. For mainstream economists, failures of this mechanism were minor (especially in comparison with government failures) and could practically emerge only in the environmental sphere in the form of negative externalities or insufficient provision of public goods. The remedy to these minor inefficiencies of the market system was to create yet another market (as in the case of the CO_2 emission trading scheme) and the reinforcement of the environmental pillar of SD.

Yet, the edifice of mainstream economics was undermined by the global financial crisis that started in September 2008 with the collapse of Lehman Brothers – the fourth largest investment bank in the US. The contagion spread to Europe and resulted in the Great Recession (the biggest recession since the Great Depression in the 1930s). This financial and economic turmoil was a clear indicator that developed countries are not immune to serious, multifaceted crises (Szydło, 2013). The aim of the paper is to assess (mainly via the extensive review of literature and UN documents and the analysis of FAO

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data) whether SD concept (especially Agenda 2030) represents a decisive break from current orthodoxy and whether it adequately addresses food security and poverty. To achieve this aim historical perspective is employed.

Sustainable development

The United Nations Conference on the Human Environment in Stockholm, June 5-16, 1972 (Stockholm Declaration) represented "a first taking stock of the global human impact on the environment, an attempt at forging a basic common outlook on how to address the challenge of preserving and enhancing the human environment" (Handl, 2012).

Colander et al. (2004) optimistically claim that "economics is moving away from a strict adherence to the holy trinity – rationality, selfishness and equilibrium – to a more eclectic position of purposeful behaviour, enlightened self-interest and sustainability".

The process of creation of the sustainable development concept coincided with the collapse of the Bretton Woods system on August 15th 1971, when the US unilaterally terminated the convertibility of USD to gold and the demise of the Smithsonian Agreement. It was soon followed by the ending of the "brief Keynesian experiment" in West Germany with the resignation of Schiller as minister of economics and finance in 1972 (Leaman, 2009).

It is also worth remembering that the collapse of the Bretton Woods system briefly preceded the first oil crisis in the early 1970s. This paradigm shift is often referred to as the Hayekian counter-revolution, monetarist revolution or, as in the case of Harvey (2005), the Volcker shock.

The creation of the SD theory can be treated as a progressive alternative to the Keynesian system, particularly in the environmental sphere or pillar. This springs from the fact that both SD and neoliberalism were being implemented in tandem. The rise to power of the new form of liberalism (i.e. neoliberalism) under Ronald Reagan, Paul Volcker (the chairman of the US Fed) and Margaret Thatcher in the early 1980s was happening practically at the same time when the SD concept was popularised by the UN conferences. In fact, Volcker replaced Miller at the Fed already in August 1979. Yet, monetarist money supply targeting, as suggested by Friedman, was first introduced in the German Bundesbank. This was preceded by "the revolt of the thirty-somethings", which initiated the monetarist anti-Keynesian revolution in German economics, especially from 1970 to 1976 (Janssen, 2006). Also, Chile was an early laboratory for neoliberal ideas and policies. Augusto Pinochet had called upon a local group of Chicago-trained economists to propose a radically different economic program (Valdes, 1995). This group was actively supported by Hayek and Friedman. In April 1975, the former economist paid

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a controversial visit to Chile, governed by a brutal dictator (De Haan, 2016). Already by 1976, the year when Milton Friedman was awarded the Nobel Prize in economics, the "Chicago Boys" gained control of Chilean economic policy. Undoubtedly, neoliberalism is based on economic freedom (especially for the rich), while political freedom, democracy and human rights are somewhat forgotten. The dominant ideology has made great progress in depoliticising many spheres of human life.

Hence, sustainable development might be viewed as a democratic, much broader and progressive approach towards human life on Earth. It became common knowledge that the term sustainable development was popularised by the so-called Brundtland report 'Our Common Future', published by the World Commission on Environment and Development (WCED) in 1987. The Brundtland report provides the classic definition of sustainable development: "development which meets the needs of the present without compromising the ability of future generations to meet their own needs". As noted by Tulloch and Neilson (2014), "the emphasis on 'needs' and 'development" in the same breath is significant as it positions economic development as the critical issue for meeting people's needs – both now and in the future – while ecological sustainability is only implicitly and indirectly identified and subtly cast as a problem of the future". According to Spash and Guisan (2021), "while needs to remain objective, how they are expressed, perceived, and fulfilled will always be subjective, conditioned by institutional arrangements and wider social and cultural contexts". Unquestionably, the definition of SD provided in Brundtland's report is vague, which makes it vulnerable to reinterpretations by the current orthodoxy. Indeed, according to Tulloch and Neilson (2014), the first step in the neoliberalisation of sustainable development was achieved in the Brundtland Report. The concept was also depoliticised, and "the power relations and historical specificity of the presently dominant capitalist mode of production are taken out of the account, and 'economic and social development' is ideologically neutralised" (Tulloch & Neilson, 2014).

The earlier definition of SD, somewhat forgotten even by the experts in the field, was formulated in the World Conservation Strategy already in 1980. This Strategy (IUCN, 1980) was prepared and advocated by the International Union for Conservation of Nature and Natural Resources (IUCN), UNEP, WWF, FAO and UNESCO. According to the World Conservation Strategy, "for development to be sustainable, it must take account of social and ecological factors, as well as economic ones; of the living and non-living resource base; and of the long term as well as the short term advantages and disadvantages of alternative actions" (IUCN, 1980). Paradoxically, this older definition by the IUCN (1980) provides a fuller and more progressive definition of SD than the younger formulated in the Brundtland report "Our Common Future" in 1987.

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It needs to be emphasised that the classic Brundtland definition introduced a new term, 'needs'. At the same time, it got rid of references to social, ecological and economic factors and resigned from allusion to the living and non-living resource base. From this perspective, it could be argued that SD was dominated by new neoliberal orthodoxy already in the 1980s to become just a little more progressive offshoot of the all encompassing neoliberal paradigm.

SD has been dominated by the new neoliberal system as it was not able to prevent a number of economic, social and environmental crises. The global financial crisis and consecutive Great Recession (a clear reference to the Great Depression of the 1930s) proved that neoliberalism, which led to financialisation and monopoly capitalism, was dangerous not only to people living in developing and least developed countries but also to the majority of those in developed countries. This proves that the SD concept (especially its economic pillar or dimension) was inept in sustaining development and standard of living after 2008.

Both neoliberalism and SD gained popularity in the 1970s. Baldwin et al. (2019) claim that" the desire to "free up" the market to drive economic growth has been pursued in tandem with the aim of sustainable development" (United Nations, 2002; Fisher, 2006; Wagner, 2006; Bakker, 2010). But one cannot deny that neoliberalism won the battle of ideas and, for over four decades, has been the dominant paradigm which structures the functioning of individuals and societies in capitalist countries. Numerous financial and economic crises both in developing and developed countries did not undermine this dominance. Even the global financial crisis and subsequent Great Recession in 2009 did not lead to a paradigm shift. The sustainable development concept has been too weak to avert financial, economic, social and environmental crises.

According to Newig et al. (2019), "current literature on sustainability governance and institutions is preoccupied with innovation, novelty, success and "best practice", but there is an emergent tendency to consider decline and failure as opportunities and leverage points to work towards and to achieve sustainability. Although failure, crisis and decay have been treated extensively, the link towards their productive potential has remained underdeveloped in the literature" (Newig et al., 2019).

The concept of sustainable development is present in the popular debate, yet the discussions often concentrate on merely one aspect of environmental order, namely climate change resulting from greenhouse gas emissions. Other environmental problems are rarely addressed. The same applies to issues belonging to the economic and social pillars of SD. As the voice of the dissenters was intelligently reduced to activists focusing solely on averting climate change, one cannot expect a decisive break from current economic

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orthodoxy. Generally, for decades the actual implementation of the SD concept has been highly selective and mainly focused on the conservation of the environment and, at the same time, maintaining economic growth. This can be illustrated by the growing popularity of the terms "green growth", "greening the economy" and as in the case of (Köhn, 2012) "greening the financial sector". The social pillar of SD is not fashionable. The widespread popularity of micro analysis operating within the current economic architecture suits the interests of multinational corporations. Macroeconomic analysis is significantly reduced.

GDP per capita and GDP dynamics were and still are the most important indicators in the economic pillar of SD. For example, Agenda 2030, in its first target of goal 8, aims to "sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries". Other key measures of economic order assessing 21st-century capitalism are either rarely discussed or simply omitted (even in the case of supposedly broad and progressive SDGs). Such a shallow analysis cannot properly assess the following issues: asset and commodity price bubbles, financialisation, monopolisation, labour market, intra- and intergenerational income and wealth inequality, indebtedness, economic sectors, demography, spatial cohesion, leisure, well-being, etc.

The UN's SDG indicators

The UN's global indicator framework was adopted by the General Assembly on 6 July 2017 and is contained in the Resolution adopted by the General Assembly on Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development (United Nations, 2015). The annex to this resolutions entitled "Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development" comprises 17 Sustainable Development Goals (SDGs) and a list of indicators to be refined annually and reviewed comprehensively by the Commission. At present, the official global indicator framework comprises **231**unique SDG indicators. However, the total number of listed indicators is 247, as twelve indicators repeat under two or three different targets (United Nations, 2017). The global indicator framework was developed by the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) and later agreed upon by the Statistical Commission at its forty-eighth session, held from 7 to 10 March 2017, as a voluntary and country-led instrument.

Classification into social, ecological and economic pillars or orders allows a clear assessment of the SD concept by the experts in particular fields. When

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the classification was erased from the classic definition of SD in Brundtland Report in 1987, officially referred to as "Our Common Future, Report of the World Commission on Environment and Development", the concept has become blurred. The same caveat applies to recent implementations of the concept in Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs). Some authors attempted to divide SDGs into four aspects (or spheres/pillars): economy (goals 8, 9, 10, and 12), society (goals 1, 3, 4, 5, 11, and 16), environment (goals 2, 6, 7, 13, 14, and 15), and governance (goal 17) (Lu et al., 2015). But the goals are not clearly grouped into pillars. This is one of the reasons why SD is still referred to as a 'contested concept' (i.e. that can be defined in more ways than one). It could well be argued that this post-modernist amalgamation has nothing to do with the heterodox noble postulates calling for broadening both the popular debate and academic analysis (as in the case of interdisciplinary studies and research). "Neoliberal articulation of sustainability with the broader field of contesting perspectives combined with a strategy of 'passive revolution', that are together summed up as the Rio process, has led earlier radical discourses being incorporated and subordinated to neoliberal hegemony" (Tulloch & Neilson, 2014). Weakening of sustainable development paradigm (especially its economic pillar) allows orthodoxy to replace it by the concept of 'green growth', 'greening the economy' and even 'greening the financial sector'. The focus on growth (measured by GDP) instead of development (especially sustainable development) is a central feature of neoliberalism. Hence, the edifice of the current orthodoxy remains intact. Naturally, sustainable development is not the only example of contested concepts. Söderbaum (2019) also adds 'democracy' and 'institution' to the list of terms whose definition is debatable and, therefore, vague. "Neoclassical economists tend to limit attention to concepts that can be quantified and therefore avoid or reduce the role of contested concepts" (Söderbaum, 2019).

At the same time, neoliberalism attempts to shape (and, if necessary, adjust) the definition of a "contested concept" so that it does not pose much threat to the orthodoxy. It could well be argued that this applies to the concept of "sustainable development" in economic and social pillars.

"Transforming Our World: the 2030 Agenda for Sustainable Development" (often referred to as Agenda 2030 or Sustainable Development Goals – SDGs) is the current United Nations (2015) sustainable development strategy which covers 15 years (2016-2030). It was adopted by 193 countries in the UN General Assembly on September 25, 2015. Agenda 2030 replaced the UN Millennium Development Goals (MDGs), which were set by the 189 UN member states following the Millennium Summit in New York, 6-8 September 2000 and Millennium Declaration (A/RES/55/2) and prior to the World Summit on Sustainable Development in Johannesburg (26 Aug.-4

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Sept. 2002). Hence, the eight (rather narrow) Millennium Development Goals:

- to eliminate extreme poverty and hunger,
- to achieve global primary education,
- to empower women and promote gender equality,
- to reduce child mortality,
- to promote maternal health,
- to fight malaria, HIV/AIDS, and other diseases,
- to promote environmental sustainability,
- to develop a universal partnership for development, were superseded by the Agenda 2030 with the 17 Sustainable Goals (SDGs):
  - Goal 1. End poverty in all its forms everywhere,
  - Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture,
  - Goal 3. Ensure healthy lives and promote well-being for all at all ages,
  - Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all,
  - Goal 5. Achieve gender equality and empower all women and girls,
  - Goal 6. Ensure availability and sustainable management of water and sanitation for all,
  - Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all,
  - Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all,
  - Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation,
  - Goal 10. Reduce inequality within and among countries,
  - Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable,
  - Goal 12. Ensure sustainable consumption and production patterns,
  - Goal 13. Take urgent action to combat climate change and its impacts,
  - Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development,
  - Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss,
  - Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels,
  - Goal 17. Strengthen the means of implementation and revitalise the Global Partnership for Sustainable Development.

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As the MDGs practically applied only to developing countries, the SDGs are global and extended the focus of international development beyond poverty to sustainability (Adelman, 2017). Realization of previous UN sustainable development strategies (MDGs) proved challenging and met with mixed success, despite its limited scope.

One cannot deny that SD (especially Agenda 2030 with its 17 SDGs) is a much broader concept than neoliberal focus on high economic growth, deregulation, privatisation and low inflation. However, the global financial crisis of 2007-2008+ and the subsequent Great Recession of 2009+ substantially undermined both neoliberalism and the current understanding of SD as big, private companies (dubbed too-big-to-fail) were bailed out by governments and central banks. It is argued that even the current understanding of SD (i.e. the 17 SDGs promoted by the UN and the EU) can be undermined or even falsified. The SDGs concept simply lacks predictive power; hence, according to the positive economics of Milton Friedman, it can be falsified. It is argued that a heterodox perspective would strengthen the informative and predictive power of SD indicators in the context of globalisation, financialisation and monopolisation. It is also claimed that the present set of SD indicators practically does not address the sources of the global financial crisis of 2007-2008+ and its repercussion in the real sphere via Great Recession in the following years.

By using heterodox analysis (Post-Keynesian, institutional and evolutionary economics), it could be demonstrated that SDGs are properly structured in order to fit into neoliberal orthodoxy (not vice versa). This caveat also applies to the Millennium Development Goals (MDGs) that preceded the contemporary SDGs, as they "focused attention on the need to reduce absolute poverty" (Shafik, 2012). According to O'Grady (2016), the UN system has been under neoliberal assault for decades and is facing its own test of contemporary relevance. The characteristic of the 17 SDGs seems to confirm this statement.

Food security

The term "food security" was first defined at the World Food Conference held in Rome in 1974(5-16 November) by the United Nations. The conference was, in part, an answer to the challenges posed by two formidable food crises in Bangladesh in 1972 and 1974. Already these tragic events pointed to the multidimensional aspect of food security. While the government in Bangladesh succeeded in averting a widely predicted famine in the first case, it failed to prevent an actual famine in the later case when such a cataclysmic disaster was least anticipated (Dowlah, 2006). According to Dowlah (2006),

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"the 1974 famine was caused by successive onslaughts of natural disasters such as floods and droughts, and man-made disasters such as the government's inability to import foods, the directing of subsidised food to the politically vocal urban population, an abrupt fall in food aid and political and administrative corruption that encouraged massive hoarding and the smuggling of food grain".

Nevertheless, the first definition of "food security" employed a narrow perspective which mainly focused on the concept of food availability (Simon, 2017). Yet, according to Caiafa and Wrabel (2019), "food security" encompassed the availability of food as well as the ability to access food. The 1974 World Food Summit defined food security as: "availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices" (United Nations, 1975).The concept was further expanded by FAO in 1983 to include securing access by vulnerable people to available supplies, implying that attention should be balanced between the demand and supply side of the food security equation: "ensuring that all people at all times have both physical and economic access to the basic food that they need" (FAO, 1983).

The definition was further adjusted by the World Bank in 1986. It introduced the distinction between chronic food insecurity (dealing with problems of continuing or structural poverty and low incomes) and transitory food insecurity (which involved periods of intensified pressure caused by natural disasters, economic collapse or conflict) "access of all people at all times to enough food for an active, healthy life" (World Bank, 1986).

Later adjustments of the term in 1996 made it more comprehensive in order to address persistent global undernutrition and growing fear concerning worldwide agricultural capacity (a clear reference to Malthusian thinking). According to the World Food Summit (1996) declaration "food security, at the individual, household, national, regional and global levels [is achieved] when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

The next adjustment by FAO in 2002 introduced the social aspect of food security "Food security [is] a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2002).

The definition of "food security" further evolved building, especially in the works of Indian economist and philosopher Amartya Sen, with influential (Sen, 1981). Sen was analysing the entitlements of individuals and households rather than concentrating on the concept of food security.A new

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approach drawing from his research focused on consumption, the demand side and the issues of access by vulnerable people to food.

For Sen, the poor lack many kinds or forms of freedom, which are perceived as obvious for the rich. A more recent confirmation of this finding is provided by Banerjee and Duflo (2012). "Development is something more than economic progress measured by the quantity of goods produced. (...) It is a social development: i.e. the increase of the number of people experiencing freedom springing from gaining the abilities indispensable to reach an adequate standard of living" (Kishtainy, 2017). Doubtless, the hierarchy of values favoured by Sen differs from the standard approach favoured by mainstream economists. Sometimes it could be easily recognised (Szydło, 2020a). For example, there is a clear contrast between "Development as freedom" – the title of Amartya Sen's book published in 1999 and the titles of two books by Balcerowicz (a leading Polish free market economist) in which freedom plays the most important role: "Freedom and development. Economics of free market" (Balcerowicz, 1995) and "Freedom, development, democracy" (Balcerowicz, 2017). The approach favoured by the Indian economist, however, concentrates on development (i.e. 'freedom to' as depicted by Berlin (1969)) rather than individualistic 'freedom from' (i.e. freedom from state coercion). Interestingly, according to Kowalik (2010), liberal Bochniarz and conservative Legutko expressed deep dissatisfaction when Sen was awarded the Nobel Memorial Prize in Economic Sciences in 1998.

Recent understanding of the term "food security" incorporates four main dimensions (features, pillars):

- Physical AVAILABILITY of food which addresses the "supply side" of food security and is determined by the level of food production, stock levels and net trade,
- Economic and physical ACCESS to food -an adequate supply of food at the national or international level does not in itself guarantee household-level food security. Concerns about insufficient food access have resulted in a greater policy focus on incomes, expenditure, markets and prices in achieving food security objectives,
- Food UTILIZATION – commonly understood as the way the body makes the most of various nutrients in the food. Sufficient energy and nutrient intake by individuals is the result of good care and feeding practices, food preparation, diversity of the diet and intra-household distribution of food. Combined with good biological utilisation of food consumed, this determines the nutritional status of individuals,
- STABILITY of the other three dimensions over time -even if your food intake is adequate today, you are still considered to be food insecure if you have inadequate access to food on a periodic basis, risking a deterioration of your nutritional status. Adverse weather conditions, political

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instability, or economic factors (unemployment, rising food prices) may have an impact on your food security status (FAO, 2008).One approach to policies that encourage stability is to reduce the chances of shocks occurring in the first place. According to Caiafa and Wrabel (2019), "This can be achieved by adopting systems for monitoring and analysing food security risks to anticipate, and potentially attenuate, disruptions. Policies that support farmers' ability to produce food and contribute to national food stocks without stress or uncertainty about their income or livelihood are additional mechanisms for achieving this".

More specifically, stability could be safeguarded, for example, by building buffers so that consumers can maintain their access to and use of food when the inevitable happens, rapid deployment of social safety net programs, plans for reintegrating refugees and displaced people, maintaining ecosystem integrity, mitigating the infrastructural and social effects of hazardous weather events, strengthening peacebuilding efforts to minimise conflict (Caiafa & Wrabel, 2019).

The two additional dimensions of "AGENCY" and "SUSTAINABILITY" are proposed by the High Level Panel of Experts (HLPE) of the Committee on World Food Security (CFS)but are not formally agreed upon by FAO or other bodies, nor is there an agreed language on the definition (FAO, 2021). However, HLPE Report 14 and previous HLPR Reports recognised "agency" and "sustainability" as vital dimensions of food security that flow directly from the principle of the right to food. In a broader sense, "agency" is defined as "what a person is free to do and achieve in pursuit of whatever goals or values he or she regards as important" (Sen, 1981). According to Alsop and Heinsohn (2005), the agency goes beyond access to material resources in that it includes empowerment – the ability to take actions that help improve their own well-being, as well as their ability to engage in society in ways that influence the broader context, including their exercise of voice in shaping policies.

In a narrow sense, connected with safeguarding food security, "agency implies the capacity of individuals or groups to make their own decisions about what foods they produce, how that food is produced, processed and distributed within food systems and their ability to engage in processes that shape food system policies and governance" (HLPE, 2020).

The concept of "agency" has similarities with the notion of positive liberty described in Isaiah Berlin's seminal essay: "For the `positive' sense of liberty comes to light if we try to answer the question, not `What am I free to do or be?', but `By whom am I ruled?' or `Who is to say what I am, and what I am not, to be or do?" (Berlin, 1969). The 'positive' conception of liberty: freedom– to lead one prescribed form of life, is therefore contrasted with the 'negative' conception of liberty: the freedom which is involved in answer to

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the question "What is the area within which the subject – a person or group of persons – is or should be left to do or be what he is able to do or be, without interference by other persons?"(Berlin, 1969).

Sustainability(the sixth overall dimension of food security, i.e. the second extra dimension) was initially defined as the sustainability of food systems in all three dimensions: economic, social and environmental, in their capacity to ensure good quality and adequate food for this generation and future generations (HLPE, 2014). After a minor refinement, it presently refers to "the long-term ability of food systems to provide food security and nutrition today in such a way that does not compromise the environmental, economic, and social bases that generate food security and nutrition for future generations" (HLPE, 2020).

Table 1. Prevalence of undernourishment* [%]

Somalia	59.5	Afghanistan	25.6	Gabon	15.7
Central African Rep.	48.2	Unit. Rep.of Tanzania	25.1	Cabo Verde	15.4
Haiti	46.8	Kenya	24.8	India	15.3
Yemen	45.4	Papua New Guinea	24.6	Côted'Ivoire	14.9
Madagascar	43.2	Lesotho	23.5	Nigeria	14.6
North Korea	42.4	Timor-Leste	22.6	Burkina Faso	14.4
Dem. Rep. of the Congo	41.7	Togo	20.4	Gambia	13.6
Liberia	38.9	Namibia	19.8	Honduras	13.5
Congo	37.7	Nicaragua	19.3	Pakistan	12.9
Iraq	37.5	Angola	17.3	Bolivia	12.6
Rwanda	35.2	Malawi	17.3	Ecuador	12.4
Chad	31.7	Guatemala	16.8	Sudan	12.3
Mozambique	31.2	Solomon Islands	16.5	Sao Tome &Principe	11.9
Botswana	29.3	Djibouti	16.2	Eswatini	11.6
Venezuela	27.4	Ethiopia	16.2	Mali	10.4
Sierra Leone	26.2				

* Figures for countries with the prevalence of undernourishment above 10% in 2019
Source: author's work based on FAO (2021).

Despite long efforts to overcome hunger in as many as 46 countries, the prevalence of undernourishment exceeded 10% in 2019. Even in the years preceding the COVID-19 pandemic the undernourishment was on the rise since 2013-2015.

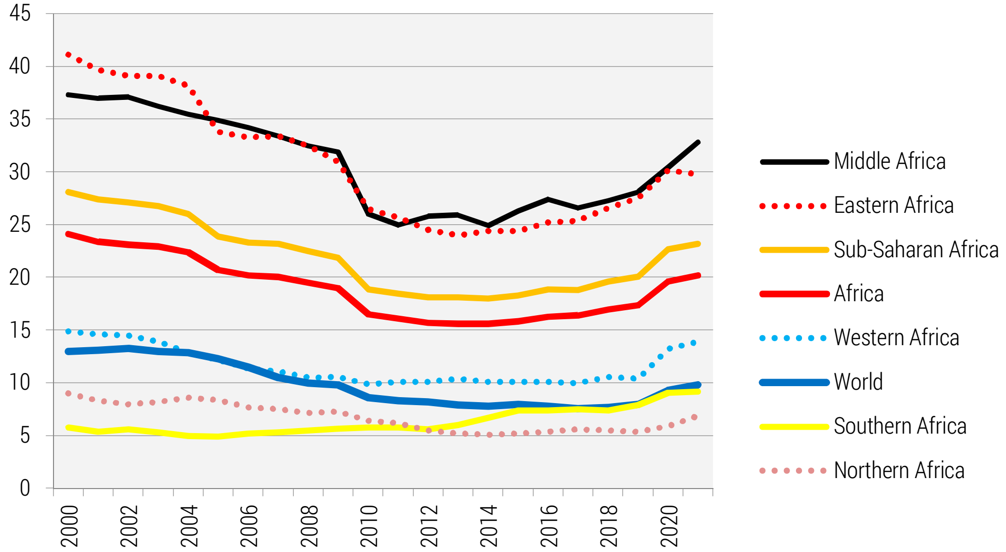

Figure 1. Prevalence of undernourishment [percent] (annual value) in Africa in 2000-2021

Source: author's work based on FAO (2021).

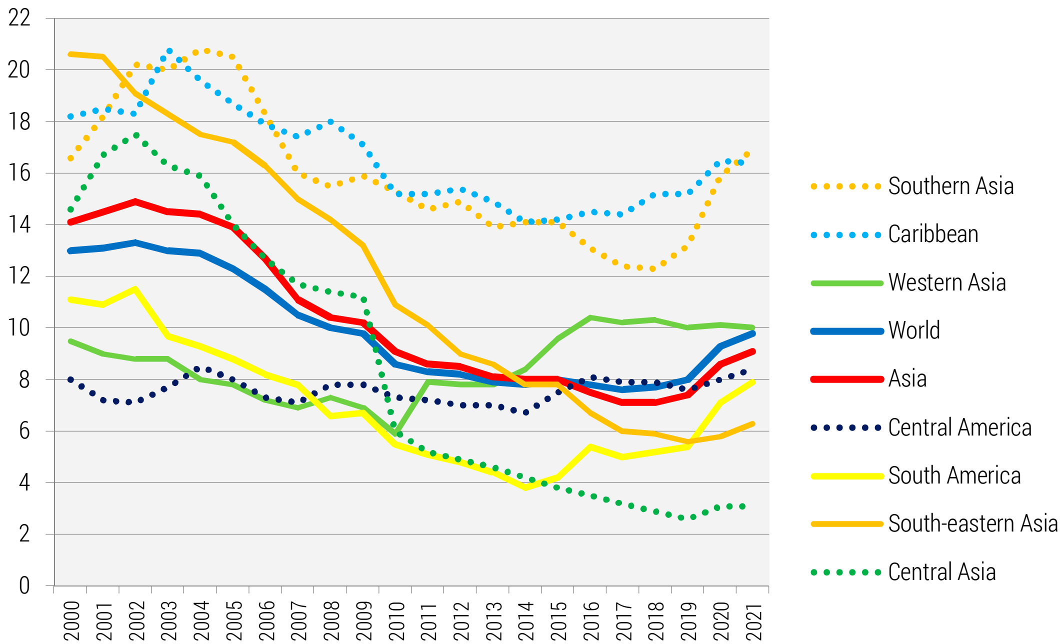

Figure 2. Prevalence of undernourishment [percent] (annual value) in Asia, Central and South America in 2000-2021

Source: author's work based on FAO (2021).

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The figures for Africa (especially Middle, Eastern and Sub-Saharan Africa) are alarming. The positive tendency was reversed in all African regions, Asia and South America. Although, the prevalence of undernourishment in Asia (especially Central Asia and South-Eastern Asia) has diminished in the last two decades.

Unfortunately, more sophisticated and comprehensive food security strategies did not lead to lowering the prevalence of undernourishment in the recent 6-8 years.

Interestingly, the commodity price boom (including food, fertilisers and crude oil) in 2004-2008 and the global financial crisis did not immediately translate into higher levels of undernourishment. The question remains whether it springs from measurement problems. It well might be that these economies are relatively closed (possibly more self-sufficient) and, therefore, better insulated from external shocks.

Higher dynamics of fertiliser and oil prices in comparison with food prices (as in the case of recent two commodity price booms in 2004-2008 and 2021-2022) must lead to the extraction of income and wealth from the agricultural sector into oligopolies or monopolies producing fertilisers and oil. Agenda 2030 does not comprise indicators measuring price changes of these two vital types of commodities but narrowly concentrates only on food price anomalies in Goal 2. It is hardly surprising as economic orthodoxy has avoided addressing asset bubbles.

Forty years of neoliberal fixation on GDP growth coupled with successive UNSD strategies (including MDGs and SDGs) proved unsuccessful in eradicating hunger and poverty. The number of undernourished stubbornly hovers well above 785.4 million (the level in 2015) and has been on the rise in recent years. The prevalence of severe food insecurity in the world population increased from 7.7% in 2014 to 11.7% in 2021, while the prevalence of moderate or severe food insecurity in the total population (percent) expanded from 21.2% to 29.3% in the same period.

Sustainable technologies in agriculture and sustainable development paradigm

Undoubtedly, one has to agree with Singh et al. (2022) that "sustainable technology-led agriculture is the need of the hour to enhance and maintain the ecosystem not only for the present generation but also for future generations". Particular challenges are faced by small farms in developing countries. Implementation of sustainable agricultural technologies (Singh et al., 2021) may prove too expensive to implement, as in the case of drones (Singh et al., 2022). Naturally, it also applies to technologies connected with smart farm-

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ing aiming to improve crop yield and product quality (such as GIS remote sensing, nanotechnology, and genome editing tools, including molecular biological techniques) (Singh et al., 2021). Development of these modern methods requires substantial funds, highly trained specialists and an adequate process of certification in line with the precautionary principle of the sustainable development paradigm. Given small spending on research and development (R&D) in the majority of countries, more advanced methods could only be developed in selected high-income countries (i.e. the USA, Canada and West European countries, such as Germany, the UK, France, Switzerland, etc.) and big developing countries such as China and India. Therefore, the majority of countries would have to import modern, often expensive technologies. Similarly, 'green' organic food may, unfortunately, prove too costly for most consumers in developing countries.

A number of smaller developing countries even do not have the capacity to produce fertilisers (N, P, K). Hence, in order to improve yield to safeguard food security, they have to rely on imports. During asset price bubbles between 2005 and 2008 (i.e. prior to the Global Financial Crisis) and during conflicts or war (as in the case of the Russian-Ukraine war), this strategy poses a serious risk. The international prices of strategic commodities such as oil (extensively utilised by agricultural machines, especially in developed and developing countries), gas (used in the process of fertiliser production), and NPK fertiliser sin crease even faster than food. Paradoxically, least developed countries (LDCs) are not severely affected by this type of crisis as they could not even afford to import fertilisers prior to asset bubbles (i.e. when the prices of fertilisers were relatively low). The vulnerability of fertilizer-importing countries with floating exchange rates is further reinforced by adverse currency movements (i.e. depreciation of the local currency against USD), which became a norm during financial and economic crises.

Therefore, the 21st-century crises prove that safeguarding food security cannot rest solely on the belief in the free-trade concept advocated by the WTO. Food security can only be maintained by the adequate implementation of broad sustainable development (SD) paradigm comprising at least five pillars or orders (i.e. economic, social, environmental, institutional and spatial). Global Financial Crisis and subsequent Great Recession also show that the inclusion of financial order as the sixth pillar of SD is indispensable. Limiting the understanding of the sustainable development paradigm to the environmental order (pillar) as in the Constitution of the Republic of Poland of 1997 would not effectively address various challenges faced by humankind in the 21st century (Szydło, 2020b). To illustrate the point, article 5 of the Constitution states: "(t)he Republic of Poland shall (...) ensure the freedoms and rights of persons and citizens, the security of the citizens, safeguard the national heritage and shall ensure the protection of the natural environment pursuant

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to the principles of sustainable development". A similar approach employs by Singh et al. (2022), who define SD as "a set of principles that guide us to effective utilisation of natural resources without undermining their integrity and stability for future generations". It could well be argued that there is a need to return to the original definition of SD, which was presented in World Conservation Strategy (IUCN, 1980). Only broad cooperation of scholars from various scientific fields (i.e. agronomy, biology, chemistry, ecology, economics, geography, meteorology, physics, etc.) could safeguard a better future for present and future generations.

At the same time, certain ecological ideas blaming agriculture for massive CO_2 emissions because of the huge livestock population (Warner, 2021) should be treated with caution.

Table 2. Agricultural methane emissions (metric tons of CO_2 equivalent per capita) as a share of total (anthropogenic) CO_2 emissions* [%]

Country Name	1990	2005	2019
Least developer countries	84.86	77.12	63.67
Brazil	55.03	49.75	43.54
Sub-SaharanAfrica	44.78	41.61	40.69
Argentina	45.77	37.91	33.58
India	43.50	29.26	16.92
World	12.95	10.36	8.95
European Union	7.77	6.11	7.22
Ukraine	8.02	5.80	5.47
United States	3.91	3.35	4.03
Russian Federation	6.47	3.51	2.90
China	13.42	5.77	2.90

*Proxy: the sum of CO_2 emissions** (metric tons per capita) and agricultural methane emissions (metric tons of CO_2 equivalent per capita); **Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during the consumption of solid, liquid, and gas fuels and gas flaring.

Source: author's work based on World Bank (2022).

The data above clearly show that the share of agricultural methane emissions in the proxy of total anthropogenic CO_2 emissions fell from 12.95% in 1990 to 8.95% in 2019.

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Summary

Undoubtedly, Agenda 2030, with its 17 SDGs is a more comprehensive United Nations SD strategy than MDGs. The current SD strategy, however, does not adequately address systemic issues (such as power relations and financialisation). Its microeconomic, bottom-up approach in the social sphere and focus on GDP growth as the main macroeconomic goal make it a little more progressive offshoot of economic orthodoxy. It is more than clear that two ambitious aims of Agenda 2030, namely to end hunger and ensure access by all people to safe, nutritious and sufficient food all year round by 2030 (goal 2) and eradicate extreme poverty for all people everywhere by 2030 (goal 1) cannot be achieved without global moral revolution and the creation of a new version of human-oriented capitalism(for example drawing from personalist worldview).More emphasis must be placed on decreasing inequality (both within a country and between countries). New relative measures of inequality (especially those advocated by Piketty (De Haan, 2016)) should be included in the Agenda 2030 and more widely popularised.

Agenda 2030 does not adequately capture relatively brief events of asset price bubbles and commodity price booms. Indexes describing price variations of agricultural inputs (i.e. fertilisers, crude oil) ought to be incorporated into the current UN SD strategy. There is a need to broaden the SD paradigm (including Agenda 2030) by the financial stability and sustainability dimension (pillar)with the aim to better address the process of financialisation. It is essential to anticipate and if possible, reduce or even pre-empt commodity price shocks. Safe guarding food security requires both adequate regulation of international commodity markets (especially food and agricultural inputs) and a long-term emphasis on structural reforms of commodity sectors.

More heterodox Agenda 2030 will especially benefit those living in poor and developing countries by steering the global system towards more harmonious development.

The paper also shows that the burden of the adjustment towards green methods of production with low CO_2 emissions should primarily fall on sectors burning fossil fuels and the manufacture of cement rather than on agriculture. Yet, the orthodoxy has been ingeniously employing Malthus to explain both hunger and global warming.

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Janina KOTLIŃSKA • Helena ŻUKOWSKA

MUNICIPAL WASTE MANAGEMENT IN MUNICIPALITIES IN POLAND – TOWARDS A CIRCULAR ECONOMY MODEL

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ABSTRACT: The aim of the study was to answer the question of to what extent it is possible in Poland to reach the target recycling rates and landfill of municipal waste by 2035 and build a circular economy model (CEM) by 2050. The authors will continue research in this area. In the article, the authors: 1) diagnose EU and Polish legislation in the given area, 2) review the literature with regard to the circular economy, 3) analyse municipal waste streams in Poland and present their forecasts for the period of Poland's approach to the CEM. The data were taken from the public statistics and refer mainly to the period 2013-2021. The study used the method of literature analysis and legal regulations, as well as methods of descriptive analysis and linear extrapolation. The results obtained, albeit aggregated, suggest that it is possible to reach the EU-targeted recycling and landfill level for municipal waste in Poland by 2035 and the CEM by 2050.

KEYWORDS: circular economy, municipal waste, municipality, recycling, landfill

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Municipal waste management in a circular economy – literature review

The concept of a circular economy has been present in the specialist literature since the end of the 1960s, yet its modern assumptions were formulated only in the late 1990s by Lyle (1996), indicating the need to reconstruct the natural environment. Other works expounding the concept of a circular economy (CE) include: 1) the theory described as *cradle-to-cradle* or *eco-effectiveness* (Braughart et al., 2007), referring to a circular metabolism, according to which all materials move in an endless biological and technological circulation, where every piece of waste becomes a material for a new product (McDonough & Braungart, 2002), 2) the concept of ecological production (*industrial ecology*) (Stahel, 2016) and of *biomimicry*, in which Nature is seen as a measure for evaluating ethical correctness of technological innovations (Blok & Gremmen, 2016), 3) the concept of functional and service, or an effective economy (Stahel, 2006), 4) the concept of industrial ecology (Lifset & Graedel, 2002), and 5) the system of blue economy (Pauli, 2010).

The implementation and improvement of the CE concept on a wider scale commenced only in the early 21st century, first in Asia (i.e. China, Japan), next in the EU legislation (European Commission, 2014; European Commission, 2015), which was then followed by numerous EU member states (Kulczycka, 2019), including Poland.

Within the EU, the breakthrough in the approach to waste management took place in 2014, with the preparation of the communique entitled "Towards a circular economy: A zero waste programme for Europe" (European Commission, 2014). This meant moving away from the model of a linear economy, "produce, use and throw away" (*cradle to grave*), towards the model of a circular economy (*cradle to cradle)*. This document was further elaborated in 2015 (European Commission, 2015). According to the EU, a circular economy (CE) constitutes "a strategy of development which enables economic growth together with the optimisation of the use of resources, deeply transforming production chains and models of consumption, and redesigns industrial systems at the level of a system". In this way, the European Commission states that it is vital to maintain the value of products, materials and resources in the economy for as long as it is possible and to minimise the production of waste. A circular economy will increase the competitiveness of the EU, protecting enterprises from a shortage of resources and instability of prices, bringing new business and innovation opportunities and more efficient ways of production and consumption. At the same time, this economy will contribute to energy saving and allow us to avoid the irreversible damage caused by the use of resources exceeding the capability of

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the Earth for their renewal. Communication regarding the matter of monitoring a circular economy, indicated the areas which, due to the transformation towards the CE model, should be observed (European Commission, 2018); these areas and indicators for their monitoring are shown in Table 1.

Table 1. Areas and indicators of monitoring the EU countries regarding transformation towards CE

Areas of monitoring	Indicators
Production and consumption	self-sufficiency of the EU in raw materials, green public orders, production of waste, food waste.
Waste management	total level of recycling, levels of recycling regarding individual streams of waste.
Recyclable materials	impact of recycled materials on the demand for raw materials, trade in recyclable materials.
Competitiveness and innovation	private sector investment in CE (work places and gross value added), patents.

Source: authors' work based on Kirchherr et al. (2017); Kulczycka (2018).

The active work of non-governmental organisations, such as the Ellen MacArthur Foundation, and introducing the concept of CE into the strategies and policies of many countries, also in the EU, contributed to the promotion and implementation of the principles of this economic model. This may be why some suggest that it is the practitioners (politicians, business people, consulting companies, associations and foundations) and not the scientists, who had a greater impact on its creation, as was confirmed by the 2021 survey prepared by a group of Indian academics on the basis of publications listed in SCOPUS up to June 2020 (Mhatre et al., 2021). This does not mean that the scientific literature does not provide definitions of CE – in fact, there are several of them highlighting its various aspects, and most of them have been made more precise in recent years.

The most frequently quoted definition of a circular economy came from the Ellen MacArthur Foundation, according to which it is an industrial system, planned and designed as self-reproducing and regenerating, aimed at the use of renewable energy, elimination of toxic chemical substances and waste through a better design of materials, systems and products in business models (Ellen MacArthur Foundation, 2012). Other authors define CE in a similar spirit, stating that it has its roots in industrial ecology, which predicts a form of industrial symbiosis between different entities and production processes, and stresses the benefits from recycling waste materials and

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side products, promoting the minimisation of resources and implementation of cleaner technologies (Andersen, 2007). Along with the concept of the circular system, the economy of circular materials and sustainable management of resources, CE is a paradigm based on the conviction that what was previously seen as waste should now be viewed as potential resources until it is decided otherwise (Park & Chertow, 2014). Production companies collaborate in order to exchange resources, waste, energy and water in such a way that new products can be designed using waste (Thomas & Birat, 2013). Thus it is an industrial system concentrated on closing the loopholes in the flows of resources and energy and contributing to long-term stability, which includes principles and strategies for the more effective exploitation of resources, and at the same time, makes minimum emissions of waste into the environment (Geng et al., 2013). Its purpose is to extend the period of exploitation of resources to maximise their use, with a simultaneous reduction of the environmental impact according to the 3R principle of reducing, reusing and recycling (Tisserant et al., 2017). Hence CE requires integrated management of the supply chain and the use of instruments aimed at stimulating technological changes, and results in the internalisation of the costs of waste management in prices of consumer goods and waste management services, higher profitability and full participation of society in its design. This is a circular economy whose aim is to reduce both the amounts of final waste (after its use) as well as decreased demand for primary resources at the beginning of the circle (production of basic material) (Stahel, 2016).

CE stands for an economy which requires organised economic activities in order to create a backflow of "resources-products-recycled resources" with low exploitation, high use and low emissions. In this economy, all that matter and energy should be used in a sensible and sustainable way, minimising the impact of economic activity on the natural environment (Pin & Hutao, 2007; Heshmati, 2015). It is a strategy of economic development based on appropriate legal and economic instruments and monitoring indicators, both in the progress of its implementation and application of the latest IT solutions. Therefore, it is a global model of economic development promoting eco-innovative solutions, meeting the following assumptions: a) the added value of raw materials/resources, materials and products is maximised in the value chain, i.e. from designer to consumer; b) the amount of produced waste is minimised, and the waste is utilised according to the hierarchy of waste-treatment methods (preventing production of waste, preparation for re-use, recycling, other ways of recuperation, waste disposal) (Kulczycka, 2019).

A circular economy redefines again the models of production and consumption because it is inspired by the rules of ecosystems and reproductive design, which increases resilience, reduces waste and creates common value

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thanks to the increased circulation of both material and non-material flows (Circular Academy, 2022). It is, in principle, a reproducing and regenerating economy, which aims at maintaining products, components and materials at the highest level of usefulness and value all the time. The future of CE is a reality in which waste does not exist, loopholes of resources are closed, and products are subjected to indefinite recycling. This is the economy which is constantly evolving without the input of non-sustainable resources (Cullen, 2017). The economic and ecological value of resources is maintained as long as possible by 1) retaining them in the economic system, or 2) extending the life of products made from them, or 3) putting them back into the system to re-use them. The concept of waste does not exist in CE anymore because products and resources are re-used and endlessly processed (Den Hollander et al., 2017), hence its other description as the *cradle to cradle* model (Hryb & Ceglarz, 2021). The CE model is implemented on three levels (macro, meso and micro), stressing the achievement of goals both in terms of ecology and economic efficiency (Zhu et al., 2010). To sum up, it can be said that today CE is no longer a concept but a global business model. It stands for effective management of resources and, above all, a new model of the economy, seeking *win-win* solutions – effective economically and ecologically (Kulczycka, 2019).

Municipal waste and its management in the Polish and EU legislation

Economic activity and functioning of society at this stage of growth bring with them the creation of ‘rubbish’ (things used-up and damaged) as well as waste (unused post-production remainder of raw materials and post-consumption remains). Polish legislation (Act, 2012) recognises ‘waste’ as a substance or object which the owner wants to be rid of gets rid of or is obliged to do so. Annually there are around 135 mln tonnes of waste produced in Poland, classified into 20 groups. However, in line with the main classification (according to the place of origin), waste can be industrial (resulting from a production activity) or municipal. The former, industrial, amounts on average to 91.5% of all the waste, out of which over half results from mining and excavation activities, while the latter, municipal, constitutes from 8.5% to 10% of the waste produced in general (Hryb & Ceglarz, 2021).

Municipal waste (Act, 2012) comprises waste generated by households and other producers of waste, which due to its nature and composition, is similar to household waste. Municipal waste does not include the following types of waste from 1) industrial production, agriculture, forestry, and fisheries, 2) septic tanks, 3) sewage system and sewage processing plants, includ-

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ing sewage sludge, 4) vehicles withdrawn from use, and 5) construction and demolition. Bearing in mind the ways of waste collection, it can be divided into: collecting selectively (paper and cardboard, glass, metals, plastics, organic waste, wood, textiles, packaging, discarded electric and electronic equipment, used-up batteries, and large-size waste (including mattresses and furniture), and unsorted waste (mixed). In the literature, one can also find the classification according to the place of generating waste (sorted – from residential housing, waste from gardens, parks and cemeteries, other municipal waste – i.e. mixed, large-size waste, as well as waste from open-air markets, street cleaning and drains) (Hryb & Ceglarz, 2021).

There are three terms strictly linked with municipal waste: waste management, municipal waste management and a system of municipal waste management. Despite their apparent similarity, they are not identical. Waste management comprises producing waste and managing it (Act, 2012). Municipal waste management comprises a series of processes related to: a) collection – gathering waste, including preliminary sorting and preliminary storing waste prior to its transport to the waste-processing plant (Directive, 2008), b) transport – involves processes of recuperation and disposal, including the preparation preceding the recuperation or disposal (Directive, 2008), c) processing, d) procedures in places of waste disposal, and e) municipal waste trading. Waste management should be conducted in a way ensuring the protection of life and health of people and the environment. In particular, it must not: pose a threat to water, air, soil, flora and fauna; cause nuisance by noise and odour; or bring undesirable effects for rural areas and places of special importance, such as cultural and environmental. Therefore, one should first prevent generating waste and then undertake actions aimed at its re-use, next subject it to recycling, and when that cannot be carried out, initiate other processes of reclaiming. Finally, after applying the previously mentioned methods, the remainder should be disposed of.

In Poland, management of municipal waste is the responsibility of the unit of local government closest to residents, namely 'gmina' (a municipality or a commune) (Act, 1996). These units were obliged to organise the collection of household waste from local residents (Act, 1996), while collecting waste from the non-residential property is optional (Act, 1996). Hence the duty of a municipality is to: define the rules of maintaining cleanliness and order, the way of collecting and gathering waste by its residents, collecting charges for the management of municipal waste, outsourcing to companies – by means of public tender – the collection of waste from residents and transporting it to the regional plant for processing municipal waste, maintenance and exploitation of municipal facilities, as well as storing and utilisation of waste.

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In Poland, there is no legal definition of the system of management of municipal waste, therefore only attempts at defining this concept can be found in the literature, which suggests that it is an organisational and technical system which offers the possibility of the correct management of municipal waste, not generating excessive (unjustified) costs (Jerzmański, 2011). This concept is strictly linked to financial flows from the management of municipal waste, namely collecting charges and incurring costs.

The management of municipal waste is of crucial importance for the European Union. Its main directions were already set in 1975 in the directive of the European Economic Community (Directive, 1975), which since then has been already updated a few times (Directive, 1975; Directive, 1991; Directive, 2006; Directive, 2008). The directive set out the fundamental directions in respect of waste management, which include: 1) establishing general principles of control of waste disposal on the national scale, 2) assuming that the main purpose is the minimisation of waste generation, the introduction of 'clean technologies', wide implementation of recycling and the use of waste as a source of energy, 3) launching products such that their usage and/or final disposal would not have any or merely minimum impact on the increase of amounts and harmfulness of waste. In its resolution (Council Resolution, 1997), the Council confirmed that the top priority in the management of waste should be preventing its generation, and that re-use and recycling should come before the production of energy from waste, and if so then only to the extent in which these are the most ecological among the available methods. In turn, in the preamble to the directive currently in force by the European Parliament and the EU Council (Directive, 2008), it is stated that the main objective of any policy regarding waste should be a reduction of the negative effects of its production and management for human health and the natural environment (in Germany, Japan and China, the legislation in this respect arrived much earlier – Mathews & Tan (2016)). The policies regarding waste should also aim at restricting the use of resources and favour a practical implementation of the hierarchy of waste processing. The recommendations of the directive should aid the EU in approaching the state of a "recycling society", striving for the elimination of waste production and using waste as one of the resources. In particular, the 6th EU programme of action regarding the environment requires the introduction of means to ensure the segregation of waste at source and the collection and recycling of the priority streams of waste. In line with this objective, and at the same time as a means of facilitating and improving the potential of its recovery, waste should be collected selectively if this is carried out technically, economically and ecologically correctly, and then subjected to the appropriate procedures.

The issue of the compatibility of the terminology used in Poland in terms of waste management with that accepted in the EU is of vital importance for the harmonisation of Polish legislative regulation. The already obsolete Act on waste dated 27 April 2001, together with other regulations addressing the subject of waste, was based on the amended, in relation to the earlier regulations, conceptual apparatus already adapted to the EU legislature. This is in line with the current law (Act, 2012), containing regulations concerning the prevention of waste production and reducing its amounts in order to reach the state of a circular economy. In terms of municipal waste, the regulations regarding the transformation into a circular economy had appeared earlier in the Polish legislation, in the amended law on the maintenance of cleanliness and order in municipalities (Act, 2011). According to that law, by 16 July 2020 communes were obliged to reduce the mass of biodegradable municipal waste transferred for storage, in relation to the amounts produced in 1995 (Act, 2020). The detailed regulations in this aspect were issued in 2012 (Regulation, 2012; Regulation, 2017), in which the indicated level was to be reached over a period of some years (Table 2).

Table 2. Levels of reduction in the mass of biodegradable municipal waste for storage

Year	Reference levels (minimum)
2012	75% weight-wise
2013	50% weight-wise
2014	50% weight-wise
2015	50% weight-wise
2016	45% weight-wise
2017	45% weight-wise
2018	40% weight-wise
2019	40% weight-wise
2020	35% weight-wise

Source: authors' work based on Regulation (2012); Regulation (2017).

The law on the maintenance of cleanliness and order in municipalities (Act, 2020) introduced new levels for recycling and preparation for re-use of municipal waste. Thus in 2020, communes were obliged to reach the level of: 1) preparation for re-use and recycling of the following shares of waste: paper, metals, plastics and glass at minimum 50% weight-wise; 2) recycling, preparation to re-use and recovery with other methods of other than dangerous construction and demolition waste constituting municipal waste at a minimum of 70% weight-wise. The levels of preparation for re-use and recycling, and of storing municipal waste including biodegradable mass, applicable after 2021 are shown in Table 3.

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Table 3. Obligatory levels of recycling and storing municipal waste in Poland since 2021

Year	Levels of preparing for re-use and recycling of municipal waste (the minimum of)	Levels of storing municipal waste (no more than)
2021	20% weight-wise	No directives
2022	25% weight-wise	
2023	35% weight-wise	
2024	45% weight-wise	
2025	55% weight-wise	30% weight-wise
2026	56% weight-wise	
2027	57% weight-wise	
2028	58% weight-wise	
2029	59% weight-wise	
2030	60% weight-wise	20% weight-wise
2031	61% weight-wise	
2032	62% weight-wise	
2033	63% weight-wise	
2034	64% weight-wise	
2035 and after	65% weight-wise	10% weight-wise

Source: authors' work based on Act (2012).

The level of preparation of municipal waste for re-use and recycling (P) is calculated as the ratio of the mass of municipal waste prepared for its reuse and subjected to recycling (Mr) to the mass of the generated municipal waste (Mw). When calculating such a level, not included are other than dangerous construction and demolition waste constituting municipal waste (Regulation, 2021). The level of storage (S) is calculated in accordance with the regulations stipulated in the executive decision of the EU Commission (Commission Implementing Decision, 2019), as the ratio of the mass of municipal waste and waste originating from the stored municipal waste (Mw) – from 2023 onwards the amounts of Mr and Mw will be given in Mg. To calculate the levels of the storage of waste after 2023, the mass of waste will not include waste generated during recycling or other recovery processes, which is then stored.

Methodology and research results

Starting out from the viewpoint of the need to reduce the amounts of the generated, and in particular of the stored waste, the authors of this study

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focused on the empirical verification of data representing the volume of the waste collected and processed in Poland over recent years, compared to other EU countries. The research covered the period from 2013 to 2021; however, some data apply to shorter periods of time. In order to demonstrate the changes related to the mass of generated and processed waste, including the sorted waste, according to the main shares of waste stored, recycled and re-used, the study used the processed and aggregated series of data, based on the official statistics of the Statistics Poland (GUS), from its database on waste, and from EUROSTAT. The calculations were carried out jointly for all the communes in Poland, including the spatial aspect (divided into regions [voivodeships]). The authors are aware that the presented values constitute averaged data and may significantly differ in individual communes. The statistical error and the model-fitting error are also present in the projections regarding the mass of municipal waste, which will be collected, recycled and stored over the period 2022-2035 and then up to 2050. The methods used in the study included the methods of descriptive analysis of selected elements (analyses of structure, dynamics, and trend), as well as linear extrapolation.

According to EUROSTAT, the level of municipal waste generated per capita in the EU countries over recent years is clearly varied, and the span of differences is very large (Table 4). In 1995 it spanned from 220 kg (Croatia) to 694 kg (Bulgaria) per person, and in 2020 from 287 kg (Romania) up to 834 kg (Austria). The largest increase in the mass of municipal waste occurred in this period in Croatia (90.4%), and the largest decrease was in Bulgaria (36.0%).

Table 4. Annual mass of generated municipal waste per capita in the EU in 1995-2020, and their changes [in kg]

Countries	1995	2000	2005	2010	2015	2020	Change 2019/1995 [%]
EU	467	513	506	503	480	505	8.2
Austria	437	580	575	562	560	834	33.9
Belgium	455	471	482	456	412	746	-8.6
Bulgaria	694	612	588	554	419	444	-36.0
Croatia	220	262	336	379	393	418	90.4
Cyprus	595	628	688	695	620	609	2.3
Czechia	302	335	289	318	316	543	67.7
Denmark	521	664	736	758	822	814	62.2
Germany	623	642	565	602	632	628	1.4
Estonia	371	453	433	305	359	383	-0.7
Finland	413	502	478	470	500	596	44.4

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Countries	1995	2000	2005	2010	2015	2020	Change 2019/1995 [%]
France	475	514	529	534	516	538	12.8
Greece	303	412	442	532	488	525	73.1
Hungary	460	446	461	403	377	403	-21.0
Ireland	512	599	731	624	557	555	8.4
Italy	454	509	546	547	486	487	11.4
Latvia	264	271	320	324	404	478	80.8
Lithuania	426	365	387	404	448	483	13.4
Luxembourg	587	654	672	679	607	790	34.4
Malta	387	533	625	623	641	643	66.1
Netherlands	539	598	599	571	523	533	-0.8
Poland	285	320	319	316	286	346	21.6
Portugal	352	457	452	516	460	513	45.7
Romania	342	355	383	313	247	287	-16.1
Slovenia	596	513	494	490	449	487	-18.3
Slovakia	295	254	273	319	329	433	47.0
Spain	505	653	588	510	456	455	-10.1
Sweden	386	425	479	441	451	431	11.7

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

The mass of municipal waste collected in communes in Poland since 2013 is clearly on the increase (Figure 1), but importantly since 2019, a growing amount of it has been subject to sorting, which means that less of it is stored. Over the analysed period (taking 2013 as the point of reference), the combined mass of collected municipal waste increased by 50%, while the sorted waste by as much as nearly 330%.

The mass of municipal waste collected in communes clearly differs among voivodeships (Figure 2). The largest amounts, both in the first and the final year under study, were collected in four voivodeships in Poland (namely: mazowieckie, śląskie, wielkopolskie and dolnośląskie), which is strictly linked to the population number, its density and financial status of residents. The smallest amounts of municipal waste are collected in voivodeships located in the east of Poland (podlaskie, podkarpackie and warmińsko-mazurskie), which is connected with their agricultural production and tourism. Over the studied period, one can observe significant changes in the amounts of municipal waste per capita collected in the communes (Figure 3).

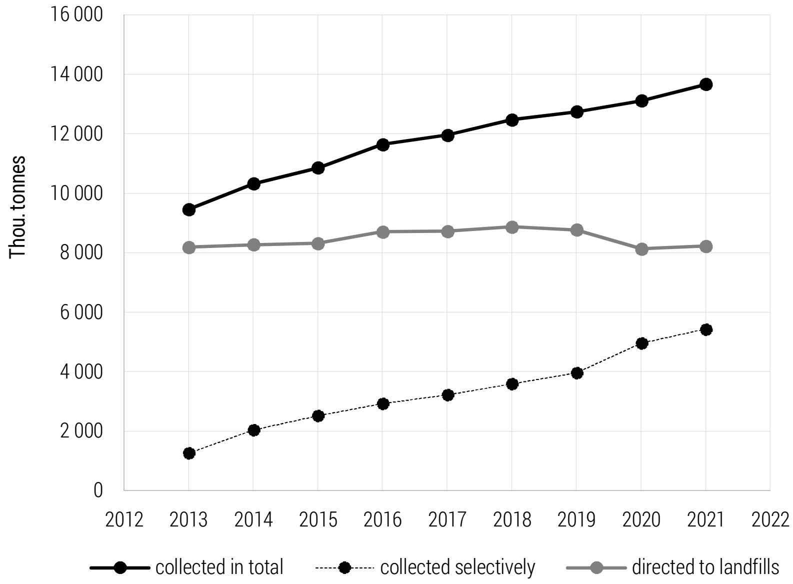

Figure 1. Municipal waste in Poland in 2013-2021 [in thou. Tonnes]
Source: authors' work based on GUS (2022).

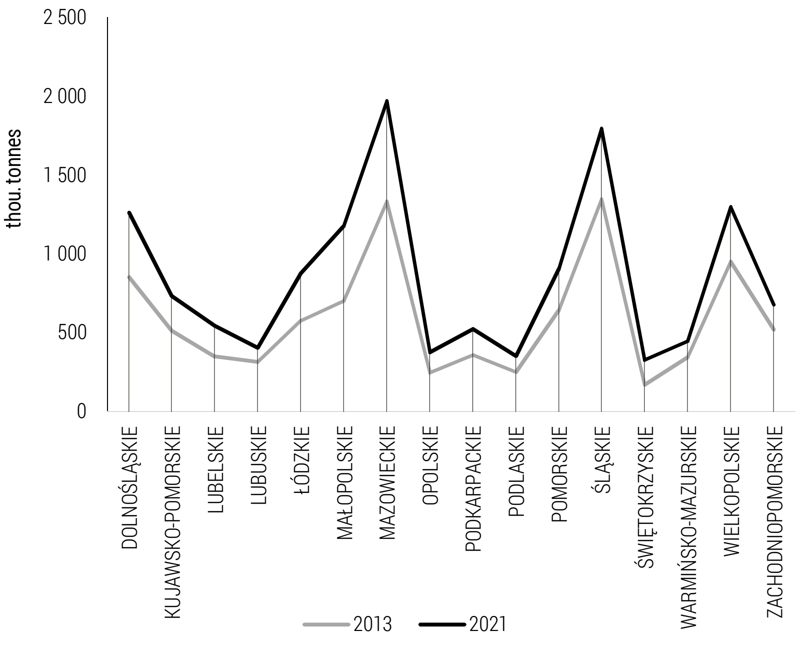

Figure 2. Municipal waste collected in 2013 and 2021 [by voivodeship in thou. Tonnes]
Source: authors' work based on GUS (2022).

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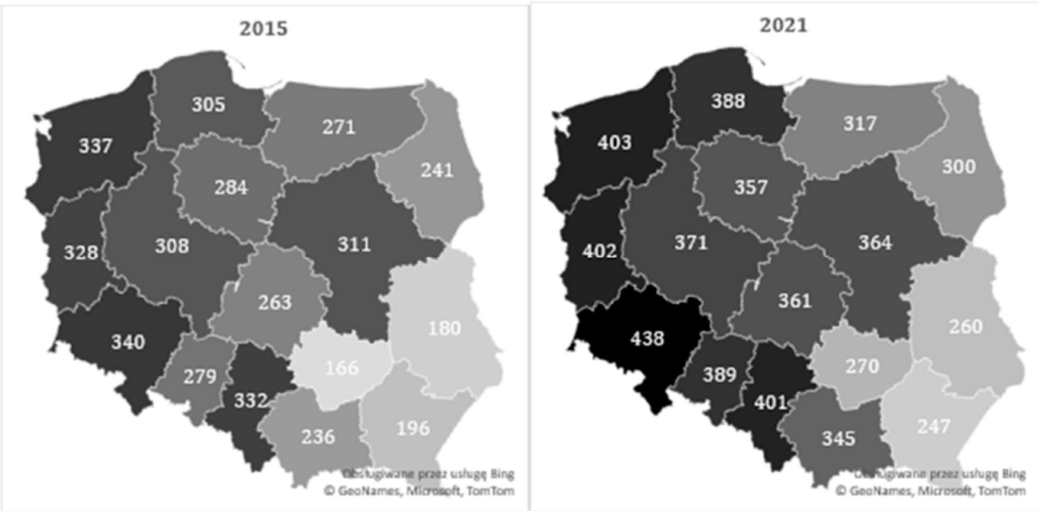

Figure 3. Mass of municipal waste produced in Poland in 2015 and 2021 [per capita in kg]
Source: authors' work based on GUS (2022).

In 2015 and 2021, the largest amounts of municipal waste were collected by residents of the following voivodeships: dolnośląskie, zachodniopomorskie, śląskie and lubuskie (in 2015 more than 320 kg, and in 2021 400 kg), whereas in the same period, the mass of municipal waste produced per person in three voivodeships (podkarpackie, lubelskie and świętokrzyskie) did not exceed 200 kg in 2015, and 300 kg in 2021.

Despite the annual increase in the amounts of produced municipal waste (by over 40% in 2021 compared to 2013), similar amounts were stored in landfills (Figure 4), while there was a significant increase in the mass of waste collected selectively. During these years, the relation between the amounts collected without sorting and those collected selectively was very strong, indicating that there is a growing amount of collected municipal waste suitable for recycling.

The projection up to 2035 of data regarding the mass of collected municipal waste according to its designation (Figure 5) demonstrates the great speed of growth in Poland of the mass of municipal waste designated for fermentation and composting (the goodness-of-fit of the function of linear regression is R^2=0.9618). There will also be a relatively quick increase in the mass of municipal waste designated for recycling (goodness-of-fit of the regression function is R^2=0.7732). Time is not entirely a determinant of the mass of municipal waste stored in landfills (it should be a slower increase).

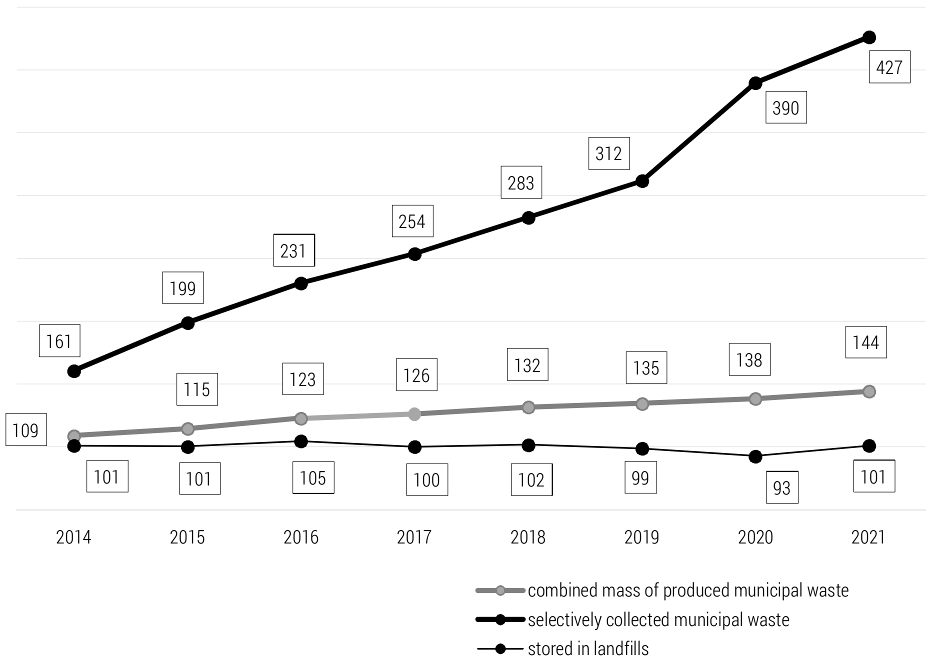

Figure 4. Changes in the amounts of waste produced, selectively collected and stored in municipal landfills in Poland in 2014-2021 [2013=100, in %]

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

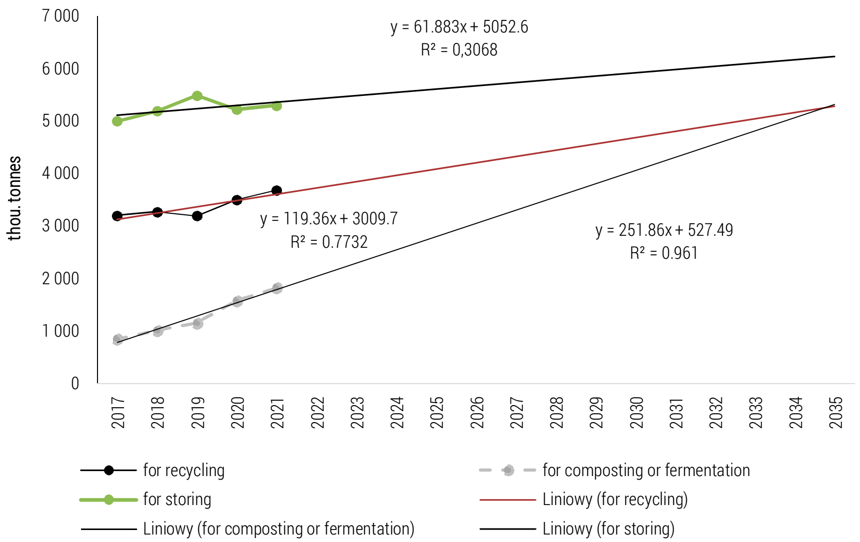

Figure 5. Mass of collected municipal waste according to designation in 2017-2021 and the projection up to 2035 [in thou. tonnes]

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

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These data suggest that residents of communes in Poland are becoming increasingly experts at the segregation of municipal waste. In the period 2013-2021, there was a growing trend in the level of four distinguished categories of waste collected selectively (Figure 6). This applies to the greatest extent to biodegradable (an increase from 312 thousand tonnes in 2013 to 1.843 thousand tonnes in 2021) and glass (from 316 thousand tonnes in 2013 to 784 thousand tonnes in 2021).

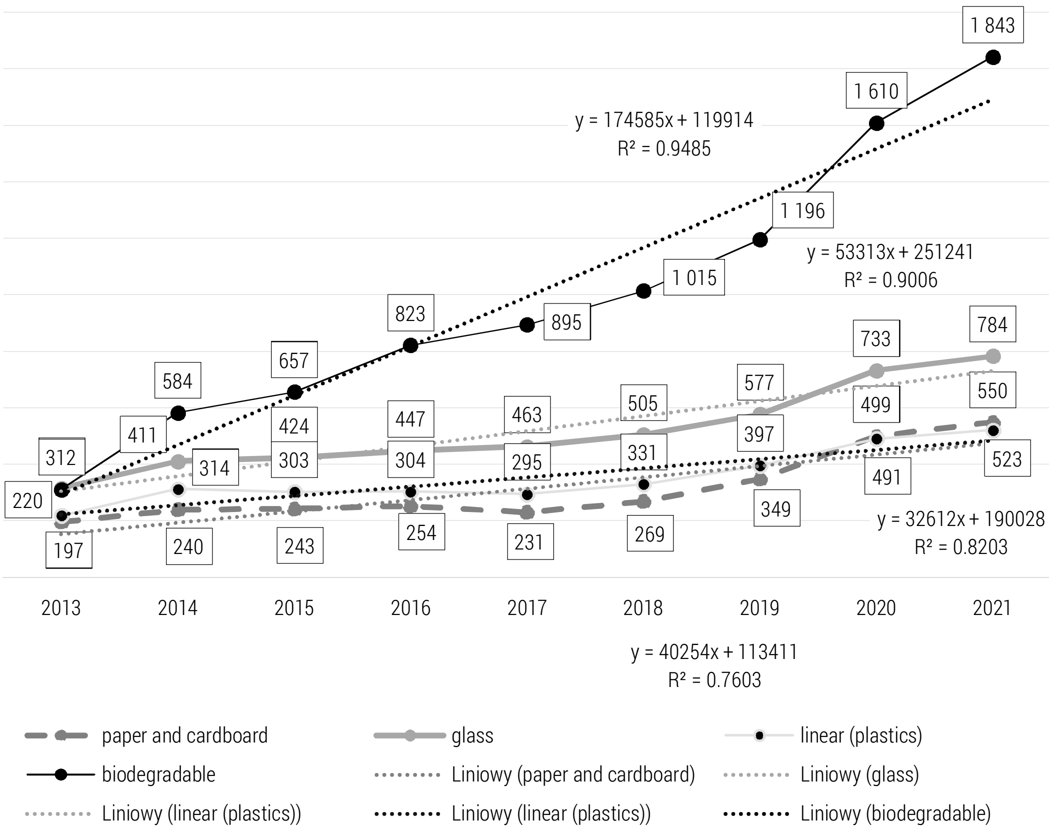

Figure 6. Municipal waste selectively collected in Poland in 2013-2021 [by segment, in thou. tonnes]

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

The level of sorting municipal waste differs in individual voivodeships in Poland (Figure 7). In 2013, sorted waste constituted from 7.3% (podlaskie) to 16.4% (świętokrzyskie) of the combined pool of collected municipal waste, while in 2021, this was already from 32.3% (świętokrzyskie) to 50.0% (lubelskie). Municipal waste designated for recycling (Figure 8) from the four segments (paper and cardboard, metals, glass, plastics) in 2013 amounted from 4.3% (podlaskie) to 13.9% (świętokrzyskie) of the combined mass of collected municipal waste, and in 2021 from 10.4% (opolskie) to 18.0% (lubelskie). The projection regarding the mass of municipal waste designated for recycling from the four segments in the combined pool of collected municipal waste up to 2035 (based on data from 2003-2021) indicates that it will exceed the level of 20% (Figure 9).

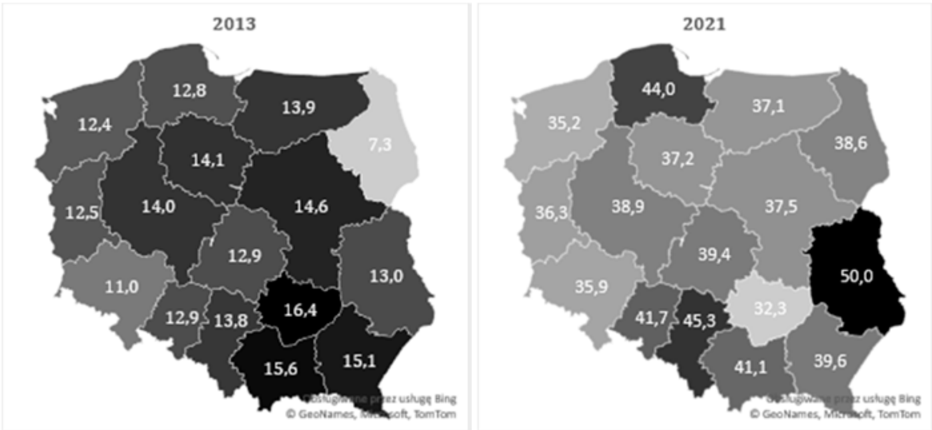

Figure 7. Municipal waste collected selectively in Poland in 2013 and 2021 [% of general municipal waste]

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

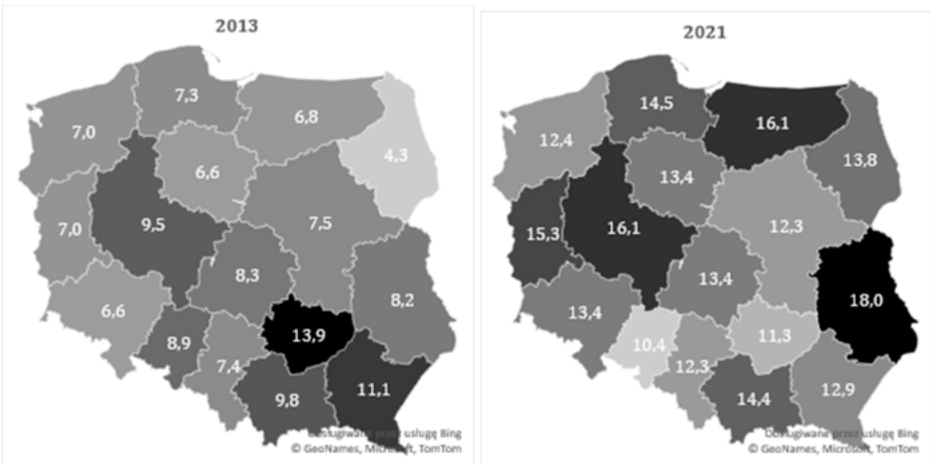

Figure 8. Share of paper and cardboard, metals, glass and plastics in a combined pool of municipal waste collected in Poland in 2013 and 2021 [by voivodeship, in %]

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

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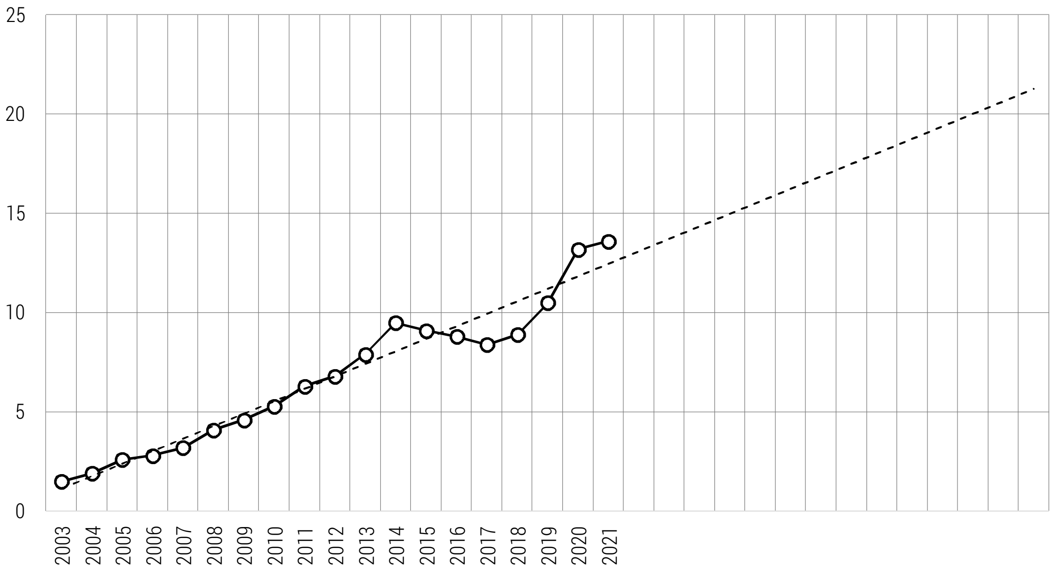

Figure 9. Share of paper and cardboard, metals, glass and plastics in a combined pool of collected municipal waste in Poland in 2003-2021 and the projection up to 2035 [in %]

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

The projection – based on historical data – for all municipalities in Poland as to (1) the level of preparation of municipal waste for re-use and recycling, and (2) the amounts of stored municipal waste (Figure 10) allow to hope that they will reach in 2035 the amounts required by the EU regulations. In individual municipalities, the situation may greatly differ, and this may result in incurring fines imposed due to not respecting these duties, which were already given by regional inspectorates for environmental protection in 2022. For example, the Pomorski Wojewódzki Inspektor Ochrony Środowiska (in the pomorskie voivodeship) already imposed this year fines amounting to PLN 3.4 mln on communes which did not fulfil their duty of achieving the required indicators for the year of 2020. In that region, out of 123 municipalities, 79 did not meet the requirements of preparation for re-use and recycling of municipal waste in the following segments: paper, metals, plastics, and glass. At the same time, 37 did not achieve the requested levels regarding other than dangerous construction and demolition waste constituting municipal waste, while 13 municipalities did not meet the requirements regarding the reduction of biodegradable municipal waste designated for storage. This resulted in the regional inspectorate imposing the fines of nearly PLN 3.4 mln.

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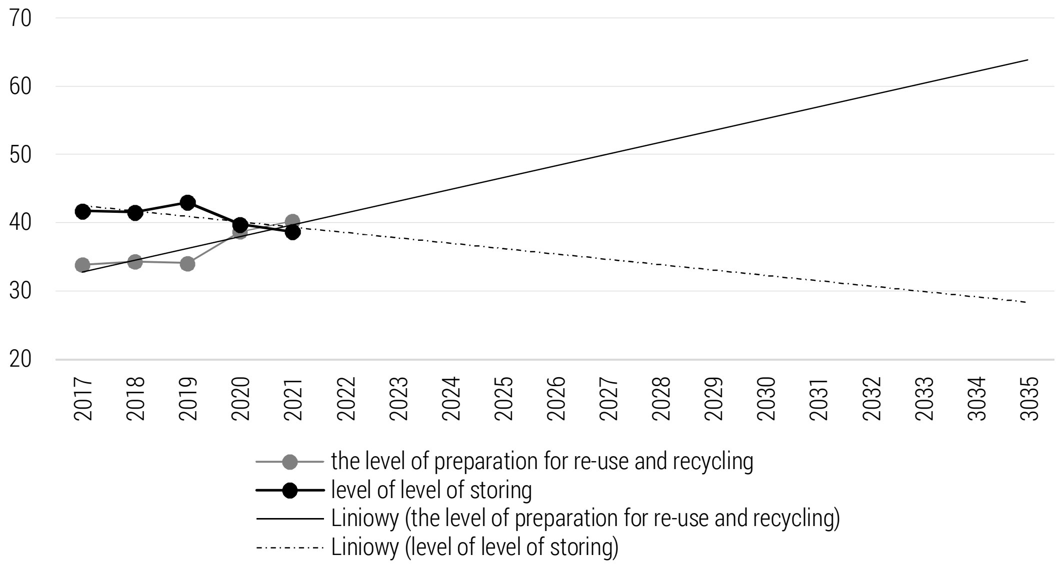

Figure 10. Preparation of municipal waste for its re-use, recycling and storage in Poland in 2017-2021, and the projection up to 2035 [in %]

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

Conclusion and recommendations

The considerations presented in this paper lean towards the following conclusions:

- waste, including municipal waste, constitutes an integral part of the functioning of modern economies and societies, which as a result of implementing diverse solutions and technologies, produce increasing amounts of waste while the limited resources and storage space enforce carrying out actions aimed at not merely limiting the amounts of the produced and stored waste, but also increasing the pool of those which are suitable for re-use as well as the implementation of the model of a circular economy,
- the mass of municipal waste produced per capita in the EU oscillated in 2020 between 287 kg (Romania) to 834 kg (Austria), while in the period 1995-2019, the amount of produced municipal waste per capita increased in the majority of the countries (mostly Croatia – by 90.4%), even though some countries managed to reduce it during that time (mostly Bulgaria, Hungary and Slovenia),
- the EU obliged its member states to limit the level of stored municipal waste and to increase its re-use and recycling by 2035 and by 2050 to

enter the stage of a circular economy, as reflected in the existing and already executed legal regulations,

- in Poland in the period 2013-2021, one could observe an increase in produced and collected amounts of municipal waste (per capita in 2015 from 166 kg to 340 kg, and in 2021 from 247 kg to 438 kg), including sorted waste globally, even though this was spatially differentiated (in 2013 from 7.3% to 16.4%, in 2021 from 32.3% to 50.0%), while during that time a comparable mass of municipal waste was placed annually in landfills,
- communes in Poland are accumulating a growing mass of biodegradable municipal waste which is not placed in landfills, as well as recovered glass, paper and cardboard, plastics and metals, but these amounts vary in individual voivodeships (from 4.3% to 13.9% of the combined pool of the collected municipal waste in 2013, and from 10.4% to 18.0% in 2021),
- the projection of data regarding the share of paper and cardboard, metals, glass and plastics in the combined pool of the collected municipal waste in Poland by 2035, and also the assumed levels of preparation for its re-use and recycling, as well as storage, allows to hope that the amounts of stored and re-used municipal waste assumed in the EU regulations will be met in Poland, but it is difficult to foresee whether this will be possible in every commune, due to various considerations.

Bearing in mind the above, one can formulate the following recommendations:

- there are numerous determinants which may decide about the fact whether the levels of recycling and storage of municipal waste required by EU regulations will be met in Poland, yet not all of them are of a systemic character which means that local authorities of every commune will have to decide, appropriately and individually, how to organise the management of municipal waste to meet the set objectives,
- the management of municipal waste comes at a cost, and only a few municipalities manage to balance their revenues and costs of the system of managing their municipal waste; nevertheless, they should not skimp on means for ecological education,
- the key to success in reaching the assumed levels of recycling and re-use, and the storage of waste, is the education of citizens in this respect, as well as clear directives regarding the conditions in which the waste can be considered municipal waste suitable for re-use, and how to proceed in order that landfills (and no other places) could receive diminishing amounts of municipal waste; it is necessary to build the ecological awareness of society (consumers and producers of goods),

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- young people provide a chance to create a circular economy in terms of the management of municipal waste, as their concern for the environment, segregation of waste, and pro-ecological attitude in life are something which is both natural and desirable.

The contribution of the authors

Conceptualization, J.K. and H.Ż.; literature review, J.K. and H.Ż.; methodology, J.K. and H.Ż.; formal analysis, J.K. and H.Ż.; writing, J.K. and H.Ż.; conclusions and discussion, J.K. and H.Ż.

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FINANCIAL EFFICIENCY VS. ENVIRONMENTAL EFFICIENCY ON THE EXAMPLE OF THE MEAT AND POULTRY INDUSTRY IN POLAND

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ABSTRACT: The purpose of the article is to assess the relationship between financial efficiency and environmental efficiency in the meat and poultry industry in Poland between 2010-2020. Firstly, the assessment of financial efficiency in the area of profitability was underdone. Secondly, the environmental efficiency in the area of selected environmental policy components was assessed. Based on the results, the author built an econometric model examining the impact of binary variables on individual financial efficiency indicators in the area of profitability. The study consists of theoretical and practical parts. In the theoretical part, methods of analysis, synthesis, comparison and graphical transposition of data were used. In the practical part, quantitative methods: ratio financial analysis, ANOVA method, panel econometric modelling, and qualitative methods – case studies, were used. The study shows that for financial efficiency, the values of the net sales profitability ratio are statistically significant. The most important factor for environmental efficiency are consistently implementing transparent environmental policies. The practical implication of the study contributes to financial support for the meat and poultry industry in Poland. The social implication of the study is the urge to implement the principle of sustainable consumption.

KEYWORDS: financial efficiency, environmental efficiency, meat and poultry industry, Poland

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Introduction

The food economy is one of the most important sectors of the national economy. Meat and poultry enterprises require constant continuity of good quality supplies of raw materials in order to produce food which corresponds to the changing needs and preferences of consumers and their ongoing changes in food patterns. On the other hand, the meat and poultry industry need to implement the practical aspects of the paradigm of sustainable development and balanced development at every level of food production and processing.

Poland is one of the largest meat producers in the European Union. It ranks first in poultry meat production in the EU-28, fourth in pork production (behind Germany, Spain, France), and seventh in beef production (behind France, Germany and the UK, Italy and Ireland). In 2020, the total production of pork, beef and poultry amounted to 4.782 thousand tons in hot weight, 17% higher than in 2014. During 2010-2020, beef production increased the most (29%) to 543 thousand tons and poultry meat (27.4%) to 2.374 thousand tons, while the smallest increase was in pork (3.4%) to 1.865 thousand tons. In 2020, poultry meat accounted for the highest decline in total meat production, followed by pork and beef. The share of other meat, i.e. calf, horse, mutton, goat and rabbit (including game), was 1.1% (Mroczek, 2020).

An overview of the literature

The environment, according to the Law on Environmental Protection, is the total of natural elements, including those transformed as a result of human activity, in particular the land surface, minerals, water, air, landscape, climate and other elements of biodiversity, as well as the interactions between these elements (Act, 2008). In the process of socioeconomic development, the environment has two functions. First, it is a source of resources and, at the same time, a source of assimilation of pollution. Woś (2004) emphasises that for the proper functioning of both the environment and the economy, it is necessary to respect both principles simultaneously:

- renewable natural resources should be used so that the rate of their consumption is not greater than the rate of their restoration,
- the streams of pollutants flowing into the environment must not be greater than the assimilation capacity.

The environment in Poland is threatened by factors related to agricultural activities like a way of farming, land use, the nature of livestock production, and drainage system, as well as factors unrelated to agricultural activit-

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ies like emissions from enterprises' production and processing, residential buildings, waste management, sewage system, public transport, etc. (Urbaniec & Tomala, 2021). Every economic activity has certain effects on the environment, which can be more or less harmful, sometimes even irreversible. According to Woś (2004), "the burden of environmental effects on Polish agriculture has an increasing trend, but the standards have not been exceeded. In every enterprise, environmental activities mean production that is environmentally friendly as a result of the minimisation of emitted anthropogenic loads, i.e. dust, gases, wastewater, and waste. In addition, such environmentally friendly production, f. ex., eco-production, is supplemented by waste-free technologies, recycling, eco-friendly packaging and the use of unconventional raw materials – secondary raw materials (Ejdys & Szpilko, 2022; Sikora, 2020; Yang et al., 2022; Żuchowski, 2001).

Sustainable production consists of a reduction in the amount of goods produced, an optimal product mix to be safe, economical and sustainable, clean production technologies, and appropriate attitudes and behaviour of employees based on pro-social and ethical attitudes (Godawska, 2021; Pabian, 2013; Zegar, 2012).

A greening activity is based on the principle of respect for the natural environment that takes into account the protection of the environment and the rational use of its resources with its simultaneous reproduction in the short term, preserving the potential of the environment (Jelonek & Walentek, 2022; Lavuri et al., 2021; Sukiennik et al., 2017). Any pro-environmental activity of an enterprise includes undertakings of the pre-and post-production and post-consumption phases (Lemkowska & Wiśniewska, 2022; Czyżewski et al., 2021), but due to the nature of the analyses carried out, this paper presents the actions taken during and in connection with the production process.

The terms production process and manufacturing process are not the same. A manufacturing process is understood as «an orderly sequence of activities that results in the consumer receiving products» (Kasztelan & Nowak, 2021). The manufacturing process, on the other hand, involves «the industrial transformation of factors of production into products" (Siderska & Jadaan, 2018).

The main environmental problem resulting from the broadly defined production activities of enterprises include production waste, emissions of atmospheric air pollutants, wastewater discharge, use for the production of agricultural and forest land, devastation and degradation of soils, electromagnetic radiation, changes in the environment due to extraction of raw materials from deep underground, changes in the landscape and other aesthetic qualities, even the final product during its use and its packaging at the disposal and storage stage (Hadryjańska, 2015).

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It should be borne in mind that taking environmental measures by a processing enterprise requires paying attention to such issues as (European Commission, 2022; European Environment Agency, 2020; Nahotko, 2002):

- if the costs of using environmental resources and services are not borne by those who generate these costs, then market prices convey false information to producers and consumers,
- preventing environmental damage is cheaper and more effective than restoring the environment to its pre-damage state after it has been destroyed,
- as much as 70% of the waste and harmful emissions produced by industry can be prevented at their very sources,
- around 20-25% reduction in emissions can be achieved without major financial outlays.

The author found current, inspiring contributions to the issue of systematisation of the financial and environmental efficiency measurement. Wasilewski and Zabadała (2012) presented changes in the efficiency of agricultural enterprises depending on the relationship between equity and debt. Filipiak and Jasińska (2018) carried out a multi-faceted classification of the concept and measurement of effectiveness. Waśniewski and Skoczylas (2004) have sorted out the fundamental categories in financial analysis.

The author found a research gap in methodology and understanding of detailed insight into profitability indicators to support management processes in the sense of investigation and quantification of relationships among profitability ratios within a financial efficiency framework (Mensch, 2008). Moreover, a second research gap consists of various attempts to quantify the assessment of environmental performance in the food sector around the world (Pawlak & Kołodziejczak, 2020; Krupanek et al., 2022).

The scientific novelty of the manuscript is the presentation, analyses and assessment of financial efficiency in terms of profitability versus environmental efficiency in the Polish meat and poultry industry. First, the financial method was used to carry profitability indicator analysis out. Second, ANOVA analysis to find only statistically significant relationships between calculated profitability indicators were used. Third, a case study on environmental efficiency in order to combine the quantitative with qualitative results of the research was used. Additionally, analysis, synthesis and comparative methods to enrichen the context of the underdone multifaced and multileveled study were used. The concurrent use of quantitative and qualitative methods deepened and broadened the underdone analyses.

The practical novelty of the manuscript is the environmental activities of meat and poultry enterprises in the area of sustainable use of raw materials and use of energy-efficient technologies.

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In view of the global trend of searching for solutions to reduce the environmental impact of the food industry, the exploration of meat and poultry enterprises' financial and environmental efficiency takes on great significance. The article undertakes three research objectives: theoretical, empirical and applicative.

The theoretical-cognitive goal is:

- To systematise knowledge of the concept, role and importance of the efficiency of entrepreneurs in the food market.

The empirical goals are:

- To select and present quantitative indicators for assessing financial efficiency and qualitative measures for assessing environmental efficiency,
- To determine changes and relationships between financial efficiency and environmental efficiency of the meat and poultry industry.

The applicative goals are:

- To formulate public institutional policy objectives for improving the environmental efficiency of the meat and poultry industry in Poland,
- To support institutions and actors responsible for the development of the food sector and individual entrepreneurs by improving their efficiency in the conditions of dynamically developing exports.

In order to carry out the study, the following research questions have to be answered:

- What is the level of financial efficiency of the meat and poultry industry in Poland between 2010-2020?
- What is the level of environmental efficiency of the meat and poultry industry in Poland between 2010-2020?
- Do the financial efficiency outcomes of the meat and poultry industry coincide with its environmental efficiency?

The author undertook quantitative and qualitative research; therefore, the article has a research hypothesis and a thesis. On the basis of theoretical analysis and empirical results of the previous studies, hypothesis (H_1) was formulated: Financial efficiency in terms of profitability differentiates the examined groups of meat and poultry enterprises. The thesis (T_1) was accepted for verification: Higher the values of profitability ratios are, the higher the environmental efficiency is.

Research methods

To assess the multifaced issue of financial efficiency vs environmental efficiency variety of research methods and tools are used. Quantitative methods such as ANOVA analysis and Panel Data Modeling to evaluate financial efficiency in the area of profitability of meat and poultry industry enterprises

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in Poland in 2010-2020 were used. Qualitative methods in the form of eight semi-structured interviews with respondents responsible for environmental issues in chosen meat and poultry enterprises in Poland in 2020 were carried out (Table 1).

Table 1. Presentation of research characteristics

Subject	Objects, Country, Time	Measurement Methods and Tools	Goal
Assessment of financial efficiency	Database on enterprises operating in meat and poultry industry in Poland in 2010-2020	Quantitative: indicator analysis, ANOVA analysis, Panel Data Modelling	A comprehensive study on financial efficiency in terms of profitability in meat and poultry industry
Assessment of environmental efficiency	Semi-structured interviews in chosen meat and poultry enterprises in Poland in 2020	Qualitative: semi-structured interviews, case-studies	A case-study on environmental efficiency in chosen meat and poultry enterprises

In the first step, the financial indicator analysis in terms of profitability ratios were used. Financial analysis is the process of using financial information to assist in investment and financial decision-making (GSU, 2022). Financial analysis helps managers with efficiency analysis and identification of problem areas within the company (Yu et al., 2021). The motivation for using financial indicator analysis in order to measure the profitability of the meat and poultry industry in Poland between 2010-2020 was the fact that it is simple, universal, and can be applicated at the industry level. Furthermore, it is characterised by a wide comparability of results over time and space. Fourthly, financial indicator analysis for individual business entities from a given sector provides a means of obtaining an overview of the economic and financial situation of the sector. As is the case with any method, financial indicator analysis is not free of flaws. Most of the limitations of this method are as follows. First, financial indicator analysis is static, which makes it difficult to take into account different dimensions of an enterprise's activities. Second, benchmarks are often tied to industry averages, not leaders. Third, balance sheets may be distorted by inflation. Fourth, ratio analysis does not give the context of an analysed enterprise or a sector (Carlson, 2022).

In the second step, the panel database in order to find and assess relationships between different profitability ratios in all four groups of meat and poultry enterprises in the Polish meat and poultry industry was created. The final panel database consisted of 38. 000 financial units of 750 enterprises in the period 2010-2020. The data processing was made with the statistical program Excel. The calculations of records for 750 enterprises in the period 2010-2020 for five profitability indicators, such as operating profitability

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(OP), return on total capital (ROI), net return on sales (NRS), return on assets (ROA) and return on equity (ROE) were carried out (see Annex A). The calculated profitability ratios for all 750 enterprises in the period 2010-2020 were used to run panel data estimations with the use of the ANOVA method for only statistically significant ratios between four groups of examined meat and poultry industry enterprises with a significant level equal to 95%. Only statistically significant values were taken for further analysis, which turned out to be the values of the net return on sales (NRS) ratio. The values of the NRS ratio were calculated with the use of approx. 10 860 data observations [1 ratio × 750 enterprises × (min. 6 max. 8 years)].

In the third step, chosen components of the environmental performance of analysed meat and poultry enterprises were tested. The identification of those components followed a specific procedure to determine which of them led to significant environmental impacts. The magnitude of the impact was considered, as well as the impact of the change on other activities and processes and on the public perception of the organisation (Czakon, 2009). Once the most relevant environmental aspects of an enterprise were determined, measurable goals were formulated and implemented with specific tasks. For instance, such environmental goals include the reduction of the amount of waste generated in the production process, more efficient use of resources, minimisation of environmental pollution, and promotion of eco-actions among employees and consumers. The implementation of environmental goals required calculable indicators to measure the company's significant impact on the environment, verified and comparable over time, at best, with environmental standards (Nahotko, 2002). Unfortunately, not every examined meat and poultry enterprise was willing to present its environmental activity; environmental efficiency was achieved with a case-study method.

In the fourth step, a one-way statistical analysis of variance (ANOVA analysis) was used to examine observations that depend on one factor acting simultaneously. A one-way ANOVA compares the effects of an independent variable on multiple dependent variables. This method explains with what probability the extracted factor can cause differences between the observed groups. There are a few limitations of ANOVA analysis (Kenton, 2022). The first one is that the groups have the same, or very similar, standard deviations. The second limitation concerns its restrictive assumptions (Davies, 2022).

In the fifth step, Panel Data Models from cross-sectional temporal data, which are objects×variables×periods were built. They describe a fixed group of objects in more than one period (Baltagi, 2001). Thanks to the information about objects and their simultaneous characteristics in particular periods, panel data models allow reducing of measurement error resulting from the omission of important unobservable variables for these objects. The panel

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database was created to find and assess relationships between different profitability ratios in all four groups of meat and poultry enterprises in the Polish meat and poultry industry. The final panel database consisted of 38. 000 financial units of 750 enterprises for five profitability indicators: operating profitability (OP), return on total capital (ROI), the net return on sales (NRS), return on assets (ROA), return on equity (ROE) in the period 2010-2020 in Poland (see Annex A). The data processing was made with the statistical program Excel. Three profitability ratios: ROE, NRS and OP, were statistically significant, which meant 28 455 panel data observations. [3 ratios x 750 enterprises x (min. 6 max. 8 years)]. From the exploratory analysis, dependent variables – indicators were extracted. A higher value of the profitability indicator obtains a better result, and lower values – a worse result.

In the sixth step, the results of the Panel Data Model with semi-structured interviews to assess and interpret the dichotomous dependencies between financial efficiency and environmental efficiency were juxtaposed with each other. According to Stańko (2008), qualitative research is no easier to conduct than quantitative research. They are not without methodological rigour at the stages of data collection and analysis or theory building.

Sample and Procedure

The basic criterion for a research selection sample in order to measure financial efficiency in the area of profitability were:

- subject of conducted activity according to PKD 2007 (Biznes.gov.pl, 2022)- classes 10.12 and 10.13,
- location within the country,
- keeping the financial statements for the period from 2010 to 2020,
- raw material processing volume (t/week), number of employees (full-time), and the volume of revenue (PLN/year).

The analysed group of 750 enterprises in the meat and poultry industry were divided into four groups: slaughterhouses, where N = 53, meat enterprises, where N = 597 (subdivided into large meat enterprises, where N = 35, medium-sized, where N = 295, and small enterprises, where N = 267), poultry meat enterprises, where N = 50, meat trading enterprises, where N = 50. Small meat enterprises employ from 10 to 49 persons, process more than 7.5 to 20 tons of slaughter material per week and obtain sales revenue of up to PLN 100 million per year. Medium-sized meat enterprises employ from 50 to 249 people, process 20 to 100 tons of slaughter material per week, and obtain sales revenue of PLN 101-499 million per year. Large meat enterprises employ over 250 people, process more than 100 tons of slaughter material per week, and obtain sales revenue exceeding 500 million PLN per year. The

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research was comprehensive (full) because it covered the entire population. It means that the number of all enterprises subjected to the research was equal to the number of enterprises in the population. The study of financial efficiency met the criterion of representativeness. The basic criterion for a research selection sample to measure environmental efficiency in the area of profitability is presented in Table 2.

Table 2. Presentation of potential factors and indicators shaping environmental efficiency of food processing enterprises

Quantity	- quantity of raw materials used in the production process [t], - amount of water used in the production process [m³], - amount of sewage discharged [m³], - amount of energy used [MWh], - the amount of gas and dust emissions into the atmosphere [t], - the type of gas and dust emissions to the atmosphere, - amount of waste generated in the production process [t], - amount of waste to be recycled [t].
Quality	- installation of own sewage treatment plants, - the purchase of an efficient furnace, which reduces the consumption of mine raw materials, - installing filters to reduce gas and dust emissions into the atmosphere, - implementation of new production technology, - organizational and improvement activities consisting in the reduction of waste generated in the production process, - improvement of the company's image resulting from environmental activities.

Results of the research

Between 2010-2022, Poland is the sixth EU food producer behind Germany, France, Italy, the UK and Spain, with a value share of around 9%. The Polish food sector accounts for more than 20% of the sales value of the entire domestic industry. It is formed by some 16,000 companies employing 402,000 people, i.e. about 16% of those employed in domestic industry (GUS, 2020). The meat and poultry industry is one of the most important among dairy, fruit and- vegetable, bakery and- confectionery industries, branches of the food industry in Poland. The meat and poultry industries are characterised by relatively low levels of profitability of sales. The Polish meat and poultry industries are classified as low-profitability sectors of the food industry, although the poultry industry is characterised by average higher profitability than the meat industry (Zielińska-Chmielewska, 2020; Mroczek, 2018; 2020; 2022).

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Table 3. Key financial indicators of the meat industry in Poland in 2010-2020

No.	Specification	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1.	Net revenues from sales of products, goods and materials [million PLN]	31 404	32 986	41 728	44 862	44 675	46 189	49 951	57 825	54 474	59 381	59 034
2.	Net profit [million PLN]	1 029	680	891	963	1 389	1 447	1 267	1 763	1 762	1 351	2 214
3.	Return on total revenues [%] - gross	3.76	2.29	2.45	2.36	3.35	3.40	2.86	3.41	3.54	2.61	4.28
	- net	3.25	1.95	2.12	2.05	2.98	3.01	2.45	3.07	3.14	2.21	3.71
	- capital accumulation*	5.31	3.80	3.74	3.69	4.69	4.80	4.21	4.71	4.83	3.87	5.58
4.	Equity	6 153	6 200	6 709	7 487	8 611	9 648	9 671	10 771	10 547	11 428	11 561
5.	Total debt	6 325	6 827	8 010	8 475	9 117	9 955	11 256	12 398	13 415	14 398	12 777
6.	Current liquidity	1.20	1.24	1.22	1.30	1.34	1.31	1.32	1.46	1.40	1.33	1.34
7.	Investment rate **	1.18	1.24	1.23	1.16	1.13	1.50	1.31	1.30	1.28	1.36	1.12
8.	Profitable companies [%] - percentage of profitable companies	86.9	77.3	81.3	84.1	87.3	89.0	82.2	85.3	87.8	83.1	88.8
	- their share in industry revenue	91.1	85.8	91.4	84.5	94.9	93.99	89.9	90.9	87.3	83.9	90.8

** net profit + amortization*
*** Investments in relation to depreciation*

Source: author's work based on Mroczek (2018; 2020; 2022).

Table 4. Key financial indicators of the poultry industry in Poland in 2010-2020

No.	Specification	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1.	Net revenues from sales of products, goods and materials [million PLN]	10 202	13 777	14 281	11 068	11 411	11 482	12 345	12 658	13 714	13807	13 198
2.	Net profit [million PLN]	193	204	180	160	314	235	280	304	455	268	81
3.	Return on total revenues [%] - gross	2.05	1.44	1.13	1.26	2.91	2.37	2.53	2.55	3.60	2.25	0.79
	- net	1.77	1.25	1.05	1.06	2.61	2.02	2.23	2.35	3.22	1.89	0.59
	- capital accumulation *	3.30	2.68	2.60	2.44	3.93	3.53	3.87	4.09	5.00	3.79	2,81
	Cash flow [%]	3.30	2.68	2.60	2.44	3.93	3.53	3.87	4,09	5.00	3.79	2,81
4.	Current liquidity	1.21	1.17	1.24	1.15	1.28	1.34	1.30	1.34	1.28	1.35	1,21
5.	Investment rate **	1.12	1.43	1.02	1.37	1.41	1.92	1.90	1.70	1.26	1.48	1,27
6.	Profitable companies [%] - percentage of profitable companies	89.4	81.3	77.6	83.1	90.7	89.3	83.6	85.5	86.1	86.7	82,8
	- their share in industry revenues	93.1	66.2	89.5	86.2	89.1	91.00	73.40	89.80	90.00	91.00	86,1

** net profit + amortization*
*** Investments in relation to depreciation*

Source: author's work based on Dybowski and Pasińska (2018); Pasińska (2020; 2021).

In Poland, in 2010-2020 the economic and financial performance of the meat industry testified to a good and secure economic situation. In 2016 and 2017 meat companies generated a record net profit of more than PLN 1.75 billion, which was 39% higher than in 2016, and 42% higher than in 2010. All of the profitability ratios were marked by high values except 2019. The average ratio of the net return on sales of the meat industry rose to 3.07% and was the highest since 2011. In 2017, compared to 2010, equity increased by 42.87% to PLN 10.7 billion, and general debt increased by 10.1% (to PLN 12.4 billion), of which long-term debt increased by 30.6% (to PLN 3.6 billion). Capital expenditure reached PLN 1.2 billion and remained at the same level as in 2016. The highest value of the investment rate was equal to 1.50 in 2015, more than ensuring the replacement of production assets, as well as the upgrading and modernisation of meat enterprises. In 2020 the value of net return of total revenues was the highest in the analysed period (3.71). In the years of COVID-19 spread, current liquidity amounted to 1.34, which fully ensured the current payment of short-term liabilities. In 2010-2020 the percentage of profitable companies was at a comparable level of 84.44%, and their share in the sector's turnover was nearly 89.40% (Table 3, Figures 1, 2, 3).

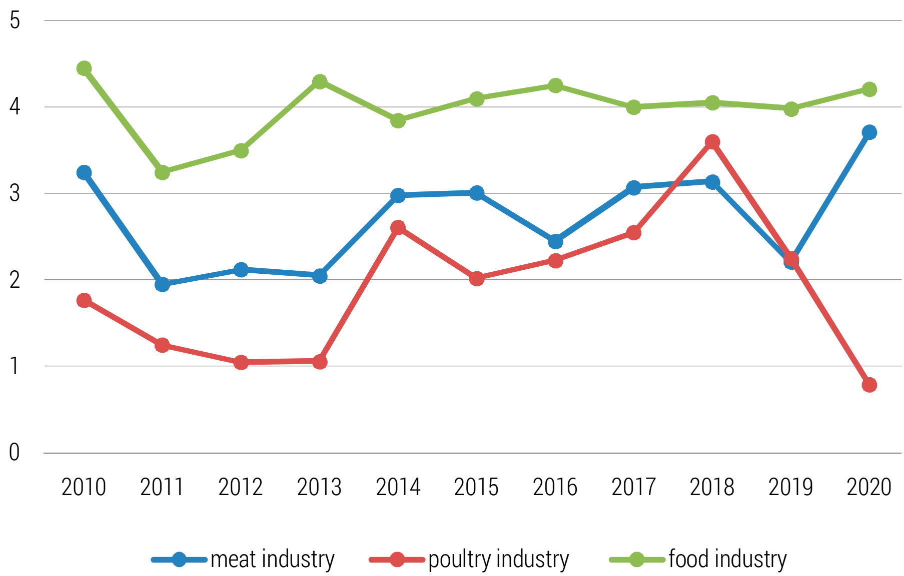

Figure 1. Values of the net sales profitability ratio of meat, poultry and food industry in Poland in 2010-2020 [in % of revenues]

Source: author's own work based on Mroczek (2018; 2020; 2022).

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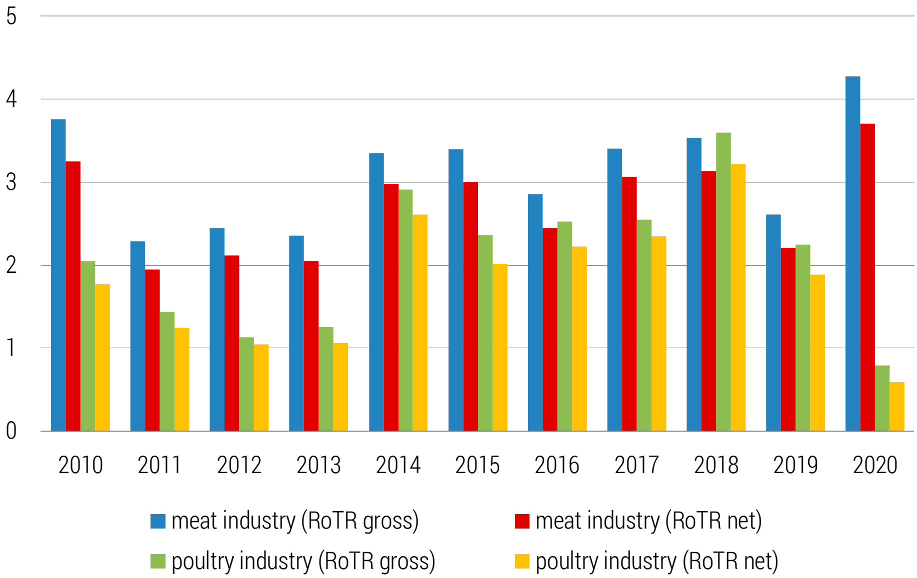

Figure 2. Values of the ratio of return on total revenue (gross and net) in the meat, poultry and food industry in Poland in 2010-2020 [in % of revenues]

Source: author's work based on Mroczek (2018; 2020; 2022).

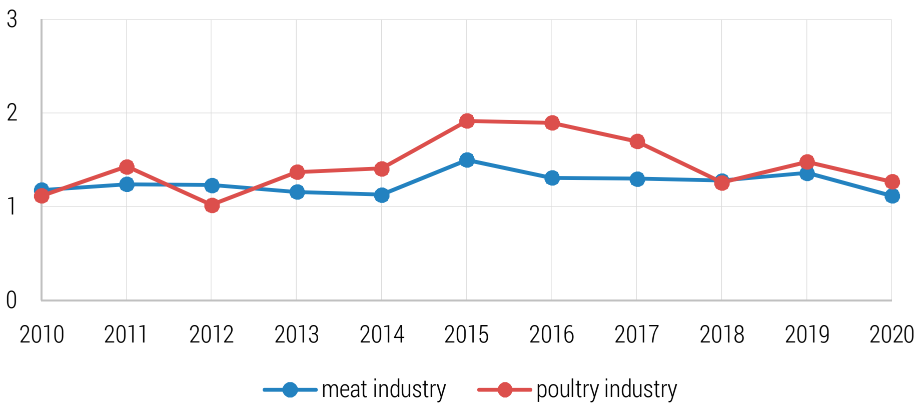

Figure 3. Values of the investment rate in meat, poultry and food industry in Poland in 2010-2020 (investment in relation to depreciation)

Source: author's work based on Mroczek (2018; 2020; 2022).

In Poland, between 2010-2020 the economic and financial performance of the poultry industry testified to its stable economic situation. In 2017, poultry enterprises generated a record net profit of PLN 2.35 billion, which was 5.1% higher than in 2016, and 12.76% higher than in 2010. Due to the outbreak of the COVID-19 pandemic in 2020, the economic and financial situation of the whole poultry industry has changed dramatically. For instance, in 2020, net profit was equal to 0.79 million PLN and was 3.3 times lower than in 2019. In 2017 the average net sales profitability of the poultry industry reached the highest turnover value of 2.35%, in 2019 dropped to 1.89 and was close to its value from 2010. In 2020 the net value of return on total revenues reached the lowest value, 0.59 million PLN. In 2019, the investment rate was 1.48 ensuring the reproduction of production assets. In 2020, the current liquidity ratio was 1.21, ensuring the current repayment of current liabilities. Between 2010 and 2019, total debt was equivalent to 60% of assets. In 2010-2020, the percentage of profitable companies oscillated around 85.34%, and their share in the sector's turnover was 85.9% (Table 6, Figures 1, 2, 3).

According to the Agency for Restructuring and Modernization of Agriculture, the aftermath of the COVID-19 pandemic was a restriction on the export of livestock and poultry products to foreign trading partners. In turn, the opening of borders caused a spike in livestock prices. Livestock purchase prices were rising, and it should be remembered that raw material accounts for 60% of production costs. Food production is under strong pressure from rising production costs, i.e., the prices of agricultural raw materials, energy, services and wages; at the same time, the parity of consumers' purchasing power is falling (Mroczek, 2022).

Table 5 presents the panel data estimation results for the variable Net Return on Sales (NRS). It is proven that there is a statistically significant dependency between the value of net return on sales (NRS) and slaughterhouses and poultry processing enterprises. It means that the coefficient of slaughterhouses and poultry meat enterprises was statistically significant. Thus slaughterhouses and poultry meat enterprises had lower NRS ratios than other groups of examined enterprises. The meat industry belongs to the sections of the agro-food industry with a lower return on sales. On the contrary, the highest return on sales is observed in the production of beverages, brewery, and confectionery. Nevertheless, in the period 2010-2020, the economic and financial performance of enterprises of the red meat industry testified to a good and secure economic situation (Pasińska, 2018; Mroczek, 2018).

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Table 5. Panel data estimation results for the variable Net Return on Sales (NRS) – general least squares method (GLSM)

Model 1: panel data estimation – 750 observations Time series length: minimum 5, maximum 8 Robust standard errors (robust HAC)				
Variables	*Coefficient*	*Standared error*	*Z*	*Critical signifance level*
Const	5.059239	1.119018	4.52	< 0.000
Slaughterhouses	-2.782779	1.351669	-2.06	< 0.040
Meat enterprises	-0.6000481	1.156463	-0.52	< 0.604
Poultry meat enterprises	-2.752528	1.37098	-2.01	< 0.045
Wald Chi-Squared Test (2) = 13.09, ***critical signififance level*** = 0.0044				
Interpretation of the model	The value of the net return on sales ratio (NRS) was significantly lower by 2.782 (critical level of significance = 0.040) in slaughterhouses, and by 2.752 (critical level of significance = 0.045) in poultry processing enterprises than in meat enterprises and trade and service meat enterprises			
Conclusions	There are statistically significant differences in the level of obtained value of the net sales profitability ratio in slaughetrhouses and poultry meat enetrprises			
Hypothesis H_1	Each type of tested profitability differentiates financial efficiency			
Decision on H_1	Do not reject H_1			
Summary	Profitability measured by the value of net sales profitability ratio (NRS) differentiates the group of meat enterprises. The obtained estimation results confirm hypothesis H_1, because the value of NRS ratio significantly differentiates both slaughterhouses and poultry meat enterprises			

Table 6. Examined components of the environmental performance of Delikatesy Mięsne Gzella sp. z o.o. and Zakłady Mięsne Mróz S.A.

No.	Delikatesy Mięsne Gzella sp. z o.o.	Zakłady Mięsne Mróz S.A.
1.	**Continuous control and improvement of raw material quality**, which enables the delivery of high-quality and healthy products to customers. Quality control of each stage of production is among the important tasks of the Quality Control Department.	**Continuous control and improvement of raw material quality** provides customers with tasty, healthy, high quality, products. Mróz Meat Plant has its own pig and cattle farms, which facilitates direct quality control of each stage of production.
2.	Delikatesy Mięsne Gzella **implements the company's code of values**, which states that human potential is the most important factor in development. In the hierarchy of the code, the most important place is occupied by: a) ensuring the highest quality of raw materials and products, b) partnership of all entities working together, which determines the effectiveness of their actions, c) care for the environment, which sets the framework for the functioning of all Gzella employees and those bound by contracts with Gzella Sp. z o.o.	Zakłady Mięsne Mróz SA **pursues the policy of**: a) ensuring the highest quality of raw material and products, b) partnership of all entities working together, which determines the efficiency of their operations, c) promotion of in-house utilization, d) innovative development directions of the Polish biogas usage – an opportunity to increase the profitability of biogas plants, e) development of the idea of a closed-loop bioeconomy.

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No.	Delikatesy Mięsne Gzella sp. z o.o.	Zakłady Mięsne Mróz S.A.
3.	Implementation of a transparent environmental policy: a) 3% annual reduction in water consumption, b) 3% annual reduction in electricity consumption, c) 5% annual reduction in municipal waste, d) 2% annual improvement in the quality of raw materials.	**Full information on the implementation of environmental policy and the construction of biogas plants:** a) reducing the cost of managing slaughterhouse waste, b) reduction of the nuisance of piggery operations by eliminating the fetor, c) constant and inexpensive source of substrates (mainly manure) from own farm, d) use of the heat generated to heat the biogas plant's fermenters, e) self-financing of the biogas plant, f) obtaining blue certificates.
4.	**Gzella company introduced innovations in food packaging** designed to increase barrier properties and extend shelf life of perishable products. It is important to reduce losses at the stage of industrial food production.	**Innovations in food packaging** by production optimization which allows to minimize the amount of unsold products, the only form of return of which is to undertake the „complaint process".
5.	**Stakeholders relations** builds and nurtures long-term relationships with its trading partners by establishing long-term contracts and negotiating mutually important terms and conditions.	**Stakeholders relations** continues long-term relationships with its trading partners, establishes long-term contracts, realizes vertical integration.

Delikatesy Mięsne Gzella sp. z o.o.

Delikatesy Mięsne Gzella sp. z o.o. priority activity is to reduce the enterprise's negative impact on the environment and strictly comply with the regulations in force in Poland regarding its protection. The scope of the company's activities is related to production processes that could have a negative impact on natural resources such as water, air, and land. Therefore, a key role is played by specialised teams for Environmental Monitoring and Analysis and systematic work on the introduction of safer production and storage technologies. Expenses related to the protection of nature and the environment of Delikatesy Mięsne Gzella sp. z o.o. can be divided into:

- expenses for pro-environmental investments, e.g., a modern plant that does not emit harmful exhaust fumes, a modern vehicle fleet, waste segregation, optimal use of bulk packaging, the introduction of paper bags and cloth bags instead of plastic bags throughout the Gzella Meat Delicatessen chain,
- fixed costs incurred by the company for the use of the environment, incurring monitoring and research costs,
- waste management fees.

Environmental efficiency expressed in the cultivation of stakeholder relations consists of the reduction of manufacturing raw materials, contributing to the operational cost reduction indirectly affecting the financial efficiency.

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Zakłady Mięsne Mróz SA

In 2013, Zakłady Mięsne Mróz in Borzęciczki, Wielkopolska, built a biogas plant for waste disposal. The operation of the biogas plant is part of the activities of the environmental policy of Zakłady Mięsne Mróz SA, the area of influence of which relates to activities in the economic and environmental dimensions. The effective management of slaughterhouse waste by external companies is cost-intensive because the disposal of 1 ton is 350 PLN. An in-house biogas plant offsets the problem of slaughter waste disposal. Residues from agri-food processing are treated as agricultural waste. The construction of a biogas plant after July 1, 2016, using substrate from agri-food processing, has a guaranteed reference price of 550 PLN for the production of 1 MW of "green energy" (Energianews, 2011). The environmental efficiency expressed in the construction of the biogas plant contributes to a decrease in the cost of waste disposal and a reduction in the operating costs and can lead to an increase in profitability (financial efficiency). Residents of Borzęciczki in Wielkopolska participated in study tours to other biogas plants inland and in Germany before the biogas plant was constructed to convince themselves of the absence of unpleasant odour. Introducing sustainable development principles in the food sector can not be done without the acceptance of a local community as beneficial of a biogas plant. The GV4+3 declaration fits in with the ongoing Europe 2020 strategy and EC's recommended closed-loop economy (Chyłek, 2016).

Expenditures related to the protection of nature and the environment of Mróz Meat Plants SA can be divided into:

- expenditures on environmentally friendly investments, e.g., a modern plant with no harmful emissions, modern vehicle fleet, waste segregation, optimal use of bulk packaging, segregation and disposal of slaughter raw materials,
- costs of exploitation and renovation of environmentally friendly installations, fixed costs incurred by the company for the use of the environment,
- incurring monitoring and research costs.

Conclusions

The results of the research contribute to the discussion on the reduction of air and water pollution by introducing the national program "Technological Foresight of Industry InSight 2030". The recognition of the development of environmental efficiency in the Polish food industry shall contribute to the accuracy of public institutional policies and financial support for this industry.

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The article's results made it possible to draw conclusions about the assessment of financial efficiency in terms of profitability and environmental efficiency on the example of the meat and poultry industry in Poland in 2010-2020. The values of the Net Return on Sales ratio for meat and poultry enterprises turned out to be statistically significant. To counteract the existing threats of the meat and poultry industry are pro-environment expenses which are leading to the reduction of raw materials losses, contributing to the reduction of operational costs indirectly affecting the financial efficiency.

The conclusions from the research can be presented in three ways.

In the context of the literature review:

- introduction of the concepts and definitions of efficiencies,
- systematisation of the greening process, eco-efficiency within the paradigm of sustainable development.

From the scientific point of view:

- on a hypothesis level (H_1): Financial efficiency in terms of profitability differentiates the examined groups of meat and poultry enterprises. H_1 has been positively confirmed,
- on a thesis level (T_1): The higher values of profitability ratios are, the higher environmental efficiency is. T_1 has been positively stated.

From the practical point of view:

- on a source basis: rationalisation of raw material use, reducing the amount of non-renewable raw materials, increasing the use of renewable raw materials, use of recycled raw materials,
- on a production process basis: implementation of new technological solutions and new production methods.

The limitations set a potential direction for future research. Firstly, the results can be distorted due to global challenges regarding the spread of the COVID-19 pandemic. Secondly, a systemic improvement in data collection can contribute to a more comprehensive assessment of environmental efficiency.

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Annex A

Table A1. Characteristics of financial efficiency indicators in the area of profitability

No.	Name of the ratio	Explanation of the profitability's ratio	Average values in the sector
1.	Operating profitability (OP) = (operating profit) / (sales revenue + other operating revenue)	The operating profitability ratio measures the relationship between profit (loss) on total operations and sales in value terms. The ratio takes into account other operating activities in the assessment of profitability, thus increasing or decreasing the profitability of the core business by a partial result achieved on other operating activities.	9.82
2.	Return on total capital (ROI) = Operating profit after tax / total capital ×100%	The return on investment ratio measures the effectiveness of a company's operations, as it estimates how much profit a company can count on by investing one monetary unit. Due to its versatility and ease of calculation, the ratio is often used to compare the profitability of several investments and can be expressed as a percentage or value.	The higher, the better
3.	Net return on sales (NRS) = net profit /(net revenue from sales of products, goods and materials + other operating revenue + financial revenue + extraordinary profits) ×100%	The return on sales ratio shows how much net profit remains in the company from sales. This means that thanks to the ratio, one can find out what profit is earned on each 1 monetary unit acquired from sales. The amount of the ratio depends to a large extent on the industry of the company and the length of the turnover cycle and the company's sales volume.	3.87%
4.	Return on assets (ROA) = net profit/total assets ×100%	The return on assets ratio, also called the return on assets ratio, informs about the company's ability to generate profits and the efficiency of asset management.	8.79%
5.	Return on equity (ROE) = net profit / equity ×100%	The return on equity ratio, also called the return on equity ratio, shows how much profit a company generates from the contributed equity.	14.85%

Source: author's work based on Bień (2011); Bragg (2010); Jaki (2012).

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STUDIES AND MATERIALS

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ANALYSIS OF THE TYPES AND EFFECTS OF POSSIBLE ERRORS IN THE IMPLEMENTATION OF ECOLOGICAL REUSABLE PACKAGING INTO E-COMMERCE USING FMEA

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ABSTRACT: One of the most important features of the e-commerce logistics process is its reliability. It is obtained by properly planning the process and then ensuring its course is in accordance with the developed plan and all procedures. As the data show, most problems appear at the stage of designing and preparing products and processes for implementation. Detecting potential causes of non-compliance can help prevent unwanted events from occurring. The aim of the article is to identify and assess the risk for the process and product in terms of the possibility of using reusable packaging in e-commerce logistics services provided by ARVATO Polska Sp. z o. o. with its registered office in Warsaw, taking into account preventive and corrective actions in relation to the risk. Through the use of research methodology in the form of risk mapping, 13 potential risk factors were identified, and recommendations were formulated to avoid and mitigate the effects of disruptions. Among the identified risk factors, the quality of the packaging itself, including the appropriate packaging material and the level of packaging flexibility, turned out to be the most important. The conclusions of the study may have practical applications to improve the functioning of cost-effective and environmentally friendly e-commerce logistics. The importance of these analyses increases in the assessment of innovative solutions that can be considered as the use of ecological returnable packaging in e-commerce logistics. Their goal is to identify and eliminate possible packaging failures on the market.

KEYWORDS: e-commerce, ecological packaging, supply chain, sustainable development

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Introduction

From the very beginning of life on Earth, man has influenced his environment. Drawing from the resources needed for life, he often had a negative impact on them, thus reducing the availability of goods on which he depended. Also, today, the rapid development of industry, as well as the increase in the population, entails degradation and pollution of the environment (Majerník et al., 2021). The constantly growing amount of waste generated has forced the public to become interested in pro-ecological activities, including in the field of resource management, environmental protection and waste management. The current trend is to minimise the risks closely related to waste (Karali & Shah, 2022; Szołtysek & Twaróg, 2017).

Concern for the quality of the environment has become an important element of marketing for many organisations, in particular in terms of shaping their image in public opinion. In the era of increasing competition between enterprises, traditional management tools, such as lowering production and logistics costs, improving the internal organisation of enterprises or even improving the quality of manufactured products, are no longer effective in the fight for market success (Sharma et al., 2020). On the other hand, the intensity of pollution caused by manufacturing and commercial activities is now reaching its maximum, thanks to the growing group of companies producing more and more products with ever shorter lifespans. At the same time, consumers increasing awareness of the deteriorating environment puts additional pressure on companies to include environmental considerations in their production and marketing plans (Block, 2009; Zhu & Shah, 2018).

Packaging performs important functions in the protection and advertising of a given product, and its importance has an increasing impact on attracting the customer's attention (Singh et al., 2019). Together with economic development and technological progress, they play an increasingly important role. Recycling and caring for the environment are very important issues these days. It is important that as little waste as possible ends up in the environment and that as much of it can be recycled and reused with proper treatment (Manavalan & Jayakrishna, 2019). Hence, extending the life cycle of packaging as a result of introducing reusable packaging and designing packaging, in accordance with the assumptions of the circular economy are increasingly treated as a priority in the development strategies of enterprises. Packaging is most often made of plastic, glass, metal and, increasingly, of paper, which is the easiest to recycle. It is also important that the packaging contains an exact description of what material it was made of so that the consumer can throw it into the appropriate waste container. More and more often, you can find packaging of new products that have been obtained from

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recycling, thanks to which less waste is released into the environment, which may pose a threat to both the environment and the human being. It is important to pay attention to the material from which the packaging is made and that the customer himself is aware that his product is sold at the right price and at the same time is environmentally friendly (Górniak & Bukowska-Piestrzyńska, 2020). Improperly disposed of packaging may pose a serious threat to the natural environment, i.e., emission of harmful substances into the atmosphere, water and soil pollution, chemical composition (especially heavy metals, harmful substances), overloading of landfills or consumption of resources (Granato et al., 2022; Korzeniowski et al., 2012).

The role of packaging is a very important aspect in the area of logistics and distribution because it is thanks to them that the product reaches the customer intact. In addition to the quality of workmanship, it is also important to improve the quality of environmental protection (Silva & Palsson, 2022). The sustainable development strategy allows for the introduction of measures to minimise the excessive depletion of natural resources in order to maintain the durability and self-sufficient development, and at the same time, ensures that the quality of life of the society is maintained at the same level. Thanks to such activities, companies care for the environment, the demand for natural resources is reduced, the amount of waste is reduced, and less pollution is emitted into the atmosphere. The use of reusable packaging or packaging that can be easily processed and recycled is cost-effective and competitive. Labelling packaging with symbols that show that they are environmentally friendly allows you to encourage and convince the customer to make more frequent purchases because he is more aware that thanks to such activities, he cares about the environment (Cooper & Gutowski, 2017).

According to the adopted thesis, the introduction of ecological reusable packaging for e-commerce is a strategic decision of the organisation from the point of view of the efficiency of supply chains. The aim of the article is to analyse the types and effects of possible errors in the process of implementing ecological reusable packaging in e-commerce logistics services using the FMEA method. Research questions were formulated for this specific purpose:

How to shape the decision-making process on the implementation of ecological reusable packaging in e-commerce services to reduce the frequency of risk factors as much as possible?

How to manage risk in e-commerce supply chains, taking into account not only the profitability of reusable packaging and the operational efficiency of chains, but also the increasingly difficult access to resources, climate change and social needs?

The issue of returnable unit packaging is at the initial stage of research projects. The systemic approach used by the authors in the study of reusable ecological packaging in the sustainable development of circular e-commerce

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contributes to reducing the research gap in this thematic area and provides practical implications for organizations in terms of risk management. Decisions related to the implementation of a new product – ecological reusable packaging – are burdened with numerous risk factors, both for the organization and stakeholders. Hence, the assessment, control and monitoring of risk with the use of decision-making tools is a manifestation of the organization's maturity and responsibility towards stakeholders, including the environment.

The research results presented in the article are part of the project implemented in 2021 under the research and development contract commissioned by Arvato Polska Sp. z o.o. with its registered office in Warsaw. The authors of the article present selected results of analyzes that were carried out for one of the research tasks of the project, i.e. the diagnosis of risk factors in the use of reusable ecological packaging in e-commerce logistics services[1].

Literature review

The efficient functioning of production and logistics processes results from the implementation of appropriate management concepts and taking actions to maintain the required quality standards throughout the supply chain (Lima-Junior & Carpinetti, 2020; Khan & Naeem, 2018). Quality and the way it is shaped is the basis for an effective organisational strategy that enables meeting customer expectations in terms of the quality of the products or services offered. The purpose of implementing specific concepts or management systems is to strive for continuous improvement of processes that allow to maintain an appropriate market position and adapt to changing environmental conditions. Quality, which is one of the elements subject to continuous improvement, plays a special role in this (Khan et al., 2020; Xie et al., 2019).

The literature on the subject of project management clearly identifies the most important criteria according to which the processes and effects of production implementation are assessed, such as time, costs, scope, quality and human resources (Wei et al., 2021; Abreu et al., 2022). Defined deadlines, compliance with the allocated budget, the project's purpose, and contractors' competencies and commitment to implementation are elements that require proper planning, scheduling and work patterns. Fulfilment of specific requirements determines the fulfilment of complex conditions of implementation: technical, functional and visual, which are related to the final effect of

1 Due to the applicable "data confidentiality" clause, the article presents selected results of the analyses.

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the project and prove its quality. These elements form the main group of success factors, at the same time being the basis for achieving the goal and customer satisfaction (Pham, 2020).

The FMEA method was developed in the USA during the preparations for the Apollo program in the first half of the 1960s. Its purpose was to support the analysis of space systems designs (rockets, flight control systems) and the production processes of these components in order to identify potential system failures as a result of adopting incorrect assumptions or design solutions. The successful flight to the Moon was an effective validation of the method and a recommendation for its use in other areas (Tsai et al., 2017). The FMEA method is based on the analytical determination of cause-and-effect relationships for the formation of potential product defects and taking into account the criticality factor (risk) in the analysis. Its goal is to consistently and systematically identify potential product/process defects and then eliminate them or minimise the risk associated with them (Moreira et al., 2020).

FMEA is a method of identifying and preventing problems related to the analysed process before its implementation (Carbone & Tippett, 2004). Focuses on preventing defects in the process or product, increasing process safety, project financial security, occupational safety and environmental protection (Chauhan et al., 2018). The FMEA method is used to analyse the types and effects of possible errors that may occur in the design and development phase. Thanks to the use of this method, it is possible to subject the product or process to further analyses and then, based on the obtained results, to introduce improvement actions (i.e. all kinds of corrections, and new solutions) that will contribute to the effective elimination of sources of defects. The most important benefits related to the implementation of the FMEA analysis include (Casado et al., 2023; Velasquez & Lara, 2017):

- continuous improvement of products and production processes,
- continuous elimination of potential sources of defects,
- reduction of production costs,
- reducing the number and costs of complaints,
- increase in product quality,
- greater reliability, and thus – greater customer confidence.

Thanks to the FMEA method, it is possible to continuously improve the product/process by subjecting it to subsequent analyses and, based on the results obtained, introducing new corrections and solutions that effectively eliminate sources of defects and provide new ideas for improving product properties. It can be used for very complex processes, both in mass and unit production (Almannai et al., 2008; Kumru & Kumru, 2013).

With FMEA, the possibilities are improbable, but without FMEA, the possibility is only probable (Oakland, 2014). One of the key factors determining

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the effectiveness of production and service activities are logistics processes, consisting of the physical flow of goods through subsequent phases of economic activity. The logistics process is often a service process, auxiliary to the basic process, satisfying a specific need – the production of a specific good. The quality and timeliness of the implementation of such supporting logistic processes determine the quality, timeliness and costs of the basic manufacturing process carried out in the system of business activity of the enterprise (Jüttner, 2005; Ennouri, 2013; Bai et al., 2018). Logistics process management is a process of comprehensive planning, organisation and control of logistics processes and activities carried out to ensure efficient and effective flow of materials, semi-finished products and final products in enterprises as well as logistics and supply chains (Colicchia & Strozzi, 2012).

The analysis of logistics processes is not a new research issue, but it is gaining special importance in the modern market, primarily because it is a factor in the fight against competition (Castillo, 2023; Hu et al., 2020). Knowledge of the logistics system and the processes taking place in it is of great importance for the efficient and effective logistics operation of any organisation. The functioning of companies on global markets requires effective logistics, which is why it is necessary to constantly search for tools to improve its processes (Liu et al., 2023; Birkel & Hartmann, 2020).

Materials and methods

When identifying and assessing the risk, an FMEA analysis was performed, illustrated with a risk matrix. The conducted FMEA analysis covers such areas of reusable packaging design and marketing as: technological, time, location, economic, economic, social and environmental areas. The risk analysis took into account the conditions related to the development and implementation of ecological reusable packaging for the fashion industry, affecting the transformation of supply chains in e-commerce. The review of the literature shows that this is a new area of analysis, which is in the initial phase of research. In order to obtain theoretical saturation, the study used conclusions from observations during two study visits to distribution centres carried out in 2021 and the results of structured interviews. Interviews with experts were conducted as part of 3-panel meetings in February – June 2021. The professional knowledge and practical experience of the speakers were used to assess the substantive correctness of the measurement (Zhu et al., 2021). The group of experts included representatives of the Arvato management board, members of the management staff and managers responsible for the implementation of e-commerce orders at various stages of the supply chain.

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The research procedure consisted of four stages.

The first stage focused on assessing the severity of the problem. Individual activities were analysed in the context of developing ecological reusable packaging for use in e-commerce logistics in terms of the process and product itself. Design FMEA (DFMEA) and process FMEA (PFMEA) are the most common types of FMEA analysis that have been incorporated into the ISO 9001 quality system (Wang, 2018). In order to assess the significance of the problem, the potential type of defect along with its effect was determined. There are different scoring methods in the risk assessment and management literature (Zhu & Shah, 2018). Based on the scale proposed by Liu et al. (2013), the probability of a defect (S) was rated on a scale of 1 to 10 (Liu et al., 2018). An improbable situation was assigned a value of 1, and a very probable situation a value of 10.

The second stage is concerned with determining the cause of the defect along with determining its value. Also, in this case, the cause of the failure was determined on a scale of 1 to 10. The value of 1 was assigned to a low probability situation (no possibility of failure) and 10 to a situation with a very high probability of the occurrence of a defect (O).

In the third stage, preventive actions / ongoing control of e-commerce logistics services were defined, and the detection parameters (D) were estimated, which were assigned values on a scale from 1 (very high importance – reliable detection of the defect) to 10 (very low importance – detecting the defect is difficult or impossible).

The fourth stage of the FMEA analysis consisted in determining the RPN parameter. Assigning the above parameters to the FMEA sheet made it possible to determine the RPN risk priority number, which was calculated according to the following formula:

$$\text{RPN} = \text{Severity (S) x Occurrence (O) x Detection (D).} \tag{1}$$

RPN allows you to determine which threats carry the greatest risk and indicates the hierarchy in which order preventive actions should be initiated. The research was aimed at demonstrating the relationship between determinants, sources of risk, and the implementation of ecological reusable packaging for use in e-commerce logistics services. During the analysis, the value of RPN=100 was established, below which the impact of potential risk factors on the packaging development process is insignificant.

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Results of the research

On the basis of previous analyses and selection of conditions as well as developed Ishikawa diagrams (Motowidlak & Tokarski, 2022), an FMEA analysis of ecological reusable packaging for use in e-commerce logistics services was carried out in terms of process (understood as e-commerce logistics services using ecological reusable packaging) and product (understood as ecological reusable packaging. The results are presented in Table 1.

Table 1. FMEA analysis sheet for the use of reusable packaging in e-commerce logistics

No.	Potential type of fault	Potential effect of the defect	Severity (S)	Potential cause of failure	Occurrence (O)	Preventive actions/ Ongoing control of e-commerce l ogistics services	Detection (D)	RPN
1	Perishable packaging material	Damage to the goods	8	Selection of material that does not meet transport requirements	8	Adjusting the transport space of the vehicle by arranging shipments in racks specially designed for this purpose	6	384
		The packaging may tear if there are sharp objects inside	8	The packaging material is unstable, no filler	5	Evaluation of the quality of returnable packaging – individual and collective (system changes)	6	240
2	Limited package rigidity	Materials in the packaging move even with the use of filler, which affects the unsightly appearance of the order	6	Choosing the right packaging material	6	Pilot study using reusable packaging Identification of real disturbances, assessment of process efficiency	8	288
3	Non-permanent closure	Due to the dimensions of the package, the zipper may jam in the corners when closing	7	Packages are not scalable	4	Taking special care	6	168
		The plastic zipper in the envelope may not be durable after prolonged use	7	Unsuitable material	6	Choosing the right material	5	210
4	Delicate handle	Detaching the handle from the packaging	7	Unsuitable/ perishable material	6	Choosing the right material or making the handle functional	6	294

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A relatively lower probability of occurrence, but also associated with the occurrence of significant consequences, was indicated in the case of packaging susceptibility to dirt, non-permanent closure, impractical sealing and non-durable handle. The average level of probability of occurrence and risk effects for activities related to the problem of scanning the label and its insertion or removal from the place intended for this, the lack of an appropriate packing station, as well as the lack of liability procedures for packaging damage at a given stage were determined.

For the Premium packaging process, a low probability of occurrence and effects was indicated. Low probability, but with an increasing tendency in terms of consequences, was noted in terms of their impact on the level of customer loyalty towards the company. The risk matrix is presented in Table 2.

Table 2. Risk matrix of using reusable packaging in e-commerce logistics

After-effects	High		• Perishable packaging material • Limited package rigidity • Incorrect packaging size for the product • Susceptibility of the packaging to dirt • Non-permanent closure	Perishable packaging material Limited package rigidity
	Medium	Decreased customer loyalty to the company	• Label scanning problem • The courier label does not fit in the designated area • Lack of a suitable packing station • No entity responsible for packaging damage at a given stage	
	Low	Complicating the premium packaging process		
		Low	Medium	High
			Probability	

* Scale: 0-1 none, 2-3 low, 4-5 medium, 6-9 high

The conducted diagnosis of the area of potential threats in the project allows us to draw the following conclusions and formulate the following recommendations. 13 potential risk factors were indicated, i.e. unstable packaging material, limited packaging rigidity, unstable closure, unstable handle, impractical closure, incorrect packaging size for the product, susceptibility to dirt, the problem with scanning the label, courier label does not fit in the designated place, the complexity of the Premium packaging process, the lack of an appropriate packaging station, reduced customer loyalty

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towards the company, as well as the lack of an entity responsible for packaging damage at a given stage. The most important of these turned out to be the quality of the packaging itself, including the appropriate packaging material and the level of packaging flexibility. In order to prevent damage to the goods during transport, it is recommended to select a material that meets the transport requirements, as well as to adjust the transport space of courier vehicles by placing shipments on specially designed racks.

In the case of products moving inside the packaging, even despite the use of filler, which affects the unsightly appearance of the order, it is recommended to choose the appropriate packaging material (paper pulp, foam plastic, corrugated or proposed cardboard), e.g., other lightness, physical and chemical resistance related to with disinfection, unlike corrugated cardboard packaging, it is more durable and less susceptible to damage during transport, fully recyclable, reusable. Printing the QR code on the packaging (using a dynamic link) will allow you to opt out of shipping labels and change the destination URL for subsequent customers using reusable packaging.

Suggested examples of risk mitigation solutions in the e-commerce supply chain using sustainable, reusable packaging could be avoidance, control, collaboration and flexibility. They should be included in strategic and tactical activities that can increase their effectiveness in mitigating potential threats to the supply chain and e-commerce in accordance with the assumptions of sustainable development, as confirmed by research (Yousefi & Tosarkani, 2022).

Conclusions

Taking into account the adopted main objective and research questions, the results of the conducted analyses indicate several important findings confirming the accuracy of the thesis.

Based on the research results presented in the article, it can be concluded that the improvement of the quality of e-commerce logistics services with the use of ecological returnable packaging is a reflection of the efforts of Arvato Polska, based in Warsaw, to implement environmentally friendly and economically effective solutions. It is recommended to pay due attention to the area of contact with individual customers and build their loyalty towards the company. Lack of or too slow a pace of acceptance of new packaging by potential individual customers may reduce their loyalty to the brand. The essence of this issue is presented in their research, e.g. Zhu et al. (2021). The phenomenon of excessive consumption is characteristic of modern society, it concerns each of us, and the consumer lifestyle is becoming more and more common. Limited resources force us to look for the optimal solution to

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achieve maximum benefits from the consumption of both food and clothing. In the theory of the consumer, it is assumed that he is a rational being who, when making decisions, strives to achieve the greatest possible benefits that can be achieved from the consumption of goods under given conditions (Abdelradi, 2018). A rational consumer bases the decision-making process on the principle of optimisation, when buying a specific product or service, he has individual preferences. With the growing popularity of e-commerce, the potential consumer began to look for new solutions that would allow him to save not only money but also time with due care for the environment (Mason et al., 2022). Building a relationship with an individual customer is particularly important when introducing new packaging to the market and withdrawing the packaging to which he has become accustomed from the offer. An important solution is the introduction of a loyalty package for regular and new stakeholders, e.g. in the form of requests for orders and returns, collecting loyalty points that allow you to reduce the amount of the deposit and take advantage of promotions. The implementation of Smart Packaging tools will stimulate consumer loyalty, increase their purchasing decisions and increase the transparency of product production.

The observations during the study visits and the conclusions of the study show that the greatest impact on the development of ecological reusable packaging for use in e-commerce logistics has technological aspects, primarily related to the strength of the packaging material, its size, stiffness, durability and purity. Particular attention should be paid to the durability of the closure of the package, as well as the practicality of using the seal and the handle. Other aspects affecting the risk management of the analysed process are the problems associated with scanning the label, the lack of an appropriate packing station, as well as the lack of procedures in the area of responsibility for packaging damage at a given stage of transport. Less important, but requiring verification and control, are the risk factors related to the complexity of the Premium package packaging process and the reduction of customer loyalty towards the company.

The originality of the conducted research was achieved through their measurable character. Potential risk factors identified with the FMEA method and formulated recommendations for avoiding and mitigating the effects of disruptions can be useful in improving the functioning of cost-effective and environmentally friendly e-commerce logistics. One of the key challenges in the field of future research directions may be the study of interrelationships between individual risk factors using the DEMATEL method (Tsai et al., 2017). The article does not formulate unambiguous strategies and tactics of solutions aimed at reducing the identified threats. A prerequisite for successfully completing such a task is the availability of a comprehensive and accu-

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rate dataset that includes more fashion case studies. The results of this analysis indicate that this may pose another challenge for future research.

The contribution of the authors

Establishing the concept, D.T. and U.M.; establishing research methods, D.T. and U.M.; creating text, D.T. and U.M.; analytical description of the phenomenon, D.T.; implementation of the research idea, D.T. and U.M.; critical assessment, D.T.; data collection, D.T. and U.M.; data analysis and interpretation, D.T. and U.M.; development of research results, D.T. and U.M.; review of the literature, D.T. and U.M.

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LIFE CYCLE ASSESSMENT OF GLASS/ POLYESTER LAMINATES USED IN THE SHIPBUILDING INDUSTRY AND ITS FIRE BEHAVIOR

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ABSTRACT: The aim of this study is to assess the environmental performance of the manufacturing process of glass/polyester laminates as well as estimate their fire behaviour and smoke release. The Life Cycle Assessment was conducted according to the ISO14040/44 standard by using the CML-IA 2000 Baseline Midpoint method. The cone calorimeter study was conducted using a cone calorimeter method according to ISO 5660. The tests were performed under 25 kW/m^2 heat flux 50 kW/m^2. The results showed that according to the requirements of the Fire Test Procedure (FTP) Code examined, laminates in this form cannot be used in some applications. The LCA study showed that the highest impact is attributed to marine aquatic ecotoxicity (88.3%), with the highest contribution of the unsaturated polyester resin and the glass fibre.

KEYWORDS: glass/polyester laminates, life cycle assessment, cone calorimeter, Fire Test Procedures (FTP) Code

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Introduction

Fiber reinforced composites, due to their high mechanical properties and durability, have been commonly used over the last few years. However, its manufacturing process and poor recyclability are the cause of a concern (Gkoloni & Kostopoulos, 2021). One of the main contributors to environmental pollution is manufacturing, especially in terms of air pollution (Rödger et al., 2021). The life cycle assessment (LCA) is a tool for the integration of environmental concerns into the product development (Segovia et al., 2019). This method also allows the identification of critical points in the life cycle and the selecting of the areas that may be improved (Flasińska et al., 2018). It addresses the complex interactions between products and the environment (Kukfisz & Maranda, 2014). The assessment of the environmental impact of the manufacturing process of glass/polyester laminates will allow us to identify the most damaging factors within the concerned impact categories and examine possibilities for their improvement.

Fire safety is one of the major issues of ships. Ongoing advances in fire detection technology, fire suppression equipment and firefighting techniques can minimise fire damage. However, materials used for the construction and other elements of ships can also affect the fire risk. Metallic materials are widely replaced by non-metallic polymers, which may release a lot of heat, smoke and toxic gases and thus reduce fire safety (Hiltz, 2011). Therefore, materials used in shipbuilding are strictly regulated by national standards and requirements. The aim of this study is an analysis of the heat and smoke release of selected laminates applied in shipbuilding and a comparison with existing requirements for fire-restricting materials for high-speed craft.

An overview of the literature

Composites were introduced to the marine industry after World War II, and they are used in all areas of the marine sector up to the present time. Because salt and seawater may be extremely damaging to steel, aluminium and wood used for watercraft, composites were designed to solve occurring corrosion problems. Due to the high corrosion and fatigue resistance of thermoset composites, their application may significantly reduce maintenance requirements.

In addition to mentioned corrosion resistance, other benefits of thermosetting resins are good strength-to-weight ratio, dimensional stability, lighter weight compared to materials traditionally used before, sound baffling and high levels of acoustic transparency, the possibility to design complex shapes and greater stiffness and stability (Rubino et al., 2020).

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Currently, laminates are considered a classic structural solution in smaller ships and boats. In larger vessels, yachts and boats, composites are used for the main structural elements. However, in ships, their application is limited to various structural and non-structural elements (Bolf et al., 2020).

The diversity of matrices and reinforcements enables the manufacture of composites with specific properties suitable for their application. However, the most commonly used materials for marine composites are unsaturated polyester resin as a matrix and E-glass fibres as a reinforcement. Other thermosetting resins, such as phenolic, epoxy and vinyl-ester resins and thermoplastic polymers, such as polypropylene, polyamide, polyester and PEEK (polyether ether ketone), also may be used as a matrix. For the reinforcement, glass, carbon and aramid fibres are the most often used (Barsotti et al., 2020).

Due to the fact that glass/polyester laminates are entirely synthetic and contain petroleum-based thermoset polymer matrix, they are non-biodegradable and may pose an environmental hazard. They may contribute to global warming and promote toxic environmental effects (Ead et al., 2021).

Glass/polyester laminates, besides their various advantages, also pose a high fire hazard. Its flammability is mainly ascribed to the thermal decomposition of a polymer matrix because glass fibres are non-combustible. Glass/polyester laminates produce a lot of heat and flammable, volatile compounds such as carbon monoxide, methane and other low molecular weight compounds when exposed to high temperatures. Improving the flame retardancy of these materials is not obligatory; however, in some applications with high flammability requirements, a proper level of fire safety needs to be achieved (Dowbysz et al., 2021).

The International Convention for Safety Of Life At Sea (SOLAS), established within The International Maritime Organization (IMO), focuses on the mitigation of risks at sea in order to protect human life. SOLAS provides necessary mitigation measures by identifying and examining risks. Chapter II-2 of SOLAS, with the associated supporting Fire Safety Systems (FSS) Code and Fire Test Procedure (FTP) Code, focuses on the fire risk (Joseph & Dalaklis, 2021).

The FTP Code refers to various fire test procedures, including non-combustibility test, smoke and toxicity test, tests for A, B, and F class divisions, test for fire door control systems, test for surface flammability, test for vertically supported textiles and films, test for upholstered furniture, test for bedding components, and test for fire-restricting materials and division of high-speed craft. Part 10, Appendix 2, describes fire test procedures for heat release, smoke production and mass loss rate for materials used for furniture and other components of high-speed craft according to ISO 5660-1 Reaction-to-fire tests – Heat release, smoke production and mass loss rate – Part 1:

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Heat release rate (cone calorimeter method) and ISO 5660-2 Reaction-to-fire tests – Heat release, smoke production and mass loss rate – Part 2: Smoke production rate (dynamic measurement)(International Maritime Organization, 2012). The criteria for fire-restricting materials are as follows:

- the time to ignition should be greater than 20 s,
- the average heat release rate over a 30 s period of time should be 60 kW/m^2 at the maximum,
- the total heat release should be 20 MJ/m^2 at the maximum,
- the average smoke production rate should be 0.005 m^2/s at the maximum.

Materials and research methods

Preparation of glass/polyester laminates

The glass/polyester laminates with a top gelcoat layer were prepared using a Norpol pre-accelerated orthophthalic unsaturated polyester resin (UPR), polyester gelcoat BUFA GC-S green or Norpol SVG white, Luperox organic peroxide as the hardener, and 450 g/m^2 fibreglass mat.

The unsaturated polyester resin undergoes free-radical polymerisation with styrene, which is the resin's reactive solvent - crosslinking monomer. Individual stages of the process of obtaining glass/polyester laminates (lining of the gelcoat layer and application of the resin layer with the mat) were performed before the unsaturated polyester resin started to crosslink, i.e. within 25-45 min.

The laminates were prepared manually using the contact method of lining the gelcoat layer and then applying the resin to the individual layers of the glass mat. Polyethylene terephthalate film was placed on the cleaned glass mould as a release layer. Five fragments of glass mat with dimensions of 250 mm x 250 mm were prepared. An appropriate amount of hardener was added to the polyester gelcoat. Then the mixture was vented in a glass desiccator under 20 mbar pressure for 2 min to remove air bubbles. The gelcoat was applied directly onto the terephthalic film using a doctor's blade. A gelcoat layer of 0.75 mm thickness was obtained. It was cured for 60 min at a temperature of 22°C. Next, the first fragment of the glass mat was placed on the cured gelcoat layer and saturated with resin with an appropriate amount of hardener. After thorough saturation, another layer of the mat was applied. The procedure was repeated for each of the 5 glass mat fragments. After the last one was saturated, the entire laminate was covered with terephthalic film, followed by a glass plate, and loaded to form the laminate. Spacers 3 mm high were used between the glass plates. The laminate was left to cure and

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season for 24 hours at a temperature of 22°C. The 3 mm thick crosslinked polyester-glass laminates with an outer gelcoat layer were obtained. The laminates were cut into shapes suitable for testing. The laminate formulations are shown in Table 1.

Table 1. Formulations of laminates

Sample	Gelcoat [g] Norpol SVG	Gelcoat [g] BUFA GC-S	Hardener [g]	UPR [g] Norpol 1	UPR [g] Norpol 2	Hardener [g]	Fiberglass [g]
Laminate 1	56.30	-	1.10	261.30	-	5.33	140.60
Laminate 2	56.30	-	1.10	-	261.30	5.33	140.60
Laminate 3	-	56.30	1.10	261.30	-	5.33	140.60

The LCA method and tool

The evaluation of the potential environmental impacts of manufacturing of glass/polyester laminates was performed using life cycle assessment (LCA) methodology according to the ISO14040/44 standard. The LCA analysis consisted of four interrelated steps: goal definition and scope, inventory analysis, impact assessment and improvement assessment. The LCA analysis was modeled in SimaPro LCA software version 9.1 (PRé Sustainability B.V, Netherlands).

Table 2. Midpoint impact categories for the CML Baseline method

Name of the impact category	Abbreviation of the impact category	Unit
Abiotic depletion potential	ADP	kg Sb
Abiotic depletion potential (fossil fuels)	ADP (FF)	MJ
Global warming potential	GWP100a	kg CO_2
Ozone layer depletion potential	ODP	kg CFC-11
Human toxicity potential	HTP	kg 1,4 DCB
Freshwater aquatic ecotoxicity potential	FAETP	kg 1,4 DCB
Marine aquatic ecotoxicity potential	MAETP	kg 1,4 DCB
Terrestrial ecotoxicity potential	TETP	kg 1,4 DCB
Photochemical oxidation potential	POF	kg C_2H_4
Acidification potential	AP	kg SO_2
Eutrophication potential	EP	kg PO_4

Source: authors' work based on Di Giuseppe et al. (2020).

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The CML-IA method developed by the Center of Environmental Science of Leiden University in The Netherlands was applied in this study to assess the environmental load of the glass/polyester laminates over the whole life cycle. The CML-IA Baseline method elaborates the problem-oriented (midpoint) approach. All impact categories in the CML Baseline method defining the environmental profile are related to the 11 recommended baseline indicators presented in Table 2.

The purpose of this LCA study is to assess and quantify the environmental impact of the manufacturing process of glass/polyester laminates used in the shipbuilding industry. The functional unit is defined as the manufacturing of a 250 mm × 250 mm × 3 mm laminate plate. For the scope of the study a "cradle to gate" LCA is carried out. The system boundaries are presented in detail in Figure 1.

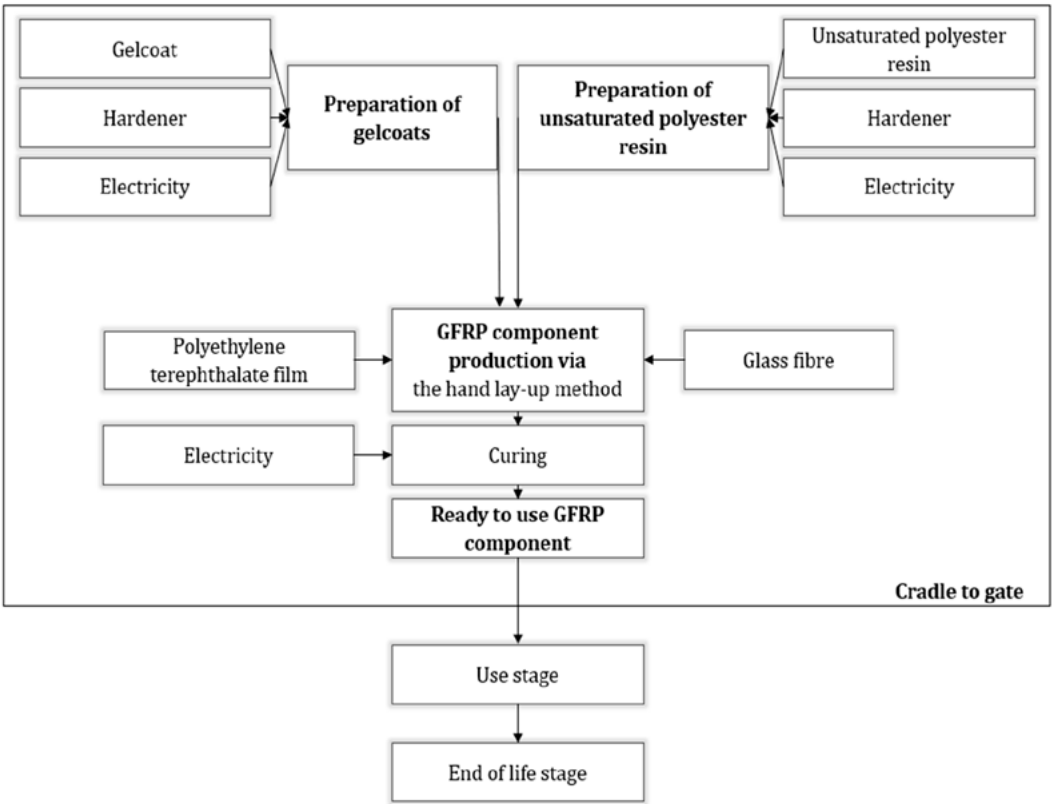

Figure 1. System boundaries for glass/fibre polyester laminates

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The LCA was based on primary data from the laboratory scale experiments, where the optimisation of power and resources was not straightforward. In an industrial scale, the energy consumption and environmental load of the manufacturing process of glass/polyester laminates will be lower. The raw materials were orthophthalic unsaturated polyester resin (0.261 kg), glass fibre (0.140 kg), polyethylene terephthalate film (0.108 kg), methyl ethyl ketone peroxide (0.006 kg) as well as gelcoat (0.056 kg). Gelcoat was modelled using 0.75 kg isophthalic acid-based UP resin, 0.1 kg of titanium dioxide, 0.05 kg of aluminium hydroxide, 0.05 kg of feldspar, 0.05 kg of calcium carbonate and 0.02 kg of chemical, organic. Manufacturing processes involved the cutting of the glass fibre and mixing of the gelcoat and the hardener, venting of the gelcoat mixture - electricity for the pump to achieve 20 mbar (consuming 0.037 kWh of electricity), laminating via the hand lay-up, conditioning of chamber (24 hours, 22°C, consuming 252 kWh of electricity) as well as cutting of the laminate (consuming 0.325 kWh of electricity). The functional unit of 1 kg of glass/polyester laminate was chosen as a representative of the laboratory-scale experiments.

The cone calorimeter test

Fire behaviour was assessed on a cone calorimeter (Fire Testing Technology, East Grinstead, UK) according to ISO 5660-1:2015 Reaction-to-fire tests – Heat release, smoke production and mass loss rate – Part 1: Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement). The test specimens (100 mm x 100 mm x 5 mm) were exposed horizontally to an external heat flux of 25 kW/m^2 and 50 kW/m^2. Spark igniter was used to ignite the pyrolysis products. Measurements were conducted in three repetitions.

Results and discussion

The Life Cycle Assessment

The Life Cycle Impact Assessment (LCIA) was carried out for a glass/polyester panel using SimaPro 9.1 according to data obtained from the inventory analysis.

Table 3 presents the results obtained using the CML Baseline method.

The Figure 2 presents the relative contributions of material production to each impact category.

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Table 3. LCIA results were calculated from the CML Baseline method

Impact category	Unit	PTFE film	Gelcoat	UPR	Hardener	Glass fibre	Electricity	Total
ADP	kg Sb eq	7.24E-14	3.41E-14	1.73E-13	1.29E-15	1.73E-13	3.72E-12	4.17E-12
ADP (fossil fuels)	MJ	2.33E-13	1.18E-13	6.62E-13	1.02E-14	1.17E-13	6.19E-11	6.31E-11
GWP100a	kg CO_2 eq	6.65E-14	3.76E-14	1.87E-13	2.04E-15	5.84E-14	3.57E-11	3.6E-11
ODP	kg CFC-11 eq	1.83E-16	2.80E-16	1.65E-15	7.77E-18	3.17E-16	8.91E-14	9.15E-14
HTP	kg 1,4-DCB eq	3.74E-14	5.58E-14	3.44E-13	6.83E-16	4.39E-14	9.60E-12	1.01E-11
FAETP	kg 1,4-DCB eq	3.15E-13	2.20E-13	9.58E-13	6.67E-15	2.60E-13	1.45E-10	1.46E-10
MAETP	kg 1,4-DCB eq	2.84E-12	2.60E-12	8.99E-12	5.54E-14	4.12E-12	2.37E-09	2.39E-09
TETP	kg 1,4-DCB eq	1.02E-14	6.25E-15	3.12E-14	1.63E-16	1.08E-14	7.27E-12	7.33E-12
POF	kg C_2H_4 eq	9.09E-15	3.78E-14	2.19E-13	2.62E-16	8.03E-15	3.56E-12	3.83E-12
AP	kg SO_2 eq	4.53E-14	4.19E-14	1.43E-13	1.13E-15	6.75E-14	2.71E-11	2.73E-11
EP	kg PO_4 eq	2.69E-14	2.31E-14	1.16E-13	7.13E-16	3.98E-14	2.59E-11	2.61E-11

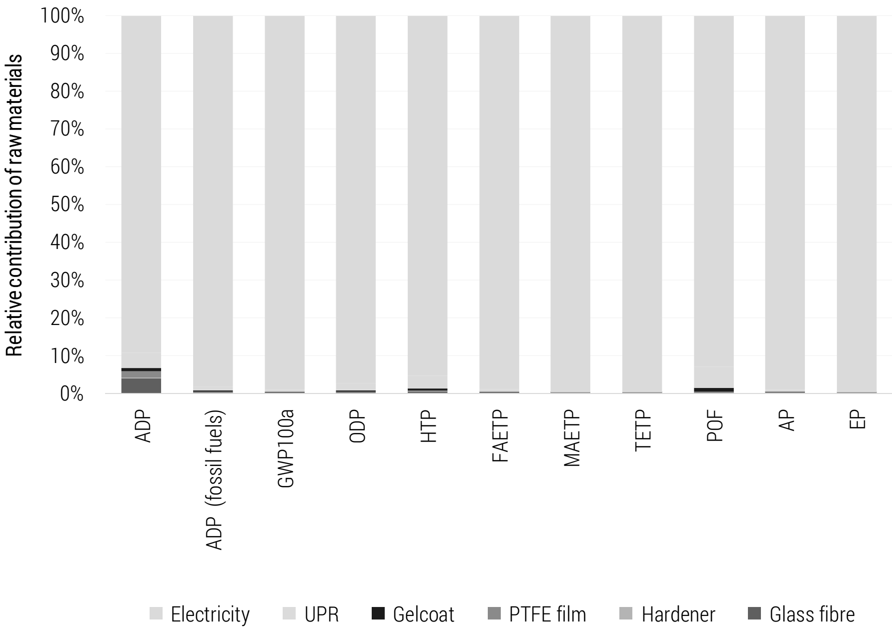

Figure 2. Relative contributions of material production [%] to each impact category

For all impact categories, electricity has the highest contribution (89% and above of the overall impact), and the hardener has the lowest contribution (0.03% and less of the overall impact). For each impact category the authors examined the most impacting materials.

The abiotic depletion of resources was considered as the loss of availability of natural elements (ADP) and as the loss of the availability of fossil fuels (ADP (fossil fuels)) (Van Oers et al., 2002).

ADP is the impact category with the highest contribution of UPR (1.73E-13 kg Sb) and glass fibre (1.73E-13 kg Sb), standing for the 4.14% each of the overall impact. In comparison, the contribution of the UPR and glass fibre to ADP (fossil fuels) is significantly lower (1.05% and 0.19%, respectively, of the overall impact). Lower values of ADP (fossil fuels) comparing to ADP were observed also for the PTFE film, gelcoat and hardener. Moreover, the glass fibre, PTFE film and hardener have the highest relative contribution to ADP among all impact categories.

The global warming potential is a category quantifying the influence of energy technologies on the climate (Lan & Yao, 2022). The highest impact is observed for the UPR (1.87E-12 kg CO_2). Significantly lower values of GWP100a were observed for the PTFE film (6.65E-14 kg CO_2) and glass fibre (5.84E-14 kg CO_2). The hardener and the gelcoat have the lowest contribution of the 0.11% of the overall impact.

The reduction of an ozone layer caused by the halocarbons is represented by the ozone layer depletion potential (Farinha et al., 2021). The UPR is the material that contributes the most to the ODP (1.65E-15 kg CFC-11). It is responsible for 1.8% of the overall impact. Other materials, including gelcoat, glass fibre and PTFE film, have HTP values of 3.17E-16, 2.8E-16 and 1.83E-16, respectively.

The impact of the chemicals released into the environment on the human health, based on their toxicity and dose, is the human toxicity potential (Hertwich et al., 2001). The obtained HTP values of materials are high comparing to other impact categories. The most impacting UPR has a HTP value of 3.44E-13 kg 1,4-DCB (3.41% of the overall value). The gelcoat, glass fibre and PTFE film cause 1.36% of the overall impact.

The highest impact to the freshwater aquatic ecotoxicity is observed for the UPR (9.58E-13 kg 1,4-DCB), standing for the 0.65% of the overall impact. Significantly lower values of FAETP were observed for the PTFE film (3.15E-13 kg 1,4-DCB), glass fibre (2.60E-13 kg 1,4-DCB) and gelcoat (2.20E-13 kg 1,4-DCB).

The impact of the toxic substances on the marine ecosystem is described by the marine aquatic ecotoxicity potential (Heijungs & Ligthart, 2004). The MAETP values are similar to those obtained for the TETP category, with a slight decrease of the UPR impact (from 0.43% to 0.38% of the overall

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impact) and slight increase of the glass fibre impact (from 0.15% to 0.17% of the overall impact). Moreover, the electricity has the highest relative contribution to MAETP among all impact categories.

The impact category that describes an adverse effect of toxic substances on the terrestrial ecosystems is a terrestrial ecotoxicity potential (Abdou et al., 2020). The most impacting is the UPR which implies a 0.43% of the overall impact (3.12E-14 kg 1,4-DCB). A hardener and a gelcoat have the lowest contribution of 0.09% of the overall impact.

The photochemical oxidation potential is related to the generation of the photochemical or summer smog by volatile organic compounds and NOx (Bałdowska-Witos et al., 2021). The UPR and gelcoat cause the 6.71% of the overall impact (2.19E-13 kg C_2H_4 and 3.78E-14 C_2H_4 respectively). Moreover, the gelcoat and the UPR have the highest relative contribution to POF among all impact categories.

Acidification is caused by the substances that supply or release the hydrogen ions or promote the leaching of the anions. The occurring increase of the acidity induce environmental problems, e.g. the acid rain (Jacob-Lopes et al., 2021). The AP is the impact category with the highest contribution of UPR and glass fibre (0.52% and 0.25% of the overall impact respectively). The lowest AP of 1.13E-15 was observed for the hardener (0.04% of the overall impact).

The most prevalent water quality drawback is an aquatic eutrophication (Berberich et al., 2019). The eutrophication is caused by the increased availability or usage of nutrients, which increases primary productivity. The main controlling nutrients are phosphorus and nitrogen (Hupfer & Hilt, 2008). The UPR has the highest EP of 1.16E-13 kg PO_4 eq. (0.44% of the overall impact). The lowest EP is observed for the hardener (7.13E-16 kg PO_4), the gelcoat (2.31E-14 kg PO_4) and the PTFE film (2.69E-14 kg PO_4).

The obtained results showed that the marine aquatic ecotoxicity potential is the main impact factor of the manufacturing process of glass/polyester laminates. It accounts for the 88.3% of all environmental impact indicators. Significantly lower impact is observed for the freshwater aquatic ecotoxicity, abiotic depletion (fossil fuels), and global warming potentials accounting for the 5.4%, 2.3% and 1.3% of all impact categories.

The cone calorimeter test results

Cone calorimeter tests provided data on the combustion behavior of laminates under real fire conditions. Mean values of the three measurements of parameters including time to ignition (TTI), peak heat release rate (pHRR), time to pHRR (t_{pHRR}), heat release rate at 180 s after ignition (HRR_{180s}), total heat release (THR), total smoke release (TSR), smoke extinction area (SEA), yield of CO (CO-Y) and residue yield at 1200 s are summarised in Table 4.

Table 4. Cone calorimeter data of laminates

Sample	Irradiance [kW/m²]	TTI [s]	pHRR [kW/m²]	t_{pHRR} [s]	HRR_{180s} [kW/m²]	THR [MJ/m²]	TSR [m²/m²]	SEA [m²/kg]	CO-Y [kg/kg]	Residue Yield [%]
Laminate 1	25	42	120.08	240	117.02	30.1	116.5	26.4	4.359	27.80
Laminate 2		64	101.52	254	97.78	24.2	123.6	31.8	4.978	31.33
Laminate 3		49	120.19	70	119.28	29.5	78.1	18.3	4.577	27.96
Laminate 1	50	12	162.97	176	161.95	33.9	101.5	24.6	3.585	38.35
Laminate 2		22	142.03	196	140.45	28.3	75.2	16.7	5.064	29.94
Laminate 3		14	182.44	144	78.43	27.9	109.3	24.4	4.350	38.89

The TTI defines the ease of ignition of a sample. It represents the time needed to reach the pyrolysis temperature and to produce a critical concentration of flammable gases (Benzarti & Colin, 2013). At a lower irradiance level, the TTI is higher for all laminates. The TTI of laminate I is 42 s, which is the lowest of all the samples at a 25 kW/m² irradiance level. The TTI of laminates II and III is higher by 7 s and 22 s, respectively. At higher irradiance level, TTI is significantly lower for all laminates. The lowest value is observed for laminate I (12 s). Slightly higher TTI is observed for laminate III (14 s). The highest value of 22 s is observed for laminate II. Thus the observed TTI values indicate that laminate II is the most difficult to ignite under combustion. However, TTI is a rough indicator for flammability since it depends on various parameters, including thermal conductivity, heat capacity and the density of the material (Schartel & Hull, 2007).

Heat release rate (HRR) curves at irradiance level of 25 kW/m² and 50 kW/m² are shown in Figure 3 and Figure 4, respectively.

One of the most important parameters needed for the fire hazard evaluation of materials is the HRR, as it provides data of the fire growth, including heat release and production of gaseous products (Marquis et al., 2013).

As can be seen in Figure 1, the HRR curves for laminates I and III is similar. However, laminate III has the highest pHRR (120.19 kW/m²) of all samples. The t_{pHRR} is achieved at the shortest time (70 s), which indicates its highest risk under combustion. The pHRR of laminate I, coincident with the subsequent peak on the HRR curve of laminate III, has a similar value (120.08 kW/m²) but is achieved (only) later at 240 s. The pHRR of laminate II (101.52 kW/m²) is the lowest and occurs at the very latest at 254 s.

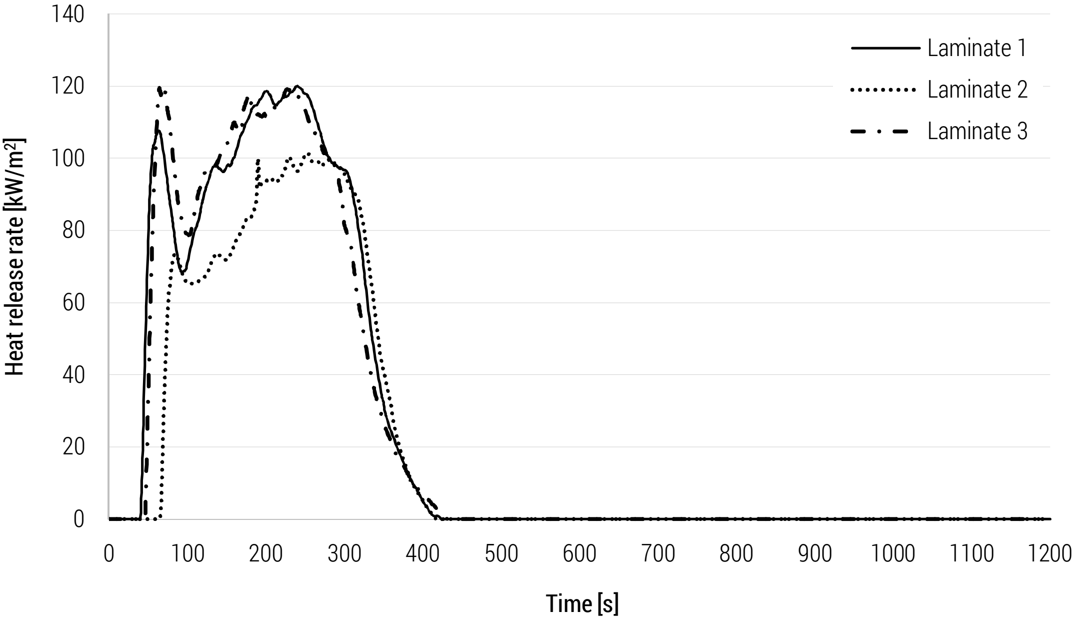

Figure 3. HRR curves of laminates under irradiance of 25 kW/m^2

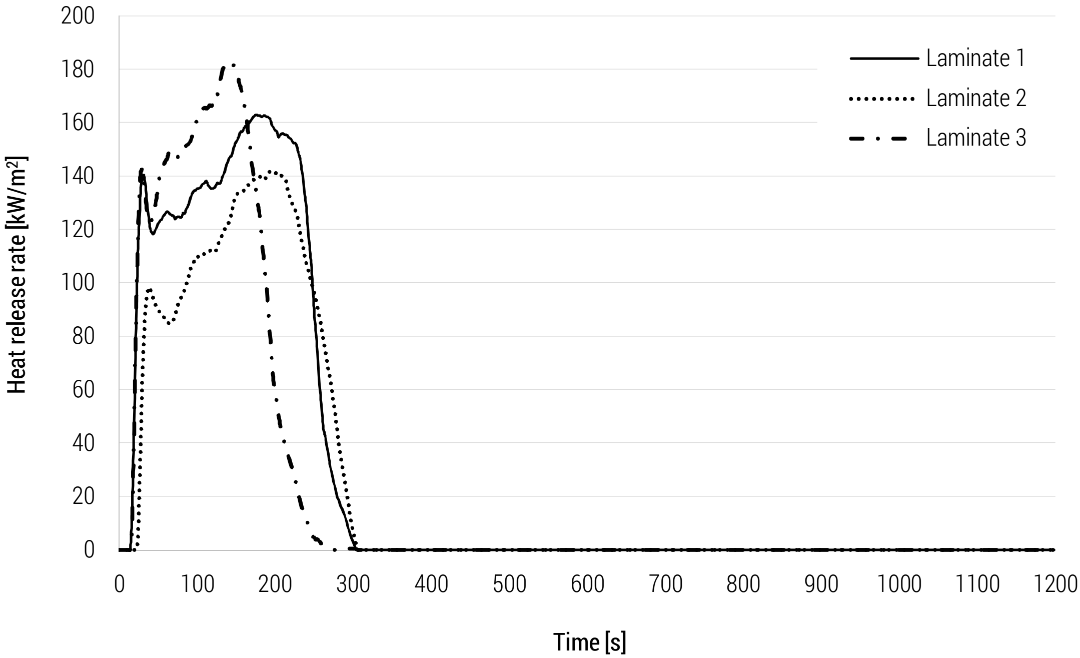

Figure 4. HRR curves of laminates under irradiance of 50 kW/m^2

At the irradiance of 50 kW/m^{2,} HRR curves of laminates are more diverse, as can be seen in Figure 4. Measurements taken at the higher heat flux show the increase of pHRR for all samples. The highest pHRR was observed for laminate III (182.44 kW/m^2). The pHRR values lower by 11% and 22% were observed for laminates I and II, respectively.

Due to the fact that in the initial period of the cone calorimeter tests is the most interesting and the most intense in changes of the measured parameters, the average HRR over a 30 s period of time and HRR_{180s} were investigated (Horváthová & Makovická Osvaldová, 2020). The average HRR over a 30 s period of time were 139.99 kW/m^2, 66.09 kW/m^2 and 142.59 kW/m^2 for laminates I, II and III, respectively. At the time when pHRR is observed, not every part of the material is at their peak burning rate. Some parts of the specimen may not be ignited yet, some may be in the middle of burning, and some of them may be burned out at already. Some studies show that HRR_{180s} may provide a better correlation than the pHRR in the cone calorimeter test (Krasny et al., 2001). At an irradiance level of 25 kW/m^{2,} laminates I and III had the highest values of HRR_{180s} of 117.02 and 119.28 kW/m^2. Much lower value was observed for laminate II (97.79 kW/m^2). All of them were similar to pHRR values. For the irradiance level of 50 kW/m^2, the HRR_{180s} values for laminates I (161.95 kW/m^2) and II (140.45 kW/m^2) were also comparable with their pHRR values. However, the value of HRR_{180s} for laminate III (78.43 kW/m^2) is more than 50% lower than pHRR, due to the fact that after reaching the pHRR, the heat release decreased quickly.

THR describes the total amount of energy released during combustion. Materials with high THR values may contribute to the development of fire (Benzarti & Colin, 2013). THR curves at irradiance levels of 25 kW/m^2 and 50 kW/m^2 are shown in Figure 5 and Figure 6, respectively.

At the irradiance of 25 kW/m^{2,} the course of THR curves of laminates I and III is similar, with a slightly higher THR observed for laminate I (30.1 MJ/m^2) compared to laminate III (29.5 MJ/m^2). Due to the later ignition of laminate II, the THR growth was observed afterwards and reached 24.2 MJ/m^2.

At the irradiance of 50 kW/m^2, the THR values were higher for laminates I and II compared to results taken at lower heat flux. The reduction of THR was observed only for laminate III from 29.5 MJ/m^2 to 27.9 MJ/m^2. The highest THR was observed for laminate I (33.9 MJ/m^2). Lower values of 28.3 MJ/m^2 and 27.9 MJ/m^2 were obtained for laminates II and III. Due to the fact that laminate I and III started burning at a similar time in the first 200s, the course of their THR curves is similar. However, because of the rapid reduction of heat release after the achievement of pHRR, the THR of laminate III is the lowest from all samples.

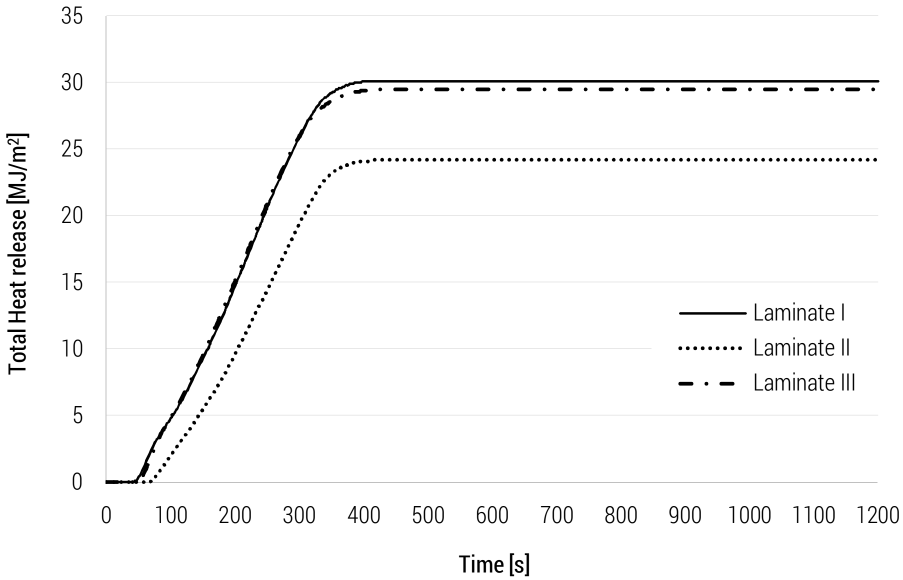

Figure 5. THR curves of laminates under irradiance of 25 kW/m^2

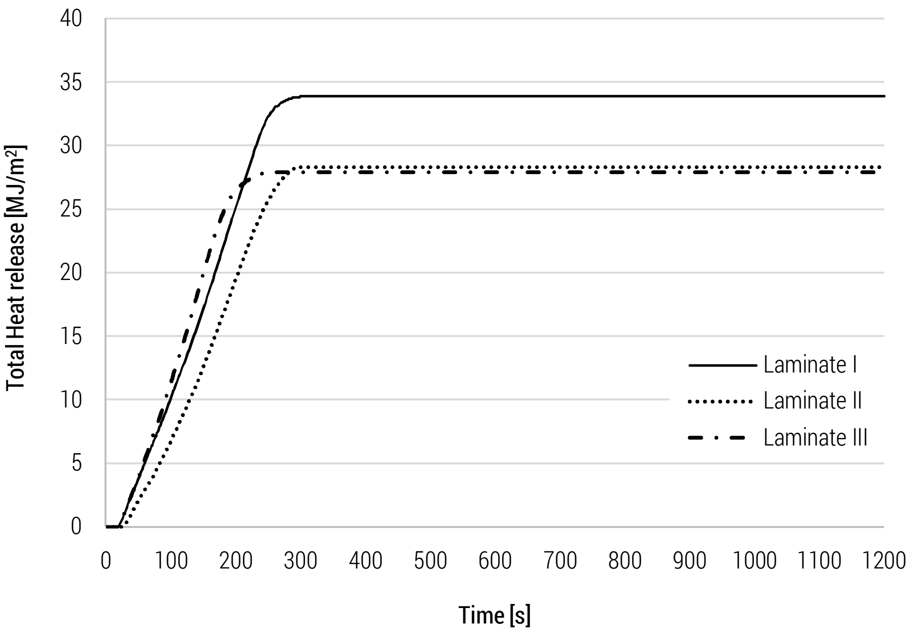

Figure 6. THR curves of laminates under irradiance of 50 kW/m^2

Smoke release data obtained from the cone calorimeter may provide additional information about the combustion of materials (Sonnier et al., 2019). The TSR at the irradiance of 25 kW/m^2 was the highest for laminate II (123.6 m^2/m^2) with the highest value of Y-CO of 4.978 kg/kg. Slightly lower TSR was observed for laminate I (116.5 m^2/m^2) with the lowest value of Y-CO of 4.359 kg/kg. Laminate III had the lowest TSR of 78.1 m^2/m^{2,} and its Y-CO was 4.577 kg/kg. At the irradiance level of 50 kW/m^{2,} the TSR values of laminates I and II were lower compared to its values at lower heat flux. The reduction of TSR was of 12.88% and 39.16% for laminates I and II, respectively. For laminate, I, the reduction of Y-CO of 17.67% was also observed. A slightly higher value of Y-CO of 1.73% was observed for laminate II, comparing them to the results obtained at lower heat flux. Significant reduction of TSR by 39.95% was observed for laminate III under higher heat flux. The Y-CO was also reduced by 4.96%. The maximum smoke production rate values observed for laminates I, II and III under heat flux of 50 kW/m^2 were 0.0014 m^2/s, 0.0016 m^2/s and 0.0018 m^2/s.

The SEA is defined as a quantity of smoke produced from kg of burned fuel (Barboni et al., 2017). The highest SEA at an irradiance level of 25 kW/m^2 was observed for laminate II (31.8 m^2/kg). Laminate I had a slightly lower SEA (26.4 m^2/kg), whereas laminate III had the lowest value of 18.3 m^2/kg. Accordingly to TSR values, the SEA values for laminates I and II at higher heat flux were lower by 6.82% and 47.48%, respectively. An increase of SEA by 33.33% was observed for laminate III.

Laminate II achieved the highest amount of residual mass (31.33%) at 25 kW/m^2 heat flux. Slightly lower values were observed for laminates I (27.80%) and III (27.96%). At the irradiance level of 50 kW/m^{2,} laminates I and II exhibited higher residual mass, which was higher by 10.55% and 10.93%, respectively. The decrease was only observed for laminate II by 1.39%.

Conclusions

In conclusion, the LCA results showed that electricity contributed most significantly to all impact categories (89% and above of the overall impact). The glass/polyester laminates manufacturing process mainly affects marine aquatic ecotoxicity and accounts for 88.3% of all environmental impact indicators. A contribution analysis showed that the use of electricity dominates; its contribution is over 99% of the MAETP impact category. It becomes clear that MAETP dominates the environmental profile. The reduction of emissions from electricity through total or partial change to electricity from renewable resources may prevent the negative effects of non-renewable

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energy consumption. Significantly lower impact is observed for the freshwater aquatic ecotoxicity, abiotic depletion (fossil fuels), and global warming potentials.

The analysis of heat and smoke release revealed that examined laminates do not meet the requirements of FTP Code Part 10. Under the heat flux of 50 kW/m^2, the TTI for laminates I and III was lower than 20 s, and laminate III had a greater value of 22 s. The average HRR over a 30 s period of time was greater than 60 kW/m^2. The THR was higher than 20 MJ/m^2 for all laminates. Only the criterion of average smoke production rate was achieved with the maximum value of 0.0018 m^2/s for laminate III.

In conclusion, the results showed that formulated laminates do not fulfil the criteria included in FTP Code Part 10 and are not qualified as fire-restricting materials for high-speed craft. Its usage has to be followed by the improvement of flame retardancy, which could be achieved by using flame retardants.

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The contribution of the authors

Conception, A.D. and B.K.; literature review, A.D.; acquisition of data, A.D., D.M. and P.J.; data analysis, A.D.; writing original draft, A.D.; review and editing, A.D., B.K., M.S. and D.M.; preparation of laminates, P.J.; conclusions, A.D.

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EFFECTIVENESS OF ORGANIC FOOD MARKETING

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ABSTRACT: The principal aim of this study was to assess the economic results and marketing effectiveness of selected companies dealing with the production and distribution of organic food. The diagnostic survey method was applied in the study. It was conducted on popular social media in 2021 with 686 respondents. The study findings show that the marketing strategy has been ineffective so far. This means that there exists an informationally excluded area, which must be filled in. Therefore, effective product marketing should be developed based on personalised advertisements on social media and online trade. The study findings can contribute to the popularisation and broadening of knowledge regarding the behaviour of organic food buyers. Determining the factors affecting the buying process and motivations will aid stakeholders in building an effective marketing strategy for organic food. This may have a beneficial effect on the development and diversification of the organic food market, whose production may contribute to an improvement of the natural environment condition and the quality of life, as well as the promotion of local food producers.

KEYWORDS: organic food, organic food marketing, marketing effectiveness

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Introduction

The organic food market in Poland is becoming increasingly popular. Eco-food producers use specially created instruments promoting eco-products to compete for customers with conventional food manufacturers. The eco fashion and the increasing awareness of society encourage entrepreneurs to introduce new production and logistics-related solutions. It is difficult to keep prices in the organic food market at a competitive level despite the relatively higher costs of production and distribution. This has been confirmed by studies conducted by IQS, which show that high prices are the most significant barrier to the development of organic food production (according to 68% of the respondents) (Gryn, 2020). The compensation seems obvious. However, the demand for organic food depends on many factors, e.g. on the consumers' wealth, their awareness of how food affects their health, the marketing instruments used by the enterprise, lack of sufficient knowledge about organic products, quality and health safety of organic food, high inflation (Jarossova & Mindasova, 2015; Grzybek, 2016; Najiib et al., 2021; Tandon et al., 2020; Hanus, 2020; Kowalczyk & Kwasek, 2020). Existing barriers in the organic food market can significantly reduce, i.e. strong structures consisting of many units providing official food control and consumer education and promotion of short food chains (Kowalczyk & Kwasek, 2020). A well-constructed marketing strategy and the use of effective promotion instruments directed at a specific segment help to increase sales, which has a beneficial impact on the financial result, especially in the organic food market (Witek, 2014).

The rapid changes in the organic food market in Poland make it difficult for new producers of such food to find a place in it. Bio Planet, Organic Farma Zdrowia and Symbio Polska are among the leading producers and distributors of organic food, supplying the majority of the certified products present on the Polish market. Their goods seem not fully recognised by customers, which is reflected in their economic results. This is a topical issue as promoting healthy nutrition rules and consuming products with a high nutritional value is important and justified now that obesity has become widespread and the threat posed by diet-related and neurodegenerative diseases is growing. However, like any kind of business activity, this one also must be profitable. These considerations raise the question: Is the current marketing strategy effective, and is it reflected in the economic results of Bio Planet, Organic Farma Zdrowia and Symbio Polska – entities producing and distributing organic food?

An attempt was made to assess the effectiveness of marketing activities of companies which produce organic food, which may have affected the

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financial condition of the companies. The financial result enables one to measure and assess a company's achievements. The data for the analyses were taken from the financial reports published by the companies under analysis. Notably, due to the small group size, the study material is of no statistical value, and it does not provide grounds for general conclusions. However, it can be a reference point in in-depth studies of the issue. Moreover, the study is partly based on the material obtained from a survey conducted with a questionnaire (which has some flaws, i.e. it is superficial and provides a limited opportunity to present the issue in question).

An overview of the literature

Organic food is becoming increasingly popular in recent years, although according to Gryn (2020), "bio- and organic food was still a caprice of royals, elites and the rich in the early 21st century". There were probably many reasons for this, e.g. many celebrities promote this market segment with their healthy lifestyle – they claim that King Charles III owes the fact that he went through COVID-19 so mildly to his healthy lifestyle, which involved switching to organic food. The British sovereign has had his organic brand (Duchy Originals) (with over 300 products on offer) since the 1980s, and it has been increasing its income steadily. Due to the media promoting new trends among the young, "zero waste" cuisine and "healthy food" are gaining popularity. This may not be as new as it might seem because housewives used to manage the scant resources in the time of deficit and shortages and tried to use eco-resources, making healthy soup from nettle and goosefoot, acorn pancakes or bread with an admixture of birch bark (Zaprutko-Janicka, 2015). New solutions appear in crisis times, promoting frugality in managing resources, e.g. co-kitchens (NaWidelcu, 2022).

The organic food market is very interesting, and it may be a promising niche in the food economy. Its output and turnover have been growing rapidly in recent years. In the European Union countries in the years 2012-2018, the area of ecological farmland increased by 33.7 p.p. (from 10 047 896 ha in 2012 to 13 438 168 ha in 2018), and a significant increase in sales of organic food was recorded in this period (from 20.8 billion in 2012 to 37.4 billion in 2018) (European Parliament, 2018). Also, in the USA and in Europe, it grew steadily, which manifests itself in a nearly 10% share of organic food in the food market in the USA and Germany and a 20% share in Denmark (Mulder & Liu, 2017; Gryn, 2020; Czudec et al., 2022). Organic food is also becoming increasingly popular in France, the UK and Switzerland (Ruiz de Maya et al., 2011; Ham, 2019) (Figure 1).

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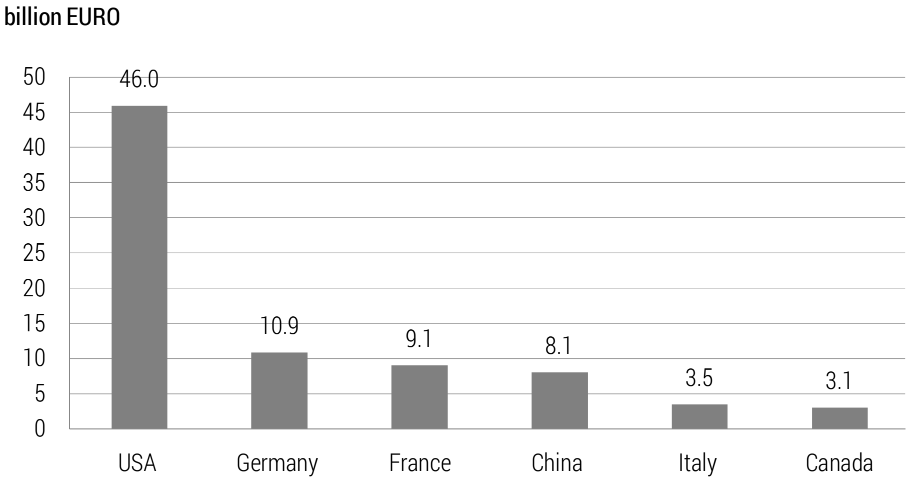

Figure 1. The volume of consumption of organic foods in 2018

Source: authors' work based on European Parliament (2018).

The value of the organic food market in Poland was estimated at 1.1 billion PLN in 2018-2020, and it is still growing. Compared to the entire food market in Poland, however, this is a small amount; according to the data of the Polish Chamber of Organic Food (PIŻE, 2019), the average consumer spending in Poland in 2017 on organic food was at the level of EUR 6 per capita per year, which was 1/10 of the EU average. The Swiss, Danes and Swedes spent the most on organic food in the year (EUR 288-237 per capita per year). Many scientific researchers emphasise that the amount of spending on organic food is influenced by the economic development of the country reflected in the level of GDP per capita (Smoluk-Sikorska, 2010; Kułyk & Michałowska, 2016; Hermaniuk, 2018).

The European Commission published the *European Strategy for Biodiversity 2030* and the *"From the Field to the Table" Strategy* in 2020 (Komisja Europejska, 2020), which specify the measures spanning the whole food production process. These will also include international cooperation concerning sustainable food systems. The measures mentioned above include the development of organic farming, whose principles cover pro-consumer activities aimed, for example, at shortening supply chains. Stimulation of the sale of goods produced and sold locally will improve the safety of food supply to customers. This is expected to improve organic food availability on the market, which may promote organic food production. This may provide many diverse benefits, and consumers will enjoy healthy products of high quality and sensory value. An increase in organic food production will help to increase the farmers' income and use the existing labour resources on farms more effectively and protect the natural environment (Czudec et al., 2022).

The popularity of organic food is also increasing in Poland because increasingly aware consumers are seeking healthy, GMO-free food (Witek & Szalonka, 2017), without pesticides and allergising or harmful additives, preferably in biodegradable packaging (Witkowska-Dąbrowska et al., 2020). Moreover, the better quality of such products is seen as resulting from a higher content of bioactive compounds, e.g. antioxidants (Żakowska-Biemans, 2009; Kułyk & Michałowska, 2018). Apart from that, according to Prof. Rembiałkowska, eating organic food regularly can contribute to "decreasing a risk of diet-related and neurodegenerative diseases (i.e. Parkinson's and Alzheimer's disease) and cancers (e.g. breast cancer or lymphoma)…" (Gryn, 2020). Some consumers in Poland are aware that organic and conventional foods are produced differently. The latter does not contain artificial additives, and it is often produced by local manufacturers, who take measures aimed at improvement of soil quality, reducing water and air pollution and increasing biodiversity (Hole et al., 2005; Mulder & Liu, 2017). Others, who want to remain fashionable, try to catch up with their influencers who promote eco-trends and environmental protection. Therefore, it is worthwhile to use the current interest in healthy organic food and attempt to build effective product marketing based on the widespread use of e-resources, i.e. digital marketing channels based on online trade and personalised advertising (Novytska et al., 2021; Abrar et al., 2016).

Research methods

The main purpose of the study was to assess the economic results and marketing effectiveness of products of selected companies dealing with the production and distribution of organic food. The diagnostic survey method was applied in the study, and a questionnaire was used as the research technique. The sample was carefully selected, and the questionnaire was addressed to consumers who bought organic food, which helped to assess the recognisability of organic food. The questionnaire was constructed by the study authors based on the literature on the subject (Ünal et al., 2018; Wang et al., 2018; Nguyen et al., 2019; Dangi et al., 2020; Loera et al., 2022). The research employed the CAWI (Computer Assisted Web Interview) method and was conducted through an online panel in popular social media in late 2021 with 686 participants. The data were verified with respect to the formal aspects and their completeness, and the study material was subsequently analysed.

This paper presents only a part of the pilot study. The questionnaire contained closed-ended questions in its first part. They revealed the motivation and preferences of organic food consumers in the buying process. The sec-

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ond part of the questionnaire contained a metric with questions concerning the age, sex, education, professional situation, place of residence and marital status of the respondents. The population under study was dominated by a group of young respondents (aged 18-25 years accounted for 93% of the population). This may be explained by the fact that the questionnaire was uploaded to a popular online social media platform, with young people having relatively easier access. The group under study included individuals with secondary (65%) and higher (26%) education, and the others had primary or vocational education. More than half of the respondents (54%) declared living in an informal relationship, a considerable portion (37%) were not in any official relationship, and only a small group (7%) were married. More than half of the respondents (55%) chose the response "I'm studying", with members of this group declaring having temporary work under a contract of mandate. Moreover, every third (36%) of respondents worked professionally, and only 4% were unemployed.

This study employed the analysis: of literature, monographic, comparative and financial data based on financial reports of companies dealing with the production and distribution of organic products. This study examined the financial results of BioPlanet, Organic Farma Zdrowia and Symbio Polska in 2015-2020. It involved document examination – this paper presents part of its results.

The obtained research results can fill the cognitive gap and contribute to deepening knowledge about the behaviour of organic food buyers. This may have a beneficial effect on the development and diversification of the market for organic food, whose production may contribute to the improvement of the natural environment, promotion of local producers of organic food and quality of life.

Results of the research

The study included an analysis of the available economic information, such as reports of the company (Bio Planet, Organic Farma Zdrowia, Symbio Polska) and its activities published online (Table 1). Part of the analysis is presented in this paper. All of the companies earned income from the sale of products in 2015-2021 (except Symbio Polska – no data available for 2020-21). According to these data, the position of BioPlanet was better compared to the other entities (dynamics of income from sales in 2015-2021 ranged from 101% to 136%). The income from sales of Organic Farma Zdrowia in 2015-2020 was relatively stable (the dynamics index ranged from 102% to 113%), but a decrease in revenue was noted in 2021 compared to the previous year. The economic results of Symbio Polska were not satisfactory. This

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was reflected in the financial result: the net profit reported by BioPlanet ranged from 2.002 kPLN in 2015 to 83 kPLN in 2018, but it increased later (it amounted to 3.610 kPLN in 2021). The other entities reported a loss in 2015-2021 (except Organic Farma Zdrowia, which reported a profit of 1.050 kPLN in 2015). The economic results of the companies under examination did not bring the desired profit to the investors in Organic Farma Food or Symbio Polska (a decrease in share value was reported in 2015-2021 – Table 1). The net profit per share of BioPlanet in the period under study ranged from PLN 0.03 PLN in 2018 to PLN 1.78 in 2020.

It seems that increasing awareness and knowledge of the beneficial properties and the fashion for consuming organic food among consumers should result in an increase in their interest, which should be reflected in an increase in the income from sales. However, this was not the case for all the selected companies – it may have been caused by numerous factors, such as the lack of/decrease in the available financial resources caused by people losing their jobs during the lockdown caused by the COVID-19 pandemic. At that time, many customers switched to traditional cooking at home in order to save money or out of necessity. A question was asked at the time, whether this was caused only by these factors. A hypothesis was put forward that the economic result achieved by Organic Farma Zdrowia and Symbio Polska depended on the recognisability of both companies' product brands. The further examination involved a pilot study in the form of a diagnostic survey concerning the knowledge of the selected companies.

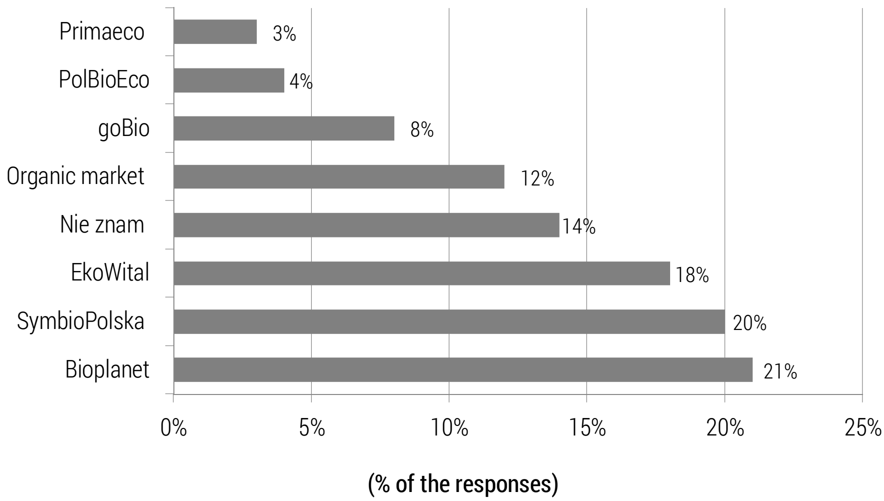

Figure 2. Recognisability of entities dealing with the production and distribution of organic food [%]

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Table 1. Economic results in selected companies dealing with the production and distribution of organic food

Item	Profit for selling (kPLN)			Dynamics index (previous year =100%)			Net profit (kPLN)			Net profit per share (PLN/share)		
Years	Bioplanet	Organic Farma Zdrowia	Symbio Polska	Bioplanet	Organic Farma Zdrowia	Symbio Polska	Bioplanet	Organic Farma Zdrowia	Symbio Polska	Bioplanet	Organic Farma Zdrowia	Symbio Polska
2015	86071	80814	24436	-	-	-	2002	1 050	-1262	0.71	0.234	-0.188
2016	113469	91126	28349	132%	113%	116%	792	-3 031	-489	0.28	-0.676	-0.036
2017	123293	93279	19274	109%	102%	68%	1016	-5 059	-3369	0.36	-1.129	-0.250
2018	128441	98223	15736	104%	105%	82%	83	-4 048	-4063	0.03	-0.903	-0.592
2019	153060	100011	4344	119%	102%	28%	1812	-5 672	-2344	0.65	-1.266	-0.342
2020	203929	102696	-	133%	103%	–	4991	-5 331	–	1.78	-1,092	-
2021	205476	100279	–	101%	98%	-	3610	-13653	–	1.29	-2.481	-

Source: authors' work based on Bankier.pl (2021; 2022; 2023).

The respondents were asked whether they knew the names of companies which dealt in the production and distribution of organic food (Figure 2). The results show the highest recognisability among potential customers for Bio Planet (21% of responses), Symbio Polska (20% of responses) and EkoWital (18% of responses). The respondents less frequently mentioned the companies of goBio (8% of responses), PolBioEco (4% of responses) and Primaeco (3% of responses).

The respondents were also asked about their knowledge of organic food in various groups of products manufactured by the selected companies, i.e. Symbio Polska, BioPlanet and Organic Farma. Photos of packaging were provided in the questionnaire to make it easier to recognise the products. More than half of the respondents (64%) did not know the dairy products shown in the illustrations (Figure 3). Only 15% of them recognised tofu of the Symbio Polska brand, 14% of them recognised vanilla cheese made by BioPlanet, and the smallest percentage recognised yoghurt made by Organic Farma (7%). The respondents were also asked about another product category – snacks (Figure 3).

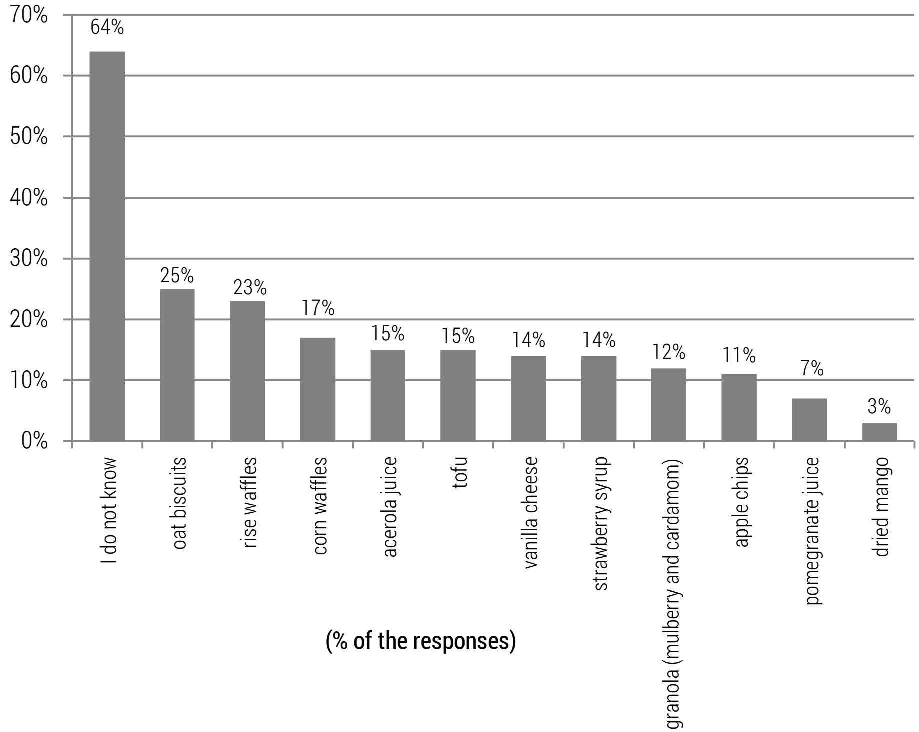

Figure 3. Recognisability of organic food products

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In this category, they mentioned oat biscuits made by Symbio Polska (25%) the most frequently and rice waffles made by BioPlanet (17% of the responses). Only 3% of them were aware of mango produced by Organic Farma. The respondents were asked about their knowledge of individual juices. Acerola juice made by BioPlanet was the most recognisable product in this category (15%). It was usually available in health food shops due to its beneficial effect on the body. Strawberry syrup made by Symbio was mentioned by 14% of the population under study, and the pomegranate juice produced by Organic was mentioned by only 7%.

There are different reasons for consumers choosing to buy organic food, e.g. their anxiety associated with the impact of the method of nutrition on the incidence of diet-related diseases may increase consumers' interest in such food. Therefore, the respondents were asked to say how often they bought organic products (Figure 4). The data show that a considerable part of the surveyed entities (28%) declared that they bought such food several times a month, and a slightly smaller part (22%) bought it once a week. A relatively small group among the respondents (10%) bought organic food once a month, whereas 3% of them claimed to buy such products only once a month.

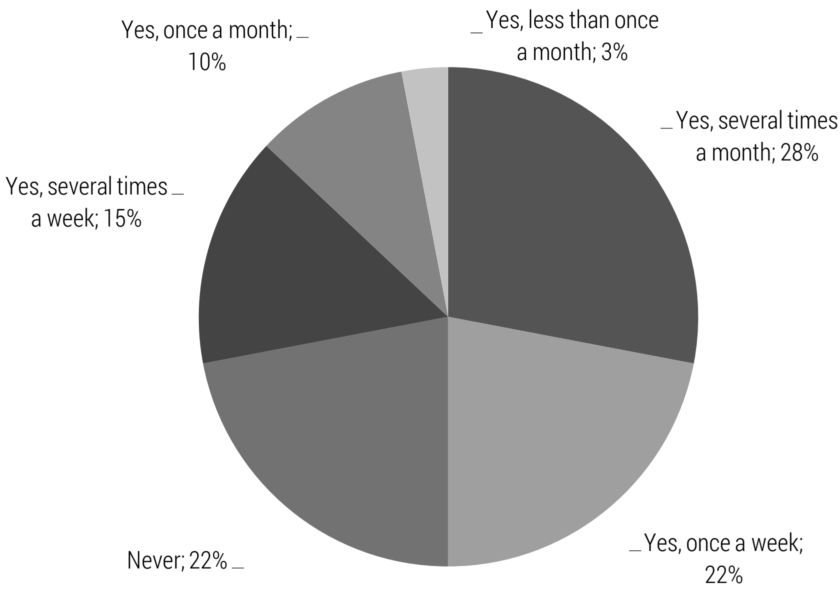

Figure 4. Respondents' declarations on the frequency of Organic Farma Zdrowia S.A., BioPlanet and Symbio Polska product purchase

Discussion/Limitation and future research

The experience of French eco-food distributors shows that success is possible in this field. Its sources can be seen in: personalisation and emphasising the pro-health activity of organic food, especially among young consumers with a high awareness level (Grzybowska-Brzezińska, 2012), branding, „…centralisation and standardisation in the intra-organisational network structure…" (Bryła, 2016) and in developing stable relations with suppliers and customers (creating a so-called "partnership brand"). The study conducted by Witek and Kuźniar (2021) shows that a greater interest in healthy nutrition and in buying organic food was demonstrated by younger female consumers, which was also confirmed by this study. Reaching this group of consumers can be facilitated by promoting eco-food by cooking bloggers (Bryła, 2015). The "…effect of synergy and complementarity between the online shop and a traditional one…" plays an important role in the process (Bryła, 2016). Development of the organic food market is affected by some limitations, e.g. relatively high prices (Kułyk & Dubicki, 2019), which results from high organic food production costs, limited availability and lack of knowledge of how eco-products are labelled (Hermaniuk, 2018). This was also confirmed in the current study.

Unfortunately, the recent reports from Germany and Austria on the regression of organic farming caused by increased production costs are worrying. The pandemic, the war in Ukraine, the energy crisis, and other factors have contributed to this state of affairs. In Austria, 1450 agricultural producers have already given up organic farming, and Austria has so far been an example of a country focused on organic farming. A significant problem is the halving of milk production and yields compared to conventional agriculture. However, thanks to eco-premiums and higher subsidies, the statistical incomes of organic farmers were higher than on conventional farms. The crisis is exacerbated by high inflation, which causes a loss of consumer purchasing power (Głuszek, 2023).

Conclusions

The advantages of good quality organic food for human health and life are obvious. Education and stimulation of good eating habits and a healthy lifestyle can contribute to developing the organic food market in the future. The price is still a determinant of purchasing in the case of food; in particular, it is important in the organic food market in countries with low GDP per capita. In addition, rising inflation may significantly reduce the demand for organic

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food. Numerous barriers in the production and distribution of eco-products in the above-mentioned scientific studies do not exhaust the list of restrictions in this area. However, the solutions proposed by the European Commission may at least partially offset the progressive regression of organic farming.

A comparative analysis of the economic results achieved by the companies dealing with the production and distribution of organic food shows that in a dynamically changing environment and under the adverse conditions of the pandemic, the best economic effects were achieved by BioPlanet. Both Organic Farma Zdrowia S.A. and Symbio Polska reported a loss. The economic results of BioPlanet and Symbio Polska indicate that the adopted marketing strategy covering the sale of the above-mentioned organic food products was not effective.

The source of failures of the last two companies can be seen in unfavourable circumstances and difficulties in eco-product distribution at the time of isolation. However, one should note that young people in the population under study (93% of the total population were people aged 18-25) did not know the other products. Such an age structure of respondents, on the one hand, may constitute a certain limitation in the case of generalisation of conclusions. However, as research indicates, „... an opportunity for further development of the domestic eco food market may be the generation of people born after 1995 (generation Z), who most often buy organic food (39% of them at least once a week...)" (Dlahandlu.pl, 2022). Therefore, despite the small financial possibilities, there is a group of young and conscious consumers who care about the quality of life and can encourage others to consume organic food by their example.

It is worth noting that sweet snacks enjoyed the best recognition among respondents. Therefore, there is still an area excluded from the point of view of information, which needs to be supplemented in order to be able to fully exploit the existing potential of the remaining organic food offer. Effective marketing of organic food products could be based on the specificity of the interests of the most open, young group of customers. Therefore, maybe targeted branding on the Internet (e.g. on Instagram, Tik Tok), the use of personalised advertising in social media, enabling identification with idols and digital commerce, which functioned successfully even during the Covid-19 pandemic, would make it possible for the companies to succeed.

The contribution of the authors

Concept, K.Ch. and A.L.; methodology, K.Ch.; literature review, K.Ch.; conclusions, K.Ch.; conducting a survey, A.L.; development of study results, A.L.

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AGRICULTURAL PRODUCERS' KNOWLEDGE OF RATIONAL WATER MANAGEMENT – CASE STAGE (POLAND, EU)

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ABSTRACT: Water is considered the most critical resource for agricultural development worldwide. The increasing extreme weather phenomena require rational management of water resources in agriculture, which is the most vulnerable to the effects of climate change. The article is an attempt to take on the subject of agricultural producers' awareness of selected aspects of rational water management in agricultural production. For this purpose, a pilot survey was used and carried out in selected poviats (counties) in the zachodniopomorskie (West Pomerian) Voivodeship, implemented as part of the "Support for the Creation of Local Water Partnerships" project (Support for the creation of LPW, SIR, 2020).

KEYWORDS: water management, agricultural production, rational use of water

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„ only then is the water respected, when there is no water in the well"
(Polish proverb)

Introduction

The recent years have particularly shown that climate change has become a reality. According to the report of the International Climate Panel (IPCC), currently up to 3.6 billion people worldwide feel the effects of climate change (IPCC Working Group I Report, 2021). Heat waves, combined with droughts, water shortages and floods are particularly troublesome and dangerous for Europe (Feyen et al., 2020, pp. 20-23, 50-53).

July 2022 turned out to be the sixth hottest month in Europe with a heat-wave setting local and national records in both Western and Northern Europe (Climate Bulletins).

Agriculture, which directly depends on the quantity and quality of water resources, is particularly sensitive to the negative consequences of climate change. It is the agricultural sector that is the largest consumer of water, which currently accounts for 70% of global consumption, including about 25% for irrigation of crops (Un World Water Development Report, 2022) As a result of changes in the distribution and intensity of rainfall and an increase in air temperature, agricultural sector is already struggling with an increasingly frequent shortage or excess of water, which causes significant losses in agricultural production.

Climate change is projected to reduce crop productivity in parts of southern Europe. While the northern regions may experience longer growing seasons and more suitable cropping conditions in the future, the number of extreme events negatively affecting agriculture in Europe is projected to increase significantly (EEA Report, 2019, pp. 12-19, 25-35).

In the geographical region in which Poland is located, we can also expect an increase in the frequency and worsening of extreme weather phenomena, in the form of increasingly severe and longer periods of drought, or sudden torrential rainfall resulting in local flooding and floods (Climate change trends, http://klimada.mos.gov.pl,Komunikat01/2020). In Polish weather conditions, in order to mitigate the described phenomena, it is necessary to: increase the natural retention capacity of the catchment area, limit the rapid runoff of rainfall and meltwater through drainage networks and introduce precise irrigation systems (Karaczun, 2020, pp. 10-12; Karaczun et al., 2020, pp. 75-94). This means that the challenges faced by Polish agriculture require the involvement of not only the government and local administration responsible for creating organizational and legal frameworks for the rational management of water resources, but – above all – the participation of farmers (Kolasińska & Wawer, 2020, pp. 74-86, 188-190) Their decisions and

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applied agricultural practices, after all, directly affect the quantity and quality of water in agriculture (EAA, 2021; Wawer, 2020, pp. 38-45). Therefore, knowledge and awareness in the area of rational management of water resources is so important in counteracting the negative effects of climate change and its impact on agricultural production. An important role in the educational area of agricultural environment is played by Agricultural Advisory Centers (AAC), which provide broadly understood consultancy in the field of agriculture, sustainable development of rural areas and improvement of professional qualifications of farmers. The tasks include organizing training and implementing knowledge exchange programs aimed at educating farmers in the use of more efficient water management practices in agricultural production (Kolasińska & Wawer, 2020, pp. 16, 55, 147-158, 179). These centers have recently expanded their information campaign with an educational and training offer in the field of melioration and retention of water resources and irrigation.

The aim of the article is to show the state of knowledge of agricultural producers in the area of rational water management in agriculture. It is a case study involving farmers in the selected poviats of the Zachodniopomorskie Voivodeship (Poland, EU), which is characterized by a certain specificity, due to its large-area and intensive nature of agricultural production.

To achieve the objective, preliminary pilot studies were use carried out among agricultural producers concerning their knowledge of irrigation, water retention and melioration treatments in agriculture, as well as knowledge of the competencies of individual institutions and bodies operating in the area of rational water management.

In order to answer these questions, the following research tools were used: analysis of existing data (reports, domestic and foreign statistical studies, source documents and legal acts), literature review and a quantitative research method – a survey.

Water resources in agriculture

Water is one of the most important elements of the natural and anthropogenic environment; necessary for life and development (Water resources in the world). In recent years, a rapid decline in water resources has been noticeable due to increasingly frequent droughts and intense weather phenomena that affect the limited and vulnerable nature of this resource. Therefore, water is one of those goods the improper use of which may limit the socio-economic development or, at best, the production efficiency of almost all branches: industry, agriculture, transport and services (Kłos, 2013b, pp. 263-274; Kaca et al., 2011, pp. 14-21).

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Agriculture is especially exposed to those deficits, potentially bringing a serious challenge to ensuring food security, due to a rapid growth in the world's population (World population., ONZ, 2022). In the early 2000s, 40% of the world's food came from 18% of the cultivated land that had been irrigated. The global irrigated area has increased more than sixfold over the last century, from about 40 million hectares in 1900 to over 260 million hectares (Chartzoulakis & Bertraki, 2015, pp. 88-98; FAO, AQUASTAT Database). Water abstraction for irrigation is a major driver of groundwater depletion worldwide, further exacerbating the water supply situation. The United States, China, Iran and Pakistan are responsible for 67% of the world's groundwater consumption. It is estimated that the increase in groundwater extraction by 2050 will amount to 1,100 km^3 per year, i.e. 39% (Boretti & Rosa, 2019, pp. 1-15). The intensification of the use of groundwater for irrigation can lead to overall water depletion at the water catchment level (Wada et al., 2016, pp. 175-222).

Due to the fact that the current efficiency of irrigation was very low, with only 55% of the water being used for crops, measures were taken to minimize water losses from storage and retention systems and to find economical crops with minimal water consumption and the use of application methods in irrigation systems (the so-called: precise – drip irrigation) (Beluhova-Uzunowa et al., 2019, pp. 142-155; Berbel et al., 2018, pp. 423-429).

Moreover, water retention capacity of the agricultural landscape can be improved by maintaining drainage systems, establishing a variable water flow regime, restoring and reconstructing morphological structures in rivers, adopting ad hoc crop rotations and utilizing other agricultural practices (crop systems, soil cover management) or creating flood protection reservoirs (Climate-ADAPT, 2019). Therefore, for environmental reasons, agrotechnical and planning measures are gaining importance (Mrozik & Przybyła, 2013, pp. 1767-1773).

Studies conducted in various countries such as: India, Israel, Spain and the United States have shown that drip irrigation reduces water consumption by 30-70% and increases yields by 20 to 90% (Postel et al., 2001, pp. 3-13). The combination of water savings and higher yields currently makes it the leading technology in addressing the global challenge of increasing crop production in the face of severe water shortages. This method is the only viable way to optimize agricultural production and encourage water conservation in order to improve the efficiency and durability of irrigation systems. For this purpose, knowledge of the water requirements of crops, water requirements and soil & water characteristics that determine the timing of irrigation is essential. In most cases, the farmer's skills determine the effectiveness of irrigation planning (Wawer et al., 2016, pp. 290-296; Savari et al., 2021).

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The problem of optimizing water management also applies to European agriculture, which – due to its geographic and climatic conditions – is particularly exposed to water deficits. According to the European Environment Agency (EEA), droughts and water scarcity are no longer rare and extreme phenomena and affect about 20% of the territory of Europe and 30% of Europeans every year (EEA Report, 2021). That is the reason why, in the past, a combination of rain and irrigation farming was used. Consequently, agriculture in Europe is responsible for about 40% of the total water consumption, in some regions reaching even 80% (Agenda 2030). In southern Europe in particular, the demand for irrigation is projected to increase in the coming years, while water availability is expected to decline in part due to climate change.

Greece, Italy, Portugal, Cyprus, Spain and the south of France are the most exposed to the risk of climate change and the need to irrigate crops. In these areas, almost 80% of water used in agriculture is currently used for irrigation purposes (EEA Report, 2021).

Thanks to the introduction of new water-saving practices and strategies, irrigation does not have to be as water-intensive. The benefits of water efficiency can now be seen all over Europe, both through efficient water transport systems (the amount of water abstracted actually delivered to the field) and through efficient water distribution in the field (the ratio of the water actually used by the crops to the total amount of water with which the crop were provided). A good example is France and Greece, where the introduction of an improved transport network and efficient water distribution has led to an increase in water efficiency of 95% compared to previously used irrigation methods (Rouillard, 2020, pp. 461-479).

Another solution for the rational management of water resources is the use of treated wastewater for agricultural purposes. For example, in Cyprus, the targets for the use of recycled water set for 2014 correspond to about 28% of the water demand reported by the agricultural sector in 2010. In Gran Canaria, treated wastewater accounts for about 20% of the water used in all sectors; such water is used, for example, to irrigate tomato plantations (Gelati et al., 2020, pp. 227-253).

Significant water savings of more than 40% of the volume of abstracted water can be achieved by improving irrigation infrastructure and technologies, such as: improving the efficiency of the provision and application of irrigation systems, changing agricultural practices, planting drought-resistant crops, and reusing treated water (EEA Report, 2020, pp. 18-24).

Poland is also one of the countries with very severely limited resources (Thier, 2020, pp. 9-16; Eurostat, 2021). According to the Togetair[1] Climate

[1] Polish Multimedia Climate Report - TOGETAIR.

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Report, there is 1.5 thousand m^3 of water per one Pole per year, which is three times less than for a statistical European (Statistics Poland, 2021). Almost 20% of Poland has precipitation lower than 500 mm, which ranks these areas among the driest in Europe (Mrozik, 2012, pp. 75-79).

Moreover, Poland's surface water resources are highly variable in time and space, which intensifies periodic water excesses or deficits in rivers (Prandecki et al., 2018, pp. 78-98; Walczykiewicz, 2020, pp. 4-10). An additional problem is also posed by the rapid disappearance of surface waters and fluctuations in the amount of water available during the year; this phenomenon being the result of the changing amount and nature of rainfall (Projekt KLIMADA, 2020). Meanwhile, agricultural production in Poland is based mainly on rainwater, which additionally worsens the situation, because Poland experiences low rainfall due to being located in a transitional climate zone, where continental and oceanic influences collide. The average annual rainfall in Poland is 619 mm, which means that 196 km^3 of water i.e. 70% is lost due to evaporation while 62 km^3 runs off into rivers (Institute of Meteorology and Water Management, 2020; Mrozik, 2012, pp. 75-79). All these conditions make the periodical scarcity of water resources particularly burdensome for agricultural production in the times of its greatest demand by crops (Furdyna, 2020, pp. 62-67).

In Poland, about 60% (and including forest crops – 90%) of the country's area is related to the demand for agricultural production and uses more than 40% of the total annual precipitation and about 70% of the volume of generally available water in the catchment area to produce food (Statistics Poland, 2021). For this reason, water management in the catchment area is of key importance for its long-term preservation and its use in a satisfactory amount (Kaca, 2015, pp. 23-30).

In order to improve water balance in Poland, more water should be kept where it falls, slowing down the process of its evaporation from the soil by storing it in retention reservoirs and by reusing drainage waters (Szymczak, 2014, pp. 53-85). Unfortunately, currently the total amount of water stored in the existing storage reservoirs in Poland is slightly more than 6.5% of the average annual river runoff volume over many years. On the other hand, the geographical conditions of Poland allow for the retention of as much as 15% of the annual river runoff. This means that the water retention program to regulate the flow of water, initiated as early as 1995, is still insufficient, does not provide full protection against floods and droughts, and does not guarantee adequate water supply. For proper water management, this indicator should be at the level of at least 20% (Opania & Gama Marques, 2021, pp. 2-10; Raport, Stop suszy! 2020, pp. 1-40). This is a huge challenge for water management in rural areas.

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Meanwhile, in the climatic conditions forecast for the coming decades – just to maintain the current agricultural production – Polish farmers will be forced to increase the area of irrigated crops (Institute of Meteorology and Water Management, 2020). It should be assumed that, in the perspective of several decades, the use of irrigation will be an indispensable element of agricultural crops in a large part of the country. For this to be possible without disturbing the country's strategic water resources, it is necessary to increase the efficiency of water use by implementing, among others, precise irrigation of plants. Detailed rules for drawing water for irrigation are regulated by the Water Law Act (Journal of Laws of 2017, item 1566). The aim should be to significantly increase the irrigated area with only a slight increase in water consumption. For this purpose, in many parts of the country, the main source of water for agriculture should be surface waters collected in retention reservoirs.

Challenges faced by water management in Poland in the face of climate change

Rational water management is a process of obtaining, collecting, using and protecting water, removing its excess and limiting the related risks, as well as mitigating water shortages and their elimination (Kłos, 2013a, pp. 198-200). It is particularly visible in rural areas, where water management is subordinated to: the challenges faced by the agro-food sector, health safety of people living in the countryside, animal welfare, production of healthy food, preservation of landscape and environmental values (Mosiej et al., 2011, pp. 25-36; Kaca et al., 2011, pp. 16-18). Due to the growing problems caused by climate change, poor water management and insufficient retention, the following aspects of water management come to the forefront in rural areas:

- development of new methods for the optimization of hydrological balance of soils in the soil-water-plant system, including water melioration through increasing soil retention and using precise irrigation,
- development of new methods for monitoring, rating and forecasting of water availability for agriculture at the farm, commune and water catchment level,
- adoption of water management as one of the leading elements of spatial planning in a rural commune,
- adaptation of agricultural practices to the changing availability of water resources,
- increase of water retention in the agricultural landscape and diversifying water sources for farms,

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- prevention of the deterioration of soil quality resulting from water deficits, especially preventing the mineralization of soil humus,
- stimulation of the economic and environmental effects of implementing good water management practices on farms through subsidies and consultancy, as well as educational and training programs (Treder et al., 2021, p. 8).

These challenges require careful planning pertaining to the use of water resources in the region in accordance with the principles of rationality in access to water and with simultaneous implementation of agricultural, social and environmental goals. Achieving these goals involves adapting agricultural production which can lead to land consolidation aiming to improve water retention and flood protection. Such activities are undertaken, among others, in Poland and the Netherlands (Stańczuk-Gałwiaczek et al., 2018, pp. 498-511).

Therefore, water management in rural areas requires a wide range of activities, ranging from planning and organizational activities, through design and investment, to operational, modernization and educational activities (Mioduszewski et al., 2011, pp. 179-202).

In the decision-making process, it is worth taking into account all the ecosystem services provided by individual treatments that increase the drainage capacity of the water catchment (Mrozik & Idczak, 2017, pp. 37-48).

For this purpose, it is necessary to develop methods of rational water management in agriculture (Wawer & Kozyra, 2021). To implement these measures, it is imperative that all water managers and water users collaborate and work together to manage water in rural areas.

Around the world, partnerships are used to solve complex problems related to rational water management. An example of participatory management of water resources in agriculture is Egypt, where numerous associations have been established involving all water users, including farmers, in the area of irrigation at the water catchment level. The result is an increase in agricultural production, savings and an increase in the productivity of water resources (El-Hafez & Negm, 2018, pp. 605-622).

This approach sees decision-making as a dialogue and negotiations with stakeholders from the central government and local government sectors, organizations operating in the field of rational water management, and rural residents themselves (Margerum & Robinson, 2015, pp. 53-58). Collaborative Partnerships have been established for a range of water issues, operating at different levels in many parts of the world: South America, Australia and Europe. In the field of drought prevention, Poland is a member of the Global Water Partnership for Central and Eastern Europe (Bokal et al., 2014, pp. 37-46, more at: Country Water Partnership; Global Water Partnership).

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This requires a number of activities and knowledge in the field of water management in agriculture, both on the part of institutions interested in the subject of water management, agricultural producers, as well as inhabitants of rural areas.

In the process of adapting Polish agriculture towards rational water management, it is extremely important to have reliable information on: the condition of water resources, forecasts of their dynamics in the current season, estimating the rate of their renewal in the current climatic conditions and consumption (Michalak, 2020, pp. 134-141). Good practices include, on the one hand, optimizing the use of water and, on the other hand, its accumulation in periods of excess, so that water stocks can be used during shortages (Kolasińska & Wawer, 2020, pp. 51-74).

Therefore, the Ministry of Agriculture and Rural Development (MARD) in cooperation with the Agricultural Advisory Centers (AAC) and representatives of local government have developed an outline of rational water management for agriculture at the municipal level, consisting of 7 pillars:

- development of a study of the commune's water resources as part of the procedure for creating and updating local spatial development plans (LSDP),
- creation of Local Water Partnerships (LWP) associating water management institutions – the Polish Water Management Authority (PWMA) and its local units, as well as units responsible for government and local administration, water companies and water users,
- reform of water companies and taxation for the maintenance of drainage networks in rural areas,
- creation of irrigation communities to manage their assigned surface water and groundwater,
- optimization of water usage in irrigation based on reliable climatic, soil or plant criteria,
- increase of the retention of water reservoirs and soil water capacity through appropriate agro-technical measures: crop rotation, organic fertilization, slowing down surface runoff to waters, collecting rainwater, reuse of greywater (gray water https://www.eea.europa.eu/pl/articles/woda-na-potrzeby-rolnictwa; Kolasińska & Wawer, 2020, pp. 54-55),
- education of farmers, advisers, local government administration in the field of water management and water-saving management in agriculture (Trader et al., 2021, pp. 7-8).

The implementation of the above-mentioned pillars of rational water management in rural areas requires an efficiently functioning organizational and legal framework, in particular:

- the inclusion of water management in the spatial planning of the commune,

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- full identification of water resources in the commune: surface and underground waters, creation of local hydrogeological models describing the boundary states of groundwater levels for resource renewal programs that enable the estimation of safe levels of annual water retainage and consumption,
- renewal and modernization of water drainage systems and the launch of small and large retention programs that increase the supply of surface water in rural areas (Trader et al., pp. 9-10).

All this will be possible through the active involvement of all users in the process of rational water management, especially at the commune and poviat level. To this end, the Ministry of Agriculture and Rural Development (MARD) initiated the creation of local communities operating to ensure access to information and transfer of knowledge in the field of rational water management in the region. The initiative to create water partnerships was taken by Voivodeship Agricultural Advisory Centers, under which Local Coordinators for LWP were appointed.

Local Water Partnership (LWP) – goals and tasks

Local Water Partnership (LWP as Local Water Partnerships) is a voluntary, informal association of people / entities interested in or involved in water management in a given area. The legal form of LWP functioning is optional and depends on the needs, for example it can be a form of a Letter of Intent.

The main purpose of LWP is to improve water management in the poviat (county). It is assumed that LPW will be a cooperation platform in the field of water management in rural areas. An efficiently functioning LWP can identify problems that may serve as the basis for the introduction of new solutions, in particular in the field of the operation of water companies or the maintenance of water drainage facilities (Support for the creation of LWP, 2020, https://sir.cdr.gov.pl/2020/ 06/22 / support).

The scope of LWP operation in the short-term period includes:

- facilitating the implementation of support for water investments financed under the Rural Development Program (RDP, transition period) and the National Reconstruction Plan (NRP),
- exchange of information on the principles of investment implementation with regard to the necessary documentation,
- in the scope of NRP, assistance in identifying investments that meet environmental criteria in accordance with the guidelines of the European Commission on the application of the principle of „do not do serious damage" (Journal of Laws UE.C.2021.58.1).

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LWP's long-term activities include:

- activating and strengthening cooperation between all entities,
- diagnosis of the situation in the field of water resources management,
- development of joint solutions (co-decision) to improve the broadly understood water management,
- expressing opinions and developing investment plans (indicating priorities),
- conducting educational campaigns to increase the awareness of farmers and all rural residents on the issues of economical and rational water management (Kamiński et al., 2021, pp. 6-8).

The Local Poviat (county) Water Partnerships (LPWP) created in 2020 are to work towards overcoming institutional barriers and creating efficient communication between various stakeholders for the efficient resolution of water scarcity, water excess and quality problems. The coming years will show whether the undertaken initiative will improve water management in the area of communes and poviats (counties).

Research methods

As part of the project called Support for the Creation of Local Water Partnerships (SiR, 2020), preliminary pilot surveys were carried out in eight randomly selected poviats (counties) of the West Pomeranian Voivodeship among agricultural producers. The following poviats were selected for the study: Białogardzki, Gryfiński, Koszaliński, Kołobrzeski, Myśliborski, Pyrzycki, Sławieński, Szczecinecki, to which 100 invitations (for each poviat) to participate in the survey were sent randomly. In total, a response was received from 277 agricultural producers who declared participation in the survey out of the total of 800 invitations sent. The largest number of agricultural producers reported in the Myśliborskie poviat, the fewest in the Gryfiński poviat.

The survey was conducted at the request of the West Pomeranian Agricultural Advisory Center in Barzkowice, which conducts training and consulting activities in the area of rational water management in agriculture and irrigation in the voivodeship. The questionnaire survey sheet contained 17 questions: four questions concerning the characteristics of the reported farm (i.e. farm size, structure of crops and breeding, agronomic category of soils), three questions were open-ended and concerned the identification of institutions providing support related to training and raising knowledge in the field of irrigation and drainage in agriculture. The remaining 10 questions were closed in the "Yes or No" answer. The study period was initially planned for 2019 but, due to the Covid 19 pandemic and restrictions on meetings and

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direct contact with the beneficiaries, it was extended to 2020-2021. The study used a quantitative research method – a questionnaire, which was made available during the meetings with farmers.

Results of the research – Characteristics of the research area

Large-area farms dominate in the Zachodniopomorskie Voivodeship (West Pomeranian Voivodeship), where the average farm is 33 ha with the national average of 11 ha. (West Pomeranian Voivodeship in numbers, 2020).

In the survey, 80% of farms were in the range of 10-50 ha. Agricultural crops dominated in 90% of farms, and no animal breeding was carried out in over 67% of farms (Table 1).

Table 1. Characteristics of farms, size, structure of crops and type of farming in the surveyed poviats, 2019-2020

Poviat, No of respondents / Characteristics of farms	Size of agricultural farm in hectares (ha) in %					Type of crops in %				Type of animal breeding in %			
	<5	5-10	10-50	50-100	>100	Agricultural	Fruit plantation	Seed farms	Vegetable farms	Cattle	Pig farms	Poultry farms	None
Białogardzki, N=28	4	0	50	21	25	96	4	0	0	43	7	3	47
Gryfiński, N=22	9	9	23	32	27	100	0	0	0	5	0	9	86
Kołobrzeski, N=49	10	20	40	20	10	96	0	2	2	25	10	0	65
Koszaliński, N=33	21	24	40	3	12	100	0	0	0	17	0	9	74
Myśliborski, N=51	6	22	40	22	10	88	2	10	0	25	4	0	72
Pyrzycki, N=17	0	0	47	12	41	71	6	23	0	12	1	0	82
Sławieński, N=35	9	9	31	29	22	83	3	14	0	31	17	0	53
Szczecinecki, N=42	16	5	55	14	10	86	2	12	0	28	5	5	62

Source: author's work based on ODR surveys in Barzkowice (Poland).

The graphical image of the voivodeship with marked poviats participating in the study is presented on Figure 1.

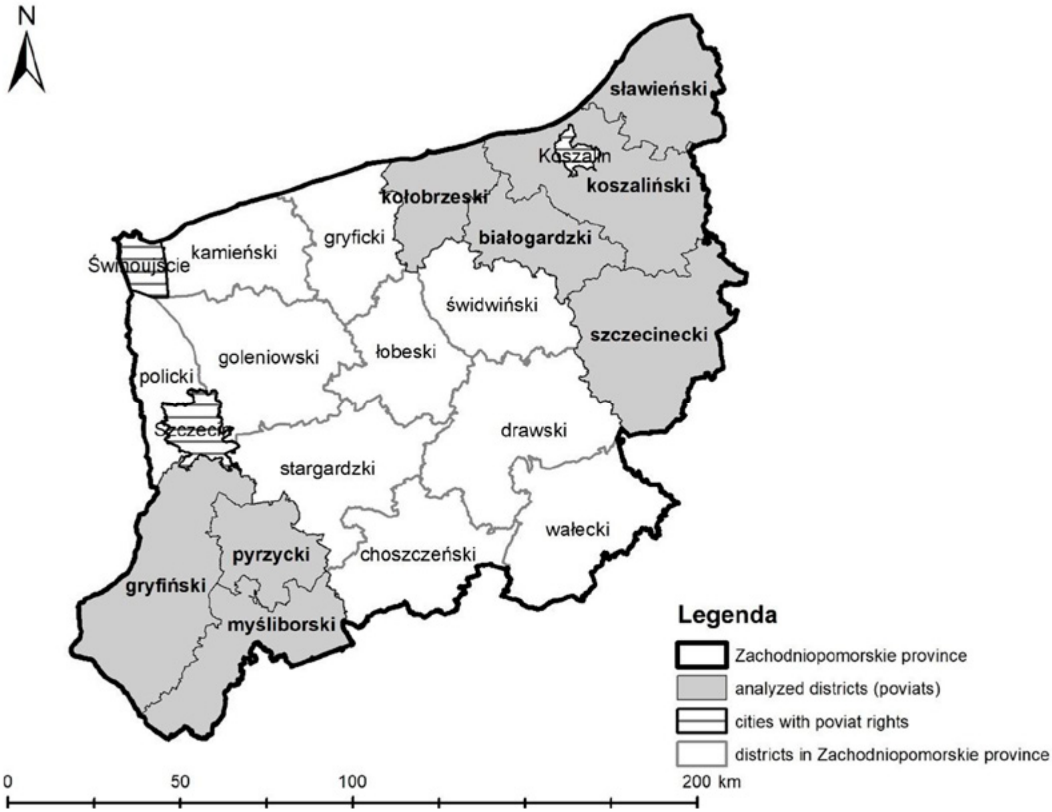

Figure 1. Poviats of the Zachodniopomorskie Voivodeship (Poland, EU)

Discussion of the obtained results and preliminary conclusions

The actual state of irrigation in the surveyed counties and losses in agricultural production due to water shortages as a result of drought periods are presented in Table 2.

In the surveyed poviats, crop losses caused by drought and water shortage exceeded 80% and, in some cases, even 100% of reported farms. Even more surprising is the small number of surveyed farmers irrigating their crops, in which the dominant form is rainwater and drip irrigation. As the main reasons for not using irrigation, the following were indicated: lack of funds for the implementation of comprehensive solutions regarding irrigation retention and ignorance of the regulations related to the possibility of developing irrigation.

Table 2. Selected answers of respondents in the poviats surveyed regarding irrigation

Poviats	What % of farmers irrigate crops	Crop losses due to water shortage [%]	Type of irrigation used [%]			Reason for non-hydration [%]				
Białogardzki	4	100	0	4	0	2	2	22	44	26
Gryfiński	4	100	0	4	0	2	2	22	44	26
Kołobrzeski	6	85	3	3	0	3	23	24	27	23
Koszaliński	6	85	3	3	0	3	23	24	27	23
Myśliborski	2	88	2	2	0	7	10	20	43	20
Pyrzycki	6	94	0	0	6	23	9	18	32	18
Sławieński	3	86	0	3	6	30	15	7	33	15
Szczecinecki	2	90	0	7	0	1	13	27	40	19

Legend: Type of irrigation used: 1 – drip, 2 – rain, 3 – percolating. The reasons for not using irrigation: 4 – lack of needs, 5 – lack of technical support, 6 – lack of water for irrigation, 7 – lack of funds, 8 – complicated regulations.

Source: author's work as in Table 1.

In terms of knowledge about support mechanisms in the area of water management, including irrigation, 18% of the total respondents confirmed the knowledge of the available activities, while 82% of the respondents had no knowledge on this subject of Figure 2.

Figure 2. Do you have knowledge about the mechanisms of supporting the development of irrigation in agriculture? (in%, n = 277)

Source: author's work based on questionnaire research.

The knowledge of the issues of irrigation support mechanisms in agriculture was significantly above the overall average in the following poviats: Szczecinecki and Pyrzycki (24% each), but the result was below the average in the Kołobrzeski poviat, where only 10% of respondents confirmed their knowledge of such mechanisms. In the study, a total of 70% of respondents

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did not have knowledge about the available training courses related to the possibility of developing irrigation or water retention in farms (Figure 3).

Figure 3. Do you have knowledge about trainings related to the possibility of irrigation or water retention development in farms (in%, n = 277)

Source: author's work based on questionnaire research.

Regarding the above-mentioned question, the concerning situation is in the Białogard poviat, where as many as 96% of the respondents are not aware of what kind of training is organized by the West Pomeranian Agricultural Advisory Center (WPAAC) in Barzkowice. On the other hand, the following poviats are much above the overall average for the above-mentioned question: i.e. the Szczecinecki and Koszaliński poviats, in which slightly less than half of the respondents had knowledge in this field (46%).

Figure 4. Have you participated in training related to the possibility of irrigation or retention development on farms?

Source: author's work based on questionnaire research.

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This lack of knowledge of the available training on irrigation and water retention translates into actual participation in the above-mentioned training. When asked about participation in trainings related to the possibility of irrigation and water retention development, only 18% of respondents in total benefited from such trainings (Figure 4).

Similarly, the smallest number of people participated in trainings in the Białogardzki and Kołobrzeski poviats (7% each). The highest rate of participation in trainings was recorded in the Szczecinecki and Pyrzycki poviats: 24% each.

Another question asked in the survey was related to access to information on support for the development of irrigation and water retention (Figure 5). Over 80% of respondents believe that access to this information is insufficient, with as many as 96% in the Białogard poviat.

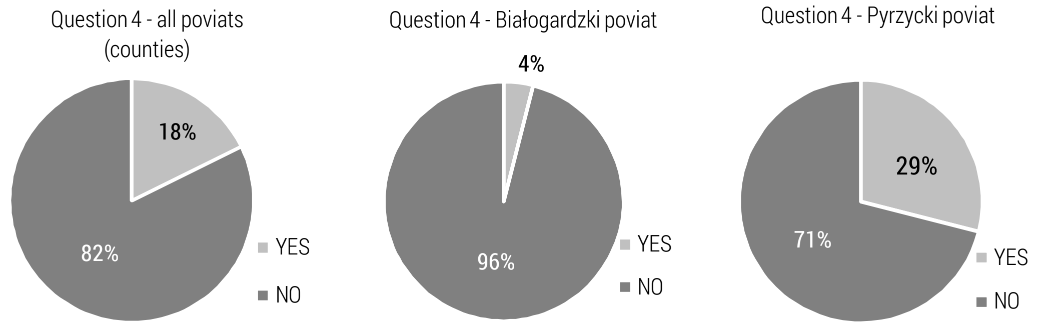

Figure 5. Do you think that access to information on the possibilities of supporting the development of irrigation and retention is sufficient? [in %]

Source: author's work based on questionnaire research.

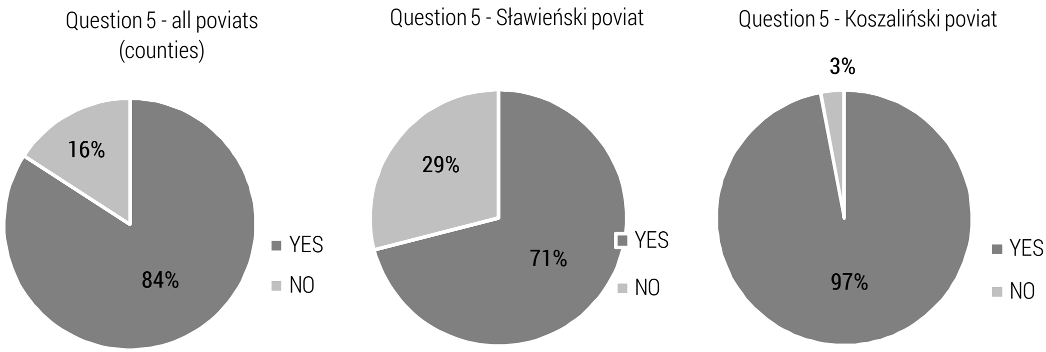

Figure 6. Do you think that training in this area is needed?

Source: author's work based on questionnaire research.

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On the other hand, in the Pyrzycki poviat, 29% of the surveyed agricultural producers considered that the access to information regarding this kind of support is sufficient.

Interesting answers were obtained in the question "Is training in this area needed", as many as 84% of respondents in total indicated the legitimacy and need for such training (Figure 6).

It is worth noting that the highest percentage of indications as to the legitimacy and need for training in the field of irrigation in agriculture was obtained in the following poviats: Kołobrzeski and Koszaliński, 97% and 96%, respectively, while the lowest number of indications was in Sławieński poviat – 71%.

An important element in rational water management in rural areas is the knowledge of the competences of individual bodies and institutions operating in this area.

For this purpose, a question was formulated regarding the knowledge of these competences among the survey respondents and the obtained results were as follows (Figure 7).

Figure 7. Are you aware of the competences of individual authorities (e.g. who should be asked for a water permit for the use of water?)

Source: author's work based on questionnaire research.

Only 32% of all respondents participating in the survey declared knowledge about the competences of individual bodies in the field of water management. In the Koszaliński poviat, only 16% of respondents had such knowledge. The highest indicator was recorded in the Szczecinecki poviat, where more than half (52%) of the respondents indicated knowledge of the competences of individual bodies and institutions in the field of rational water management.

The lowest level of knowledge about the applicable regulations concerning irrigation, development, maintenance of drainage and retention was recorded in the Białogardzki poviat (64%) (Figure 8).

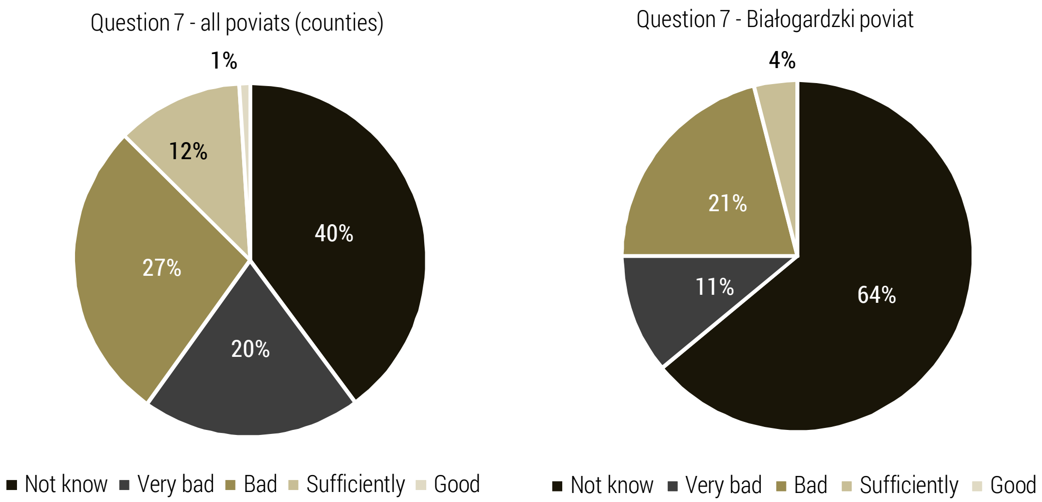

Figure 8. How do you rate the regulations on irrigation, development and maintenance of drainage and water retention?

Source: author's work based on questionnaire research.

Then, the respondents were asked for their opinion on the newly established Local Water Partnerships (LWP) to coordinate and support activities in the field of rational water management in the poviat (Figure 9).

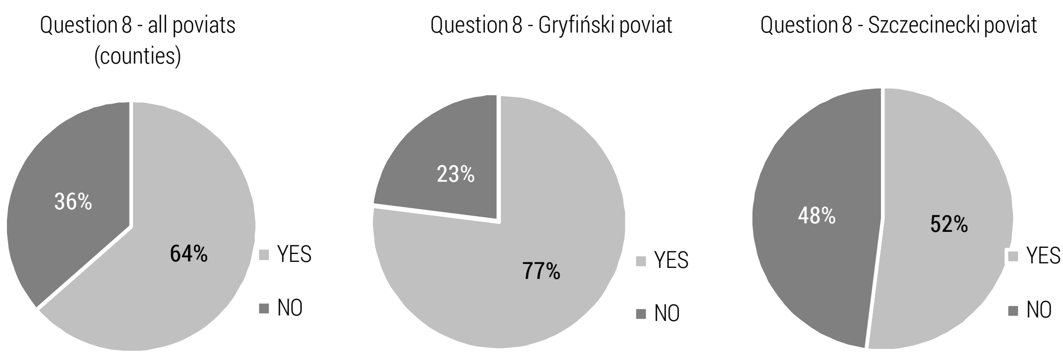

Figure 9. Do you think the Local Water Partnership initiative could have a positive effect?

Source: author's work based on questionnaire research.

In total, 64% of the respondents expressed their positive opinion on the establishment of the LWP. The highest number was recorded in the Gryfiński poviat – 77%, while the lowest in the Szczecinecki poviat, where only 52% of the respondents positively assessed this initiative.

Despite the differences in the number of respondents reported in individual poviats of the West Pomeranian Voivodeship, the obtained results give the opportunity to formulate very preliminary conclusions related to the level of awareness of rational water management in agriculture among the participants of the survey and their interest in the available training offer.

Summary and conclusions

The escalating extreme weather events require a revision of the current approach to water management in agriculture; an industry most vulnerable to the effects of climate change and the related water shortages. In rural areas, this requires a holistic approach to rational water management, taking into account all the needs of residents with an emphasis on maintaining agricultural production, which is crucial for the country's food security. Rational water management means striving to meet the current needs related to the use of water resources in such a way as not to reduce the access of other users and, at the same time, to protect water and water-dependent ecosystems in order to maintain the sustainability of natural processes in the natural environment. Rational water management in rural areas includes not only the drainage of water from the fields, but also its retention, e.g. by building appropriate devices for irrigation or retention on farms. This requires the knowledge and commitment of agricultural producers in the use of economical water management practices in agricultural production. It is the farmers who, through the way of carrying out agro-technical operations on their crops, have an impact on the rational management of water resources and counteracting the effects of water deficit in agriculture and in rural areas.

The following conclusions can be drawn from the conducted pilot study:

1. In general, there is very little interest of agricultural producers in participating in surveys and meetings organized in poviats on rational water management in rural areas (277 people, i.e. less than 30%).
2. The vast majority (86%) of respondents participating in the study showed knowledge about the agronomic category and soil class on their own farm and the existence of areas that can be used for water retention in the farm area.
3. In terms of knowledge about support mechanisms for water matters – retention, drainage infrastructure or construction of irrigation systems, only 18% of farmers showed such knowledge.

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4. 90% of the farmers participating in the survey believe that trainings on water management in agriculture and the application of good agricultural practices conducted by the Agricultural Advisory Center in order to increase and restore small retention are very necessary.
5. Over 70% of the respondents did not participate in training on water management in agriculture, pointing to insufficient publicity and poor access to information on this kind of training. At the same time, they postulated to introduce – apart from traditional lectures and thematic meetings – an online form, e.g. in the form of webinars.
6. Nearly 2/3 of the respondents do not know the competences of individual institutions dealing with water management, and the regulations on irrigation, development and retention maintenance are either completely unknown or incomprehensible to them – participants in the meetings indicated that the reception of complicated and constantly changing regulations posed a significant challenge.
7. The initiative to establish a Local Water Partnership was assessed very positively by the farmers. They hope it could create a a communication platform for efficient problem solving in the field of water management in poviats.

In the poviats surveyed, there is a need to implement comprehensive irrigation solutions, mainly through financial support for the purchase of water retention devices for irrigation purposes and training in the applicable administrative procedures and the possibility of obtaining target funds.

This study attempts to look at only selected aspects of rational water management in agriculture related to the agricultural production retention and irrigation system, the main contractors of which are farmers. Unfortunately, the obtained conclusions from the conducted pilot study give a not-very-optimistic picture of the awareness and involvement of farmers in selected poviats of the West Pomeranian Voivodeship. However, there is no doubt that, without their active participation, activities in the area of rational water resources management in rural areas will not be possible to implement.

The issues raised regarding retention and introduction of irrigation systems constitute an important aspect of rational management of water resources in agriculture and counteracting the effects of water deficit in rural areas. However, to complete the presented issue, further research will be continued on the functioning of the established Local Water Partnerships, which will be presented in subsequent studies.

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Wytyczne techniczne dotyczące stosowania zasady „nie czyń poważnych szkód" na podstawie rozporządzenia ustanawiającego instrument na rzecz odbudowy i zwiększenia odporności (DZ.U.UE.C. 2021.58.1). (in Polish).

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CHARACTERISTICS OF SEWAGE SLUDGE COMPOSITION FOR AGRICULTURAL USE

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ABSTRACT: The article focuses on the research conducted on sewage sludge in Ternopil City, Ukraine, with a specific emphasis on its microelement composition and implications for disposal and utilisation. Bacterial contamination in both old and new sludge storage facilities is revealed by the study. It is found that the sludge holds potential as a fertiliser due to its nutrient content and organic matter, although adjustments may be necessary for specific soil conditions. However, it is determined that the permissible limits for agricultural use are exceeded by heavy metal concentrations, indicating pollution resulting from landfills, old pipes, and intensive agriculture. According to existing regulations, the sludge is considered suitable only for composting. The importance of sludge monitoring, treatment, and management is underscored by the findings, as they are crucial for ensuring safe disposal, mitigating environmental risks, and addressing potential health hazards.

KEYWORDS: sewage sludge, sewage treatment, heavy metals, sludge's physical and chemical composition

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Introduction

Sewage sludge poses a significant challenge resulting from population growth and industrial development. Large volumes of sediment are generated during wastewater treatment, posing environmental and human health risks. These sediments, accumulating on sludge sites, can result in soil, groundwater, and air contamination, as well as contribute to greenhouse gas emissions. Research reveals extensive sewage sludge production in different countries, with the United States producing 6.5 million tons annually, of which only 29% is properly treated (EPA, 2009).

Sludge undergoes stabilisation and, in most cases, dewatering processes to facilitate efficient handling and transportation. Stabilisation procedures usually decrease putrescibility, minimise potential odours, and reduce pathogens and vectors attractants. Dewatering methods transform solids containing at least 95% water into semi-solid material with a water content ranging from 50% to 85%.

China is currently facing challenges in the land application of sewage sludge due to inadequate treatment and disposal practices. This has resulted in environmental pollution and potential risks to human health. As China's municipal wastewater treatment ratio increases, the production of sewage sludge is expected to rise rapidly, making the issue of disposal even more serious and unavoidable. However, if properly managed, stabilised sewage sludge can positively impact agriculture, forestry, horticulture, and urban development. The main obstacles to land application are the high concentrations of heavy metals, organic pollutants, and pathogens in sewage sludge resulting from wastewater treatment (Wang, 1997).

In Japan, approximately 2 million tons of sludge are produced yearly as a byproduct of wastewater treatment. However, despite this substantial volume, only a small fraction of the sludge is utilised as fertiliser. Efforts to maximise the utilisation of sludge as fertiliser can contribute to resource conservation, reduce environmental impact, and support the development of a circular economy in Japan's agricultural sector (Nakamaru et al., 2023). Within the European Union, the quantity of sediment amounts to approximately 10 million tons annually, highlighting the magnitude of this resource. However, despite its vast volume, only around 36% of this sediment is currently being utilised in agricultural practices (Eurostat, 2023).

Ukraine, as a prosperous country with a well-established industry and a substantial population, is also confronted with the challenge of sewage sludge disposal. According to the data, 3 million tons of sediment are generated annually within the country, of which only 3 to 5% are used as secondary raw materials, mainly for the production of organic-mineral fertilisers.

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This indicates an untapped potential that has yet to be fully utilised in Ukraine. It is crucial to explore and implement innovative strategies to optimise the utilisation of sewage sludge, thereby fostering sustainable practices and minimising waste in the country (Tymchuk et al., 2020).

In the processes of mechanical, biological, and physico-chemical purification of domestic, industrial, and agricultural wastewater at treatment plants, various types of sediments are formed, which differ in composition, properties, and impact on the environment. Mostly sediments from primary settling tanks, excessive activated sludge, and their mixtures, sediments from sludge maps are applied to the soil as fertiliser (Shevchenko et al., 2012).

Sewage sludge contains a wide range of bacterial species, surpassing the quantity found in sewage. Sediments contain many microorganisms and microscopic fungi, including pathogenic species. These sediments can contain up to 10 different types of parasitic pathogens, posing a potential threat to human health. Proper disposal or burial of sediments requires compliance with sanitary and hygienic standards to prevent direct or indirect risks. Storage of sediments on sludge cards for less than one year is not enough for their complete disinfection. Some pathogens can remain active for a long time, but after long-term storage (more than 3 years), the risk of infection with helminths is practically absent.

Sewage sludge from urban wastewater treatment plants contains many organic matter, macro- and microelements, and biologically active substances. Certain types of sewage sludge exhibit comparable effectiveness to conventional organic fertilisers. The availability of phosphorus in sewage sludge varies depending on its type, with fresh sludge displaying similar availability to monocalcium phosphate, while dried sediments provide less accessible phosphorus for plants (Kelley et al., 1984). Phosphorus content increases the most during the 2-3 year period of organic matter mineralisation in sewage sludge. Nitrogen within sewage sludge is predominantly found in organic compounds, with mineral nitrogen primarily as ammonium. This enhances nitrogen assimilation by plants from the soil, stimulates root system development, and boosts soil microorganism activity. These factors contribute to an additional 15-20% nitrogen uptake from fertilisers.

The utilisation of fermented sludge as a substitute for or in conjunction with organic fertilisers proves to be highly beneficial. Sediments exhibit higher levels of phosphorus and calcium compared to manure. Moreover, nitrogen and phosphorus within sediments are readily absorbable by plants. Multiple researchers testify the feasibility of such an application. However, it is imperative to subject sewage sludge to specialised treatment to prevent the introduction of substantial quantities of pathogenic microorganisms and heavy metal salts. Additionally, strict control over their content is necessary

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when using sludge as fertiliser on land plots (Milieu Ltd et al., 2010; Ali et al., 2017; Chen et al., 2018).

In addition, there are different approaches to wastewater treatment methods used in different regions, which also affect sewage sludge composition and properties. For example, sewage sludge usually contains chemicals harmful to plants and soil in regions where chemical methods of wastewater treatment are used. At the same time, sewage sludge contains biologically active substances beneficial for plant growth if biological wastewater treatment methods are used in the region. Therefore, research on the suitability of sewage sludge as a fertiliser must take into account regional characteristics in order to determine their usage efficiency and safety. This research aims to assess the possibility of sludge use as fertilisers in agriculture, taking into consideration various factors such as quality, heavy metal content, etc. The study focuses on investigating the characteristics of sewage sludge in Ternopil City as a region in Ukraine and its suitability as a fertiliser in agriculture because research results on sludge suitability vary depending on regional and geographical characteristics.

Research methods

A technique of sewage sludge sampling. At the time of sampling (March 2021, May 2021), the sediments of the sewage sludge field were finely dispersed and loosely compacted, and, in some places, it was noticed as water-saturated sludge. A sampling of accumulated sediments was conducted using a cylindrical metal pipe with a lower valve. The sampler had a diameter of 128 mm and a length of 1 m. A pipe was attached to the upper part of the sampler, allowing for increased length through coupling connections. The sediment deposits had a thickness of 3 m or more. Sampling was performed at specific depth intervals: 0-0.2 m, 1.4-1.6 m, and 2.8-3 m. These intervals were selected to investigate the ecological, biogeochemical, and parasitological characteristics of the sediments in near-surface, mid-depth, and bottom conditions. Each sample had a volume of 2.5 dm^3 and was carefully packed in double polyethene bags. A unique serial number was assigned to each sample, which was recorded in the sampling log. The selection points were geodetically measured and marked in the area (International Organization for Standarization, 2002). Fresh sediment samples were collected immediately after being unloaded from the centrifuge and placed into polyethene bags for further analysis.

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The techniques of analytical determination of sewage sludge composition

As a standard on the technique of sludge composition's indices from the treatment plants determination hasn't yet been developed, the study was carried out according to the current regulatory documents on soil analysis (Clesceri et al., 1998; Van Reeuwijk, 2002).

The organic substance content was determined gravimetrically after dry burning of the sample. The moisture content was determined gravimetrically after being dried to the constant mass at 105ºC. The sludge acidity was determined potentiometrically by measuring water extract pH (water: soil ratio 1:5). Total content of metals (Cu, Ni, Pb, Cd, Mn, Cr and Zn) was determined by the atomic absorption method after samples acid decomposition in the hydrogen peroxide presence.

Mercury (Hg) from the sludge samples was removed by acids and determined in the obtained solution by the spectrophotometric method. The extraction of exchangeable forms of metals (Cu, Ni, Pb, Cd, Mn, Cr, Zn, Co, Fe) was conducted by ammonium-acetate buffer solution with pH 4.8 at the solution: soil ratio 1:5, with the further analysis of the obtained extracts by the atomic absorption method. Total and ammonium Nitrogen were determined by the titrimetric method. Phosphorus moving compounds were extracted from the soil by the ammonium carbonate solution of 10 g/dm^3 concentration at the soil: solution ratio 1:20, and further, the phosphorus was determined as a blue phosphorus-molybdenum complex on the spectrophotometer. A bacteriological and parasitological study of the sewage sludge was carried out by the titrimetric and microscope methods, respectively.

During the correlation analysis, various statistical characteristics were calculated, including the arithmetic mean values of system parameters, the standard root mean square deviation, and the coefficient of mutual correlation. The confidence interval limits were determined by multiplying the root mean square deviation by the dimensionless Student's coefficient. The calculations were performed using the standard Excel package.

Results of the research

The main sanitary and biological, physical and chemical and agrochemical indices of six obtained samples have been determined during the research of Ternopil city sewage sludge (Tables 2-4).

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Table 2. Sanitary-biological indices of sewage sludge in Ternopil City

№ of lot	Time of sample obtaining	№ of sample	Area of sample obtaining	Number of bacteria	Titre coliform bacteria	Helmints eggs	Titre Cl. perfringes
1	March 2021	1	Storage platform (old)	94100	<0.00001	none	0.1
		2	Storage platform (new)	52000	0.001	none	0.1
		3	Sludge lagoon №21 – 2 years	77200	<0.00001	none	0.1
2	May 2021	4	Storage platform (new)	119200	0.0001	none	>0.1
		5	Sludge lagoon №1– V. Myshkovychi	6520	0.01	none	>0.1
		6	Sludge lagoon № 25 – 4 years	79200	0.01	none	>0.1

The common feature of all six sludge samples is their bacterial contamination (titer coliform bacteria less than 0.1), although its extent varies.

Table 3. Sludge agrochemical characteristics city

№ of lot	Time of samples obtaining	№ of sample	Samples obtaining area	pH	Humidity %	% of dry substance				Ash content %
						N	P2O5	K2O	C	
1	March 2021	1	Storage platform (old)	7.1	68.6	1.13	2.1	0.48	10.66	22.34
		2	Storage platform (new)	7.6	84.8	1.41	2.11	0.49	15.96	31.12
		3	Sludge lagoon №21	7.2	77.6	1.10	2.41	0.46	16.91	24.32
2	May 2021	4	Storage platform (new)	7.1	32.3	1.39	2.62	0.45	10.94	28.68
		5	Sludge lagoon №1 – V.Myshkovychi	7.3	85.4	1.42	2.35	0.58	13.26	24.35
		6	Sludge lagoon № 25	6.7	20.9	1.66	2.21	0.29	11.2	24.01

It is important to note that the possibility of sewage sludge being used as fertiliser also depends on the presence of any contaminants or heavy metals. Specific information about heavy metal concentrations is presented in Table 4.

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Table 4. Heavy metals content in the Ternopil city sewage sludge, mg/kg of dry substance

№ of lot	Samples obtaining time	№ of sample	Samples obtaining area	Sr	Cr3+	Ni	Co	Cd	Mn	Pb	Cu	Fe	Zn
1	March 2021	1	Storage platform (old)	214	196	25	26	47	476	248	249	12670	1562
		2	Storage platform (new)	123	106	188	25	26	487	118	101	13220	888
		3	Sludge lagoon №21	356	226	26	35	47	486	520	448	13430	1568
2	May 2021	4	Storage platform (old)	368	307	526	0	54	468	489	418	14540	1327
		5	Sludge lagoon №1 – V. Myshkovychi	326	24	327	0	36	487	450	316	13800	1218
		6	Sludge lagoon № 25	287	326	563	0	64	435	377	346	14440	1364

Discussion and future research

Various factors cause fluctuations in the trace element composition of the sewage sludge at different depths. One significant factor is the leaching of chemical compounds from the upper layer of the sewage sludge, which then are accumulated in the lower layers. The leaching process is also influenced by meteorological and seasonal conditions, such as rainfall and temperature fluctuations. Additionally, the intensity of biochemical processes occurring in the sewage sludge can also contribute to the variations in trace element composition. These processes involve the activities of microorganisms, plants, and other biological agents, which can alter the concentration of trace elements over time. Furthermore, the wastewater components can impact the trace element composition of the sewage sludge.

The samples obtained from the old and new storage platforms, as well as from sludge lagoon №21 with a storage period of 2 years, have demonstrated the highest levels of bacterial contamination. This finding emphasises the importance of careful control and treatment of these sludge samples before their utilisation or disposal. It's worth noting that the titers of coliform bacteria in all samples were less than 0.1, except for one sample where it was greater than 0.1. Although the exact unit of measurement is not specified, the low titers generally suggest a relatively low level of contamination by coliform bacteria. However, it is important to assess the sanitary and biological aspects of the sewage sludge comprehensively, taking into account other parameters such as the presence of helminth eggs and Titre Cl. perfringes, as

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presented in the table. These additional parameters provide insights into the potential health risks associated with the sludge. Overall, the findings emphasise the need for proper monitoring, treatment, and management of sewage sludge to ensure its safe handling and minimise potential environmental and health hazards.

The provided information in Table 3 includes the details of the samples collected from different sources, their time of collection, and various parameters related to the sludge's physical and chemical composition. The table consists of six samples collected in March and May 2021. The first two samples were obtained from storage platforms, one from the old storage platform and the other from the new storage platform. The third sample was collected from Sludge Lagoon №21. There were others, the Storage platform (new), Sludge Lagoon №1 – V.Myshkovychi, and Sludge Lagoon № 25.

Based on the provided information in Table 3, the possibility of the sewage sludge being used as a soil fertiliser can be assessed. The sludge samples exhibit various characteristics that are desirable in a fertiliser, such as significant nutrient content. The nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) concentrations are present in measurable amounts, indicating that the sludge contains essential nutrients that can contribute to plant growth and development. Additionally, the carbon (C) content suggests the presence of organic matter, which can enhance soil fertility and improve its overall structure and water-holding capacity. However, certain factors need to be considered when evaluating sewage sludge use as a fertiliser. The pH values of the sludge samples range from slightly acidic to neutral, which may require additional adjustments depending on the specific soil conditions and crop requirements. Furthermore, the ash content indicates the mineral composition of the sludge. Higher ash content may indicate a higher concentration of inorganic compounds, which can be beneficial for certain crops but may require careful consideration to prevent excessive buildup of specific elements in the soil. When comparing the heavy metal content in the Ternopil city sewage sludge samples (Table 4) with permissible limits and analysing the data, several observations can be made:

1. The concentrations of Cd in all samples are noticeable, with values ranging from 36 mg/kg to 64 mg/kg. These values exceed the maximum permissible concentration for sludge application in agriculture, indicating potential environmental and health risks associated with Cd contamination.
2. The sludge samples also demonstrate elevated Pb concentrations, ranging from 118 mg/kg to 520 mg/kg. Similar to Cd, these values exceed the permissible limits for agricultural use, suggesting the presence of potentially harmful levels of Pb in the sludge.

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3. Chromium concentrations vary across the samples, ranging from 24 mg/kg to 326 mg/kg. Although these values do not exceed the maximum permissible concentration, they indicate the presence of Cr^{3+} in the sludge, which may require careful monitoring and management to prevent further accumulation.
4. The concentrations of other heavy metals such as strontium (Sr), nickel (Ni), cobalt (Co), manganese (Mn), copper (Cu), iron (Fe), and zinc (Zn) also vary among the samples. While some values fall within acceptable ranges, others approach or exceed the maximum permissible concentration.

Overall, the results indicate the presence of various heavy metals in the Ternopil city sewage sludge, with several metals exceeding the permissible limits for agricultural use. Landfills and water systems, which consist of old metal pipes, are determined as the main sources of heavy metal pollution in the Ternopil region. Landfills might contain heavy metals, such as lead and mercury, which gradually enter groundwater and surface water sources and contaminate wastewater. In addition, intensive agriculture, the usage of mineral fertilisers, pesticides, and other chemicals can also cause heavy metal pollution in soil and wastewater. According to the above-mentioned indices and existing standards that regulate the content of heavy metals ACs, all identified sludge samples in Ternopil city are of the fourth group (Norm, 1999), i.e. it can be applied only for composting (Kalamdhad & Singh, 2013; Osman et al., 2017; Van Reeuwijk, 2002; J. Zhang et al., 2017; Q. Zhang et al., 2017).

Technological solution:

One of the possible examples of sediments for composting preparation with increased content of heavy metals in bioconvectors may include the following steps: a preliminary analysis of the heavy metals content, which will help to define the level of contamination and determine the necessary measures to prepare material for composting; material sorting with separation of heavy metals and other unwanted impurities; chemical treatment of sediments by using chelating agents, which ensure binding of heavy metals and their removal from the material; composting of sediments in bioconvectors, while observing the optimal temperature, humidity and ventilation to ensure the effective decomposition of organic substances and finished compost formation; analysis of heavy metals content in finished compost to ensure its safe usage (Osman et al., 2017; El-Fadel et al., 1997; Chen et al., 2018; Zhang et al., 2017).

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Conclusions

The microelement composition of the sewage sludge of the Ternopil City, located in the Western region of Ukraine, was studied at various depths. It was found that bacterial contamination is observed in samples from both old and new sludge storage platforms, emphasising the importance of proper control and treatment before disposal or utilisation. The possibility of the sewage sludge being used as a fertiliser was assessed based on its nutrient content, carbon levels, pH values, and ash content. It was revealed that significant amounts of nutrients and organic matter are present in the sludge, although adjustments might be necessary depending on specific soil conditions. Furthermore, the permissible limits for agricultural use were exceeded by the concentrations of heavy metals in the sludge samples, particularly cadmium (Cd) and lead (Pb), as well as other elements. The presence of various heavy metals in the sewage sludge indicates pollution sources such as landfills, old metal pipes, and intensive agricultural practices, which have the potential to contaminate groundwater, surface water, soil, and wastewater. Consequently, the identified sludge samples are only suitable for composting following existing standards and regulations. Overall, the importance of proper monitoring, treatment, and management of sewage sludge to ensure safe disposal, minimise environmental risks, and reduce potential health hazards is emphasised by the results. Future research should focus on the development of effective treatment methods to reduce heavy metal concentrations in sewge sludge and the exploration of alternative options for the disposal or utilisation of contaminated sludge.

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The contribution of the authors

T.V. conceived of the presented idea, developed the theory and performed the computations, suggested the research methods, and designed the figures. T.V. wrote the manuscript with support from N.M. and I.K. N.M. prepared the research results analysis. I.K. summarised the research results.

All authors discussed the results, and contributed to the final manuscript.

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ANALYSIS OF ROAD ACCIDENT CAUSES IN THE VOIVODSHIPS IN THE YEARS 2014-2021 IN THE ASPECT OF SOCIO-ECONOMIC COSTS – TOWARDS THE IMPLEMENTATION OF SUSTAINABLE DEVELOPMENT

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ABSTRACT: The article addresses the topic of road safety. The objective of the research was to assess road accidents caused by voivodships. The analysis took account of the socio-economic differences in the voivodships, which determine the unit costs of fatalities and injuries. A descriptive analysis is given to show the dynamics of changes in the years 2014-2021 in the voivodships and how different factors influenced change. The article analyses the relation between road safety and the region's socio-economic development. Data availability determined the time series applied. As we know from research, accidents fall in relation to the (demographic) density of improved roads. Accidents increase, however, in relation to the density of population and GDP per capita. These relations take the opposite direction if the (demographic) fatality rate or accident severity rate (fatalities per 100 accidents) is the dependent variable. Socio-economic losses were estimated using Statistics Poland data. To value the unit costs of road accidents, the PANDORA method was used. The analysis helped to group the voivodships for their highest and lowest socio-economic costs of road accidents with a special focus on the unit costs of road deaths. The originality of the research is related to the updated voivodship level research.

KEYWORDS: Agenda 2030, sustainable development, road accident, socio-economic costs, voivodships

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Introduction

In the context of sustainable development, road accident injury and fatality reduction is of key importance, not only because of the human tragedies but also because of the socio-economic costs. Road accidents generate huge financial losses. The analysis takes into account the number of injuries and fatalities, broken down by voivodships, and their causes, i.e. accidents caused by drivers (including failure to adjust speed to the traffic conditions, failure to respect the right of way, incorrect overtaking, incorrect behaviour towards pedestrians, failure to keep a safe distance between vehicles) and by pedestrians. In addition, the types of roads and surfaces are taken into account and the type of the perpetrator's vehicle. Particular attention was paid to road accidents involving drunk road users. The analysis was carried out in the context of different rates of socio-economic development, which determines the unit costs of fatalities and injuries in individual voivodships.

The UN 2030 Agenda, which came into effect on 25 October 2015, consists of 17 Sustainable Development Goals and 169 targets. The main challenge is to achieve a more integrated approach to sustainable development. Building on the Millennium Development Goals of 2000, Agenda 2030 calls on each UN member state to implement the 17 goals and related targets and in addition to supporting the implementation of the goals in all other parts of the world by 2030 (Weiland et al., 2021; Venturelli & Pizzi, 2022). With regard to the subject of this work, Goal 3, which is to ensure a healthy life for all people of all ages and to promote well-being, should be considered key. Target 3.6. is to halve the number of global deaths and injuries from road traffic accidents (Venturelli & Pizzi, 2022) by 2020 compared to 2010. Poland as a whole and none of its counties have achieved the Agenda 2030's goal (Romanowska et al., 2022). From the point of view of road safety, research should focus on the causes of accidents with particular attention to infrastructural factors and the human factor, i.e. drunk road users. While a road accident happens in a fraction of a second, it causes different types of costs, including health, psychological and socio-economic costs. If treatment measures are to become more intensified in areas of the greatest risk, the goal should be to reduce road traffic fatalities and injuries and the resulting socio-economic costs. This is because road accidents involve very high costs paid by society as a whole. The Polish public cannot afford to pay the increasing costs of road accidents. Therefore, actions that are part of sustainable development focus on reducing casualties (KRBRD, 2021b). The people affected both perpetrators and victims of accidents, are usually of working age. In Poland, road accidents are the number one cause of death for men under 44 years of age (Goniewicz & Goniewicz, 2016). This translates into measurable negative

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economic consequences as measured by a country's economic growth (Decae, 2021; Neelakantan et al., 2017; Mohan, 2002; Nantulya & Reich, 2002).

Poland is among the top EU countries for the most dangerous roads. In 2021 there were 65 fatalities per one million population, while the EU average is 42 (Eurostat, 2022). The costs of all road accidents in Poland amounted to PLN 39.3 billion in 2021 (KRBRD, 2021b), representing 1.5% of GDP (BDM, 2022). The research results presented in the article are related to the voivodship level. The data comes from Statistics Poland's Local Data Bank (GUS, 2022a), the SEWIK database (SEWIK, 2021) and the National Road Safety Council (KRBRD, 2021a). The descriptive analysis is preceded by a brief characterisation of the causes of road accidents and the methodology for valuing their costs.

Causes and methodology for valuing the costs of road accidents

The literature usually distinguishes four groups of theories regarding the causes of road accidents, namely stochastic, causal, systemic and behavioural (Weszczak, 2018; Jamroz et al., 2018). We divide the aetiological factors of road accidents into environmental (e.g. the wealth of society and the road infrastructure, including road network loads, the quality and length of the network, the expenditure on its construction, upgrading and safety improvements) and human factors (concerning drivers, pedestrians and passengers), with the latter accounting for 90% of accidents (Rosiak, 2022; Singh & Kushwaha, 2016). The most common human errors responsible for accidents as regards drivers include: speeding, failure to respect road traffic regulations, intoxication (alcohol, substances), fatigue and drowsiness, and using the phone or texting while driving. From the point of view of pedestrians who cause accidents, the most common cause is carelessness when crossing the road, including the simultaneous use of a phone. Human factors are also related to the behaviour of passengers and may distract the driver. The causes of accidents can also be divided into environmental, socio-demographic, technological, medical, political, organisational and human factors (Yasmeen, 2019).

The methodology for valuing road accident consequences, i.e. their costs, is an extremely difficult task because human life cannot be expressed in simple mathematical operations, and not all costs can be estimated. In general, we divide the costs of road accidents into direct, indirect (long-term) and additional costs, which are difficult to estimate. Table 1 gives examples of costs associated with road accidents. As well as causing injuries, road acci-

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dents can lead to death, which in economic terms means lost GDP and unrealised consumption. The costs of serious road injuries are higher than those of fatalities.

Table 1. Socio-economic costs of road accidents

Costs of road accidents	Examples
direct	– medical expenses (costs of treatment and rehabilitation of injuries caused by road accidents) – costs of damage to vehicles, roads, roadside structures and cargo – administrative costs (operational and policing services, insurance, legal costs) – incapacity to do paid work – lost quality of life
indirect (long-term)	– deterioration of physical health (e.g. permanent disability) – psychological effects (on the victims, relatives of victims, on perpetrators, participants and witnesses) – social consequences (loss or change of job, situation of the victim's relatives, legal problems of the perpetrators) – economic consequences (medical, administrative, loss of property, loss of ability to work and deterioration of financial situation, costs of operational and policing services, e.g. personnel costs) – death (funeral and mortuary costs)
additional	– time lost – increased fuel consumption – carbon footprint

Source: authors' work based on Gwarda-Żurańska (2016); Jaździk-Osmólska (2014); Wijnen (2021).

Socio-economic costs are divided into internal (individual social consequences, costs covered by, e.g. insurers who pay out compensation) and external costs (the country's general economic losses, costs generated by individuals and paid by society as a whole at the same time) (Jaździk-Osmólska, 2014). Households pay huge costs of road accidents. In the case of disability or death of the main breadwinner, households can be plunged into poverty with road accidents incurring disproportionate costs, especially for low income households (Aeron-Thomas et al., 2004), which may lead people to take out loans and incur debt and may result in a drop in consumption.

The costs of road accidents are generally divided into medical costs, production losses, human costs, vehicle damage and administrative costs. The costs of road accidents are borne by society, with a significant part of the cost falling on the health sector (costs of medical rescue) and employers (a premature loss or disability of an economically active employee). While the costs of road accidents can be estimated and presented as financial consequences, it is extremely difficult to calculate the value of human life: pain, suffering, poorer quality of life of the casualties and their loved ones and how the fam-

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ily will cope in the case of death – both from an emotional and socio- economic point of view.

According to the welfare economics theory, human costs (loss of quality of life and years of life) as intangible costs should be included in road accident studies to reflect the full impact of road accidents on socio-economic welfare (Boardman et al., 2011; Freeman et al., 2014; Wijnen et al., 2019). Three methods are used to value the socio-economic costs of road accidents (Wijnen, 2021):

- restitution costs generated by the road accident,
- the cost of human capital,
- willingness-to-pay (WTP).

As regards the costs of restitution, the objective is to estimate the costs of treatment, property damage and administrative costs. The estimation includes the direct costs of resources (e.g. labour, equipment) for treatment, vehicle repair, rescue, legal, administrative and insurance matters. In most cases, market prices are used to estimate these costs (Alfaro et al., 1994). To calculate production losses, the human capital approach is followed. It values the loss of production capacity due to the victim's road accident (Wijnen & Stipdonk, 2016). To calculate human costs, the WTP method is used – how much people are willing to pay to reduce risk? This helps to define the value of a statistical life (VSL), which includes human costs and consumption losses (Wijnen et al., 2009). The share of human costs in overall road accident costs varies, depending on the methodology. In the WTP approach, human costs represent 34% to 91% of overall accident costs. In countries which use the alternative method, the share is less than 10%, with the main costs being property damage and production losses, while medical and administrative costs are relatively low (Wijnen et al., 2017).

In Poland, accident and collision costs are calculated using the PANDORA method. It is based on the valuation of human capital costs and restitution costs generated by a road accident. The method values total costs and unit costs of four categories: death, serious injury, slight injury, and financial consequence. Unit costs are valued based on: the work of police and rescue services, mortuary and funeral, hospitalisation, criminal proceedings, compensation and reparation, material consequences and the country's economic loss (KRBRD, 2022b). The method is designed to value the losses to the economy from the death and ill health of an individual as a result of a road accident. The valuation results are a function of the lost GDP and unrealised consumption due to the premature death and incapacity of accident victims. This means that working-age road accident victims have the highest social costs while older victims have the lowest (Jaździk-Osmólska, 2015). In Poland, the most common cause of casualty accidents is speeding. In addition to speeding, the causes of accidents in Poland are: not wearing a seatbelt,

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driver distraction and driving under the influence of alcohol. Despite a decrease in the overall number of road accidents, there has been an upward trend in Poland in the number of accidents caused by drunk drivers (ITS, 2022).

Road incidents are divided into: road accidents and road collisions. An accident is an event that has unintentionally happened that results in damage, injury or harm. A collision is an event that has unintentionally happened, but this may not result in damage, harm or injury. The costs of all road incidents in Poland in 2021 amounted to PLN 39.3 billion. In 2021 the unit costs of road accidents were as follows (KRBRD, 2022b):

- the cost of a fatality: PLN 2.6 m,
- the cost of a serious injury: PLN 3.5 m,
- the cost of a slight injury: PLN 51.3 thousand,
- the cost of a material consequence: PLN 4,700,
- the cost of a road accident: PLN 1.6 m.

The social costs of all road incidents (accidents and collisions) in Poland in 2021 decreased by PLN 17.3 billion (a decrease of 31%) compared to 2018 when these costs amounted to PLN 56.6 billion. The low value concerning the cost of a material consequence was because of the Covid-19 pandemic and the related road traffic restrictions. In 2021 the total value of material as a consequence result of collisions and road accidents amounted to PLN 3.3 billion, which is 73% less than in 2018 – then it was PLN 12.1 billion (KRBRD, 2022b). The unit cost of a material consequence amounted PLN 4,700 in 2021, while in 2018, it amounted to approx. PLN 16,000. To reflect the socio-economic differences between the voivodships, the costs and causes of road accidents are presented by voivodship.

Road safety diagnosis and socio-economic costs of road accidents in the voivodships

Between 2014 and 2021, there were a total of 242,679 road accidents in Poland (Figure 1), with 22,504 deaths (Figure 2) and 288,269 injuries (Figure 3). Over seven years (2014-2021), the number of accidents was reduced by 35% (34,970 to 22,816) and the number of fatalities by 30% (3,202 to 2,245). Despite that, the number of casualties is significantly higher than the targets set in the National Road Safety Programme 2013-2020 (KRBRD, 2021a) (the programme assumed fatality reduction down to 2,000 in 2020) and far from the Agenda 2030 target (Weiland et al., 2021).

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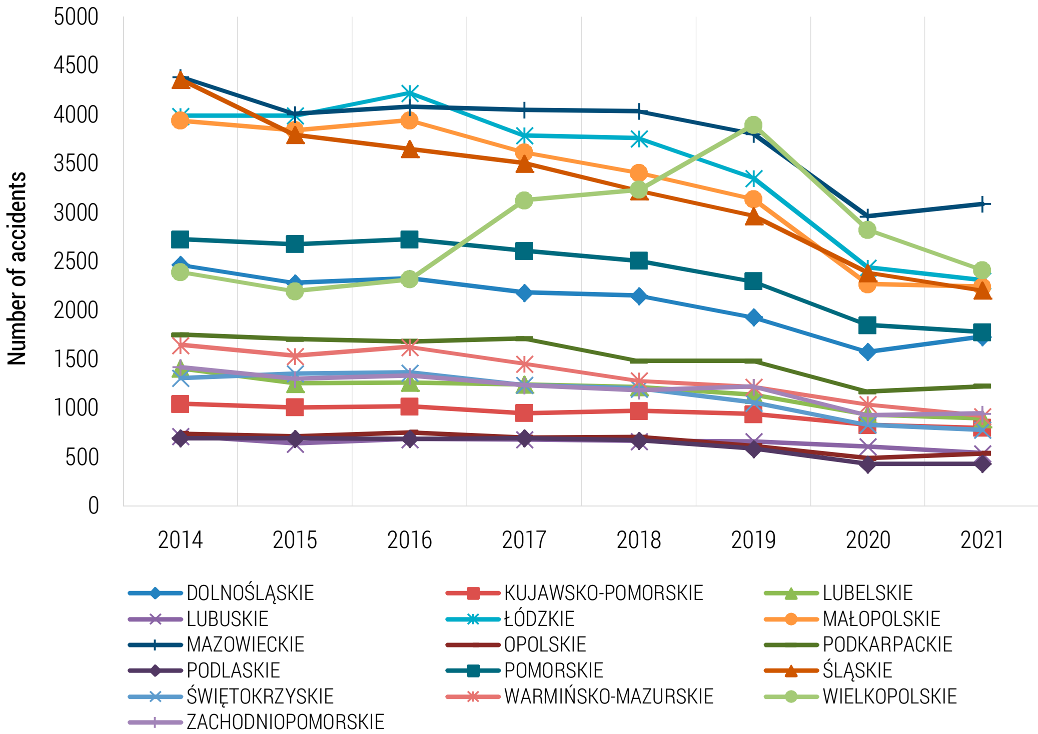

Figure 1. Number of road accidents in voivodships between 2014 and 2021

Source: authors' work based on GUS (2022b).

The highest number of road fatalities is recorded in the voivodship of Mazowieckie. In 2021 this was 375 people. However, because of the Covid-19 pandemic and the related road traffic restrictions, the year 2019 should be considered instead, with 469 fatalities. The lowest number of fatalities is in the voivodships of Lubuskie, Podlaskie, Opolskie and Świętokrzyskie. Similar variations at the voivodship level can also be seen in road accident injuries. In order to compare the data, the analysis must take into account the number of victims per 100,000 population, as presented further in the work.

The year 2021 shows a renewed upward trend in both the number of road accidents and fatalities and injuries. When analysing Poland's road safety data at the voivodship level, there are clear spatial differences. The fatality rate per 100,000 residents is the highest in the voivodships of Opolskie (8.32) and Łódzkie (7.87). The voivodships with the lowest rates include Śląskie (3.31), Małopolskie (4.22) and Podkarpackie (4.49). Accident severity (measured as the number of fatalities per 100 accidents) is the highest in the voivodship of Podlaskie (18.2), with the lowest rates observed in Małopolskie (6.4), Pomorskie (6.6) and Śląskie (6.7).

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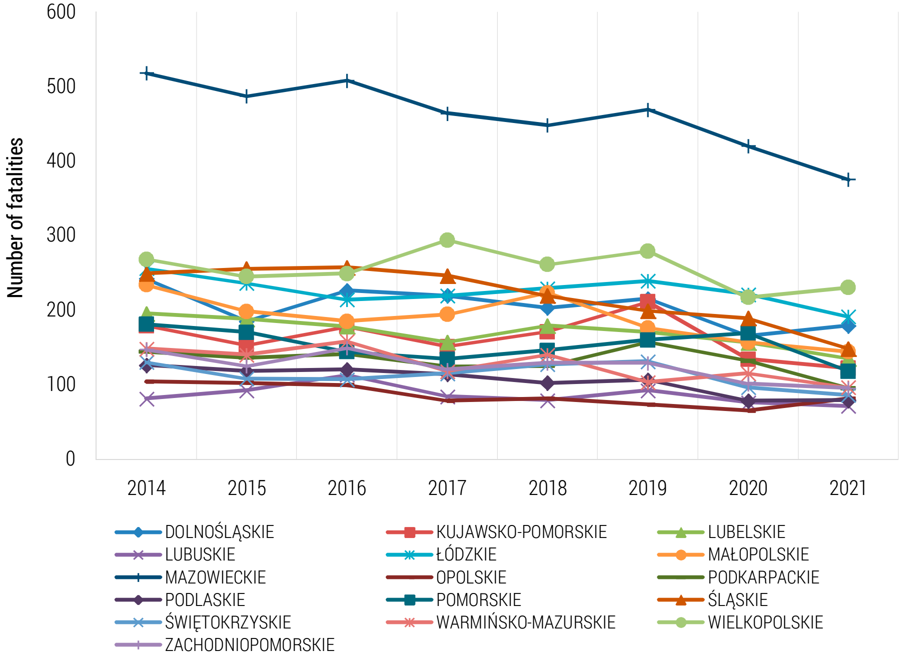

Figure 2. Number of road accident fatalities in the voivodships in the years 2014-2021
Source: authors' work based on GUS (2022b).

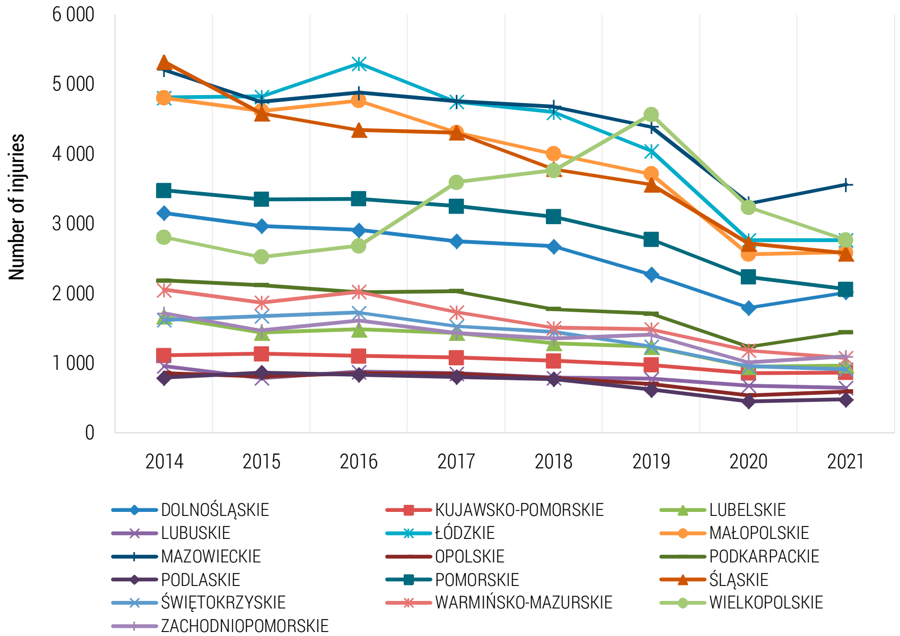

Figure 3. Number of road accident injuries in the voivodships in the years 2014-2021
Source: authors' work based on GUS (2022b).

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The highest reduction in fatalities was recorded in the voivodships of Śląskie (-41%), Małopolskie (-38%) and Podlaskie (-37%), and the lowest in Wielkopolskie (-14%) and Lubelskie (-12%). The map (Figure 4) shows that the decrease in fatalities was the highest in north and east Poland voivodships and the lowest in central and west Poland.

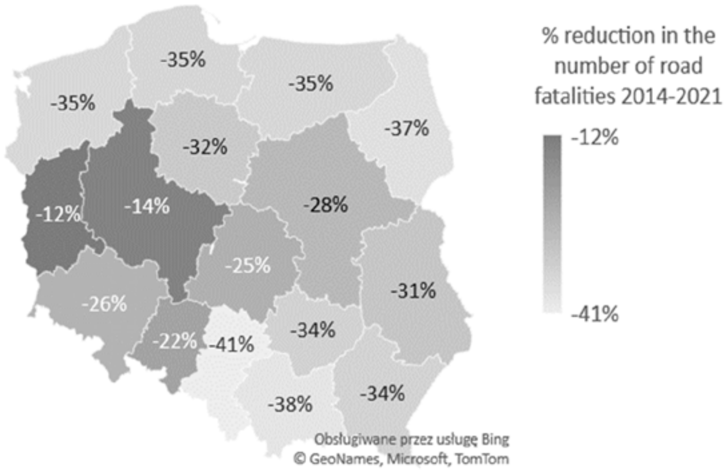

Figure 4. Fatality reduction in the voivodships in the years 2014-2021
Source: authors' work based on GUS (2022b).

The annual costs of accidents are the product of the number of fatalities, injuries and accidents (financial losses) and the respective unit cost. The basic source of data for valuating these costs in Poland, according to the PANDORA method, are police data from SEWIK and Statistics Poland, which provides socio-economic data required for the road accident unit cost valuation (KRBRD, 2022). The costs of victims differ from voivodship to voivodship, which is determined by regional differences in socio-economic development. Below are the unit costs of fatalities and injuries (Table 2) in the voivodships in 2021.

The costs of road accidents in Poland in 2021 amounted to PLN 35.8 billion, which represented 1.4% of Poland's GDP, at the same time and 91% of total costs of all road incidents in our country. It means that 9% were collision costs. The largest share of accident costs was production losses due to employee death or incapacity to work, which represented 71% of all costs. The share of administrative and operational costs was 19%, material losses 8%, and the remaining 2% where the costs of intangible losses and medical expenses (KRBRD, 2022).

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Table 2. Unit costs of road accidents in the voivodships in 2021 [PLN]

	fatality	serious injury	slight injury
DOLNOŚLĄSKIE	1 514 684	2 702 642	54 404
KUJAWSKO-POMORSKIE	1 551 562	2 444 507	81 575
LUBELSKIE	2 262 008	2 705 516	83 152
LUBUSKIE	3 359 895	3 481 045	66 401
ŁÓDZKIE	2 124 028	3 125 627	30 735
MAŁOPOLSKIE	2 271 327	3 031 816	39 237
MAZOWIECKIE	2 394 069	4 018 667	47 228
OPOLSKIE	3 323 760	3 644 542	61 154
PODKARPACKIE	2 521 899	3 199 676	49 167
PODLASKIE	2 101 360	2 985 847	77 246
POMORSKIE	3 407 663	3 795 534	42 904
ŚLĄSKIE	2 787 053	4 040 526	57 667
ŚWIĘTOKRZYSKIE	1 951 739	2 671 298	39 637
WARMIŃSKO-MAZURSKIE	2 810 808	3 427 377	51 171
WIELKOPOLSKIE	2 394 641	3 429 435	46 640
ZACHODNIOPOMORSKIE	2 826 447	3 633 801	49 972

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

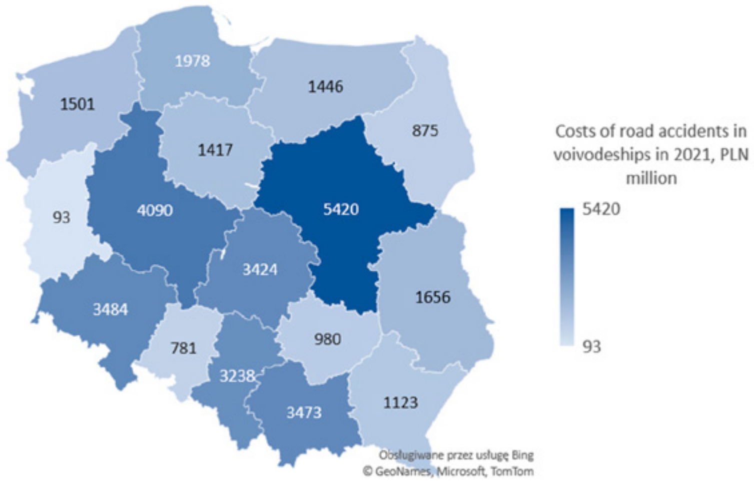

Figure 5. Costs of road accidents in the voivodships in 2021 [PLN million]

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

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As shown in Figure 5, the highest road accident costs were paid in the voivodships of: Mazowieckie (PLN 5.4 billion) and Wielkopolskie (PLN 4.1 billion). Next are the voivodships of Dolnośląskie, Małopolskie and Łódzkie (PLN 3.4 billion each) and Śląskie (PLN 3.2 billion). The lowest costs are incurred by the voivodship of Lubuskie (PLN 93 m).

The above analysis looks at how road accident costs are generated. The causes of accidents should also be analysed.

Causes of road accidents by voivodship

Table 3. Causes of accidents in the voivodships to total accidents in 2019

Region	Caused by driver							Caused by pedestrian
		Speeding	Not giving priority	Unsafe overtaking	Inappropriate behaviour to pedestrians	Maintaining unsafe headway	Other	
DOLNOŚLĄSKIE	85%	22%	22%	4%	13%	6%	18%	7%
KUJAWSKO-POMORSKIE	89%	19%	22%	7%	19%	4%	19%	5%
LUBELSKIE	88%	22%	23%	6%	9%	5%	23%	7%
LUBUSKIE	88%	24%	20%	5%	11%	6%	22%	6%
ŁÓDZKIE	87%	22%	24%	3%	11%	6%	21%	5%
MAŁOPOLSKIE	87%	20%	20%	3%	11%	10%	23%	7%
MAZOWIECKIE	89%	22%	27%	5%	12%	6%	17%	7%
OPOLSKIE	88%	18%	24%	6%	8%	12%	20%	4%
PODKARPACKIE	90%	20%	25%	4%	10%	11%	21%	6%
PODLASKIE	88%	21%	22%	9%	14%	6%	16%	6%
POMORSKIE	87%	21%	22%	4%	13%	6%	20%	6%
ŚLĄSKIE	86%	13%	27%	3%	13%	10%	19%	7%
ŚWIĘTOKRZYSKIE	85%	21%	21%	3%	10%	7%	22%	6%
WARMIŃSKO-MAZURSKIE	87%	31%	18%	4%	10%	5%	18%	5%
WIELKOPOLSKIE	90%	21%	28%	4%	11%	8%	19%	5%
ZACHODNIOPOMORSKIE	86%	18%	23%	4%	16%	8%	18%	7%
POLAND	88%	21%	24%	4%	12%	7%	20%	6%

Source: authors' work based on GUS (2022b).

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Irrespective of the voivodship, drivers are responsible for almost 90% of road accidents, with only a few percent attributed to pedestrians (Table 3). Accidents caused by pedestrians are usually a result of stepping onto the road carelessly.

The main causes of accidents include speeding (21% of accidents) and failure to give the right of way to another road user (24% of accidents). Two voivodships stand out for their speeding accidents: Śląskie, with its lowest share of speeding accidents (13%) and Warmińsko-Mazurskie, with the highest share of speeding accidents (31%). Warmińsko-Mazurskie, on the other hand, had the lowest share of accidents caused by failing to give priority (18%). Other causes of accidents account for several to a dozen per cent of accidents in Poland: dangerous overtaking was the cause of 3% – 9% of road accidents, incorrect behaviour towards pedestrians caused 8% – 19% of accidents (the lowest share in Opolskie and Lubelskie, the highest in Kujawsko-Pomorskie), maintaining unsafe distances between vehicles was the cause of 4% – 12% of road accidents (the highest share was observed in south Poland voivodships).

Analysis of the relationship between road safety and the socio-economic development of the voivodships

The data comes from Statistics Poland's Local Data Bank (GUS, 2022a) and the road accident database (SEWIK, 2021). The data covered the years 2014-2021 and the main indicators of socio-economic development and road safety at the voivodship level in Poland.

To assess road safety at the voivodship level, five road safety measures were selected: the number of fatalities in the voivodships was chosen as an absolute measure; the relative measures include road fatality rate, accident severity, the share of accidents involving drunk road users and the share of accidents caused by excessive speed. The fatality rate (FR) was calculated as the total number of fatalities and serious injuries per 100,000 population in a given voivodship. Accident severity was calculated as the number of fatalities per 100 accidents. In addition, variables related to demographic, socio-economic and road infrastructure characteristics were included in the analysis and treated as potential independent variables in the analysis (Table 4).

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Table 4. Variables used in the analysis, 2019

Variable	Abbrev.	Unit	Min	Max	Avg.	Std.
Demographics						
Density of population	POPD	people/km²	58.0	366.0	128.7	75.8
Urbanisation	URB	%	41.4	76.6	58.5	9.7
Motorisation						
Motorisation rate	MOTR	cars/1,000 people	548.3	706.6	625.8	46.2
Economy						
GDP per capita	GDPC	thous. PLN	40.7	96.6	53.6	14.2
Public expenditures for transport per capita	TEXC	PLN	75.2	146.4	105.0	21.7
Road network						
Density of roads	RD	km/100 km²	87.6	206.8	139.1	33.4
Density of roads with improved pavement	RDIA	km/100 km²	53.2	168.9	94.0	33.1
	RDID	km/10 thous people	46.1	108.1	79.6	17.0
Density of motorways	RDM	km/100 km²	0.5	2.8	1.4	0.7
Road safety (dependent variables)						
Road fatalities	F	fatalities	73.0	469.0	181.8	95.2
Fatality rate	FR	F/100,000 people	4.4	10.6	7.9	1.7
Accident severity	AS	F/100 accidents	5.6	22.4	11.3	4.5
Accidents involving drunk road users	ALC	% of all accidents	4	10	7	2
Accidents caused by speeding	SPD	% of all accidents	13	31	21	4

Source: authors' work based on GUS (2022a).

Table 5 shows the values of the variables in each voivodship in 2019 (this year was chosen because of the possible impact of COVID-19 on the 2020-2021 results). The table shows that Polish voivodships are strongly differentiated in terms of socio-economic development. In this respect Mazowieckie clearly stands out due to its highest GDPC and MR. The most densely populated voivodship is Śląskie. The highest density of RDIA improved roads is also observed there. Voivodships with a low degree of urbanisation generally have lower GDPC, compared to voivodships with a high degree of urbanisation. The lowest TEXC is allocated in Łódzkie, highest in the voivodships of north Poland (Pomorskie, Warmińsko-Mazurskie, Zachodniopomorskie) and Mazowieckie. The highest density of improved roads per RDIA area is found in Śląskie and Małopolskie, which are also the most densely populated voivodships in Poland. Considering the demographic indicator of road density RDID, Śląskie has the lowest rate among the voivodships.

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Table 5. Socio-economic and road safety characteristics in the voivodships in Poland, 2019

VOIVODSHIP	POPD	URB	GDPC	MR	RDIA	RDID	TEXC	F	FR	AS	ALC	SPD
	people/km²	%	thous. PLN	cars/1,000 people	km/100 km²	km/10,000 people	PLN	number	F/100,000 people	F/100 accidents	%	%
DOLNOŚLĄSKIE	145	68	65.2	655	97.4	67.0	111	215	7.4	11.1	6.3	21.7
KUJAWSKO-POMORSKIE	115	59	47.5	624	95.9	83.2	86	211	10.2	22.4	6.5	18.9
LUBELSKIE	84	46	40.7	619	86.8	103.4	93	170	8.1	14.9	10.4	21.6
LUBUSKIE	72	65	48.4	679	57.3	79.2	116	92	9.1	13.9	7.9	23.8
ŁÓDZKIE	135	62	56.1	643	107.2	79.6	75	239	9.7	7.1	7.1	22.4
MAŁOPOLSKIE	225	48	54.5	598	157.4	70.1	83	176	5.2	5.6	6.5	20.5
MAZOWIECKIE	153	64	96.6	707	105.2	69.0	123	469	8.7	12.3	7.1	22.1
OPOLSKIE	104	53	47.0	674	84.6	81.1	103	73	7.4	11.9	8.0	18.4
PODKARPACKIE	119	41	41.8	573	92.1	77.2	88	157	7.4	10.6	5.9	20.4
PODLASKIE	58	61	43.0	548	63.1	108.1	97	106	9.0	18.1	9.2	20.7
POMORSKIE	128	63	58.0	621	71.8	56.1	146	160	6.8	7.0	5.3	21.2
ŚLĄSKIE	366	77	61.0	606	168.9	46.1	77	199	4.4	6.7	6.8	13.2
ŚWIĘTOKRZYSKIE	105	45	42.7	596	113.3	107.5	98	131	10.6	12.4	8.8	21.5
WARMIŃSKO-MAZURSKIE	59	59	40.8	572	53.2	90.4	133	103	7.2	8.5	9.3	30.6
WIELKOPOLSKIE	117	54	64.6	695	93.7	79.9	115	279	8.0	7.2	4.4	20.5
ZACHODNIOPOMORSKIE	73	68	50,7	634	58.7	75.2	128.4	101	6.0	10.9	7.9	18.3
POLAND	129	59	53.6	626	94.0	79.6	105.0	2909	7.92	11.3	7.3	21.0

Source: authors' work based on GUS (2022a).

In terms of safety measures, the highest number of fatalities was recorded in Mazowieckie (469) and the lowest in Opolskie. On the other hand, the FR demographic rate was the highest in Kujawsko-Pomorskie and Świętokrzyskie, and the lowest in Śląskie (however, please note its very high population density). In terms of accident severity, Kujawsko-Pomorskie stands out strongly in comparison with others, even though its socio-economic situation is not much different from the other voivodships. The lowest accident severity AS was recorded in Łódzkie and Małopolskie. In terms of the share of drink-driving accidents ALC, the rate was clearly higher in east Poland voivodships (>9%). The same voivodships featured the lowest GDPC. On the other hand, the lowest share of drink-driving accidents ALC was observed in Wielkopol-

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skie (<5%). Speeding accidents SPD, as mentioned in the previous sections, were most prominent in Warmińsko-Mazurskie, with nearly every third accident caused by excessive speed. It should be mentioned that Warmińsko-Mazurskie is one of the voivodships with the highest public spending on transport. In terms of the SPD, the best performing voivodship is Śląskie, with only 13% of accidents caused by speeding.

To test the relationship between safety measures and measures of socio-economic development, Pearson's linear correlation analysis was conducted, which is a statistical method for determining strength of the linear relationship between variables (Kirch, 2008). The relationship between the variables was considered strong, if [r]>=0.7 and moderate if 0.4=<|r|<0.7.

Table 6. Correlations between variables 2019

	POPD	URB	MR	GDPC	TEXC	RDIA	RDID	RDM
Dependent vs. independent variables								
F	0.31	0.19	0.55*	0.89*	-0.01	0.35	-0.32	0.25
FR	-0.66*	-0.22	0.15	-0.13	0.00	-0.44	0.66*	-0.23
AS	-0.45	-0.09	-0.08	-0.25	-0.13	-0.36	0.54*	-0.38
ALC	-0.38	-0.13	-0.37	-0.46	-0.06	-0.29	0.68*	-0.41
SPD	-0.61*	-0.21	-0.05	-0.14	0.42	-0.54*	0.41	-0.31
Collinearity of independent variables								
POPD	-	0.34	0.04	0.39	-0.45	0.89*	-0.70*	0.62*
URB		-	0.22	0.44	0.27	-0.01	-0.57*	0.62*
MR			-	0.66*	0.19	0.03	-0.31	0.33
GDPPC				-	0.20	0.32	-0.55*	0.35
TEXPC					-	-0.66*	-0.12	-0.30
RDIA						-	-0.42	0.46
RDID							-	-0.62*
RDM								-

* Statistically significant with p-value<0.05

Table 6 gives the results of the analysis. It shows that the number of fatalities F is strongly dependent on GDPC and the motorisation rate MR – the higher the GDPC and MR, the higher the number fatalities in the voivodship; it should be taken into account that both variables (GDPC and MR) are strongly correlated. However, considering the demographic fatality rate FR, its value increases with POPD population density and road density rate per capita RDID. As the road density per capita increases RDID, so does accident

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severity AS. Voivodships with a high RDID rate have a higher share of drink-driving accidents. The analysis also shows that a higher share of speeding accidents is observed in voivodships with a low population density POPD and the lowest density of improved roads relative to the size of the voivodship RDIA. The analysis did not show any effects of motorway density RDM and transport spending TEXC on road safety measures in the voivodships.

What is notable in the results of the correlation analysis is the reverse direction of their relationship between FR and improved roads density per capita RDID and improved roads density per RDIA area (Figure 6). The fatality rate increases with the road density per population RDID. It falls, however, as road density per RDIA area increases. The situation is similar with the accident severity rate – voivodships that have a dense road network (a high RDIA) have a lower accident severity, while voivodships with more roads per capita, observe a higher accident severity (Figure 7).

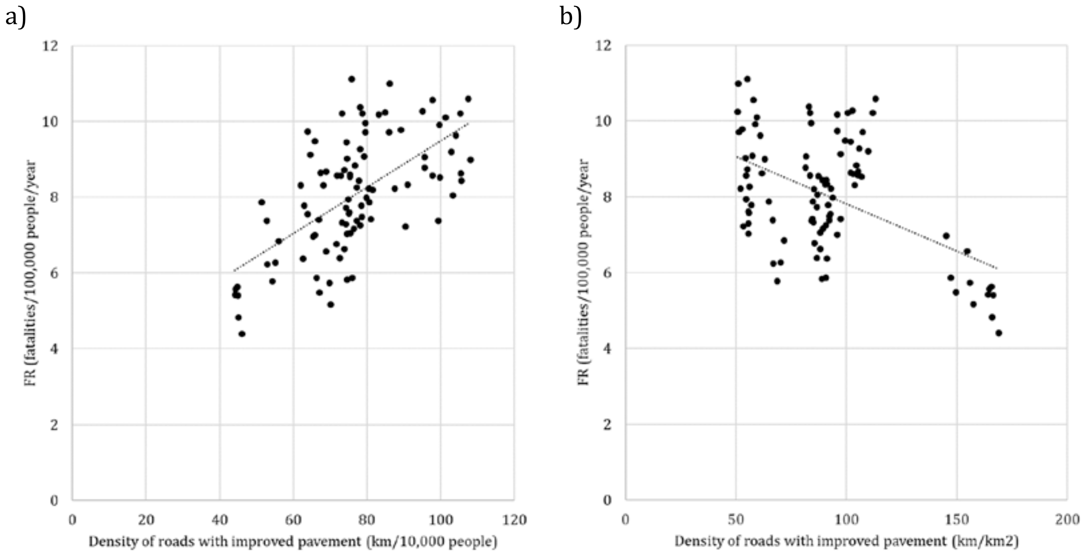

Figure 6. Relationship between fatality rate FR and density of improved roads: a) in km per 10,000 population, b) in km per km^2 of land

Source: authors' work based on Statistics Poland data for the years 2014-2019 (GUS, 2022a).

The relationships between FR and the density of improved roads RDIA and RDID can be partly explained by the interdependencies between the independent variables. Table 5 shows that a high density of high quality road network (per area) RDIA is found in densely populated voivodships. On the other hand, the per capita length of these roads is higher in sparsely populated voivodships with a low rate of urbanisation and a lower GDP per capita

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(GDPC). The relationships between AS and RDID and RDIA, on the other hand, may suggest that a higher density of high quality roads is associated with lower consequences of road accidents.

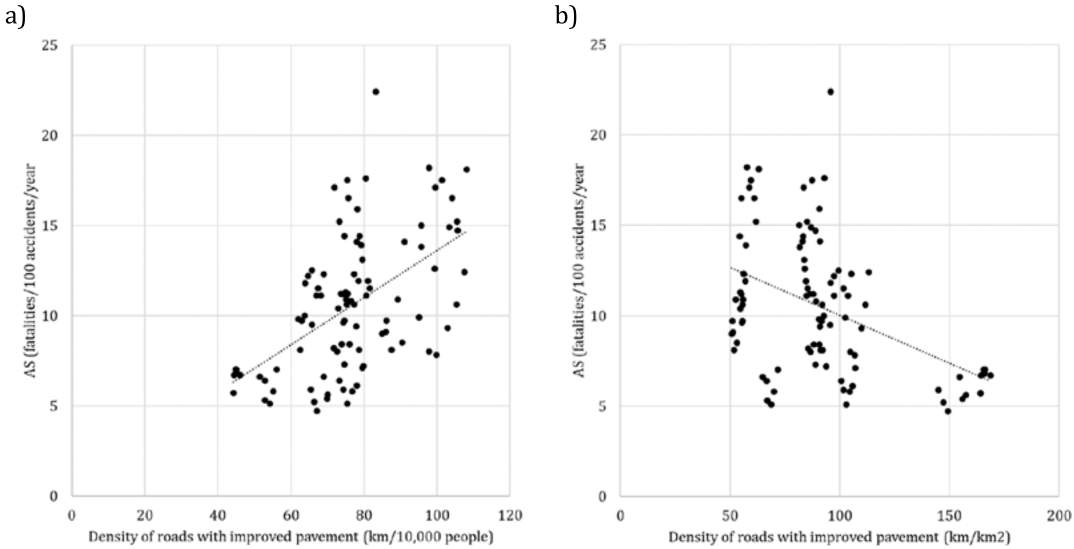

Figure 7. Relationship between accident severity rate AS and density of improved roads: a) in km per 10,000 population, b) in km per km^2 of land

Source: authors' work based on Statistics Poland data from the years 2014-2019 (GUS, 2022a).

Conclusions

The results of the descriptive analysis of accident statistics, their consequences and causes in the voivodships may be helpful with analysing the costs and benefits of road safety spending in the voivodships and of other projects designed to improve road safety.

The data presented in the article shows that voivodships differ significantly from one another in the area of road safety and accident causes. For example, voivodships in east Poland tend to have a higher share of accidents with drunk road users, while the least populated voivodships have the lowest fatalities per 10,000 population. The analysis of the relationship between road safety measures and socio-economic development in the voivodships was conducted to explain the differences between the voivodships. The results of the analysis confirm the conclusions of previous Polish studies at the national and regional level which studied the effects of socio-economic conditions of a region on its road safety level. The analysis shows among

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other things that the fatality rate decreases with increasing population density. Voivodships with a high road density per capita, which are at the same time less populated and less urbanised, have a higher demographic fatality rate, a higher share of accidents with drunk road users and a higher share of speeding accidents. On the other hand, voivodships that have a high road network density (per area) and are more populated, have lower rates of fatalities, accidents involving drunk road users or speeding accidents. The analysis shows that the density of improved roads may be an interesting variable when analysing the causes and consequences of road accidents at the regional level. It reflects the population density and socio-economic development of the voivodships. More research is required to formulate clear-cut conclusions. This article could be a starting point for future research concerning other variables including the impact of location.

The contribution of the authors

Conception, A.R., S.P.-K., M.B., K.W. and J.P.; literature review, A.R., S.P.-K., M.B., K.W. and J.P.; writing, A.R., S.P.-K., M.B., K.W. and J.P.

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GENERAL ENVIRONMENTAL AND SOCIAL PROBLEMS

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ACTIVITIES OF LOCAL GOVERNMENT UNITS IN THE POPULARISATION AND PROMOTION OF A HEALTHY LIFESTYLE AMONG AN AGING RURAL SOCIETY – THE CASE OF POLAND

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ABSTRACT: Purpose: Three goals were set in the study, which was met: to present the expected changes in the population of Poland, discuss the concept of "living in health" and prognoses regarding this issue. Methodology: The objects of the study were rural and urban-rural communes of the Lesser Poland Voivodeship. The statistical analysis of collected survey data was used as the method. Findings: The level of health popularisation and promotion by Local Government Units (LGUs) is varied. The activities related to the popularisation and promotion of a healthy lifestyle are moderate in 47.9% of respondents in rural communes and 17.4% in urban-rural communes. The level of indebtedness has an impact on undertaking activities in the field of health popularisation and promotion but does not affect the availability of sports and recreation infrastructure. At the same time, too few actual observations were indicated for TSUs taking the full range of measures and having a debt level falling into the 21-30% group (76%). However, too many observations (126%) relate to debt levels of 11-20%. Access to sports infrastructure does not affect the level of health popularisation and promotion. The obtained answers indicate that 34.5% of rural communes and 10% urban-rural have no problem with access to recreational infrastructure, for 35.5% of respondents from rural communes and 11.8% from urban-rural, this is a moderate problem. Implications: The ageing society causes changes and consequences in all areas of socio-economic life. The activities of some local governments are insufficient, and there is a lack of consistency in their conduct in this area.

KEYWORDS: population forecasts, ageing of the population, physical activity, healthy lifestyle

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Introduction

The problem of an ageing society is eagerly taken up in both journalistic and scientific publications. This is due to the character of the problem, proving the inevitable changes occurring around the world. Ageing in society is a major social and personal challenge. This difficult experience will affect everyone individually, their closest ones and entire communities. Ageing is not just a matter of the individual. There is a difficult problem of creating social and health security and organisation of general public space adapted to the needs of a growing group of older people. Demographic changes, the consequence of which is the ageing of societies, make it necessary to apply long-term governmental and local policies that support the needs of older people.

The ageing of the population is more and more noticeable in the case of Polish agriculture. Older people constitute an increasing proportion of people working in agriculture. The most numerous age groups among those running Polish farms are people aged 45-64 (GUS, 2017). Therefore, it should be assumed that the age structure of farmers will be further shifted towards the dominant share of older age groups.

The ageing of societies has been the subject of scientific analysis and public debate since the 1990s. Negative demographic trends are becoming more and more noticeable in all European Union countries. In Poland, it is expected that the problem of ageing will intensify in the coming years at a faster pace than in other European countries (Ciura & Szymańczak, 2012). Demographic ageing is a systematic increase in the percentage of elderly people in the population (Okólski, 2004). This means that the growth rate of the number of old people is greater than the growth rate of the population in general. The proportion of children in the total population is falling, and the proportion of older people is increasing. The greater share of elderly people in the overall rural population results mainly from the increase in life expectancy, low fertility rate and migration processes. The ageing of the population, both in cities and in the countryside, is a common phenomenon in most regions of the world. However, it is especially intense in Europe and North America.

The projected median age will increase in all European countries but at a different rate. According to forecasts, in 2030 Italy will have the highest median age among European countries, with half of the population aged 52 and more, and in 2060 the highest median (over 54) will occur in Slovakia and Poland (Giannakouris, 2008).

One of the characteristics of the ageing population process is the progressive ageing of the older population (Butler et al., 2004). In many European countries, seniors aged 80 and over are currently the fastest-growing group

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in the entire population. In Poland, along with the progressive ageing of the population, the percentage of people in the oldest age group, 75/80 and more, is also expected to increase. This percentage will start to increase dynamically around 2025 when the age of 75 and more will be reached by people belonging to the generation of the post-war baby boom (Błędowski et al., 2012).

The issue of old age can be considered from two points of view: medical and social. Rapidly developing science, which is medicine, can ensure (under various conditions) maintaining human life until old age. Another issue is the quality of life in which they will exist. The latter is influenced by many factors that appear throughout life.

In this study, special attention will be devoted to the elderly and the possibility of influencing their lives through the activities of the local government in the field of promoting a healthy lifestyle, including existing sports infrastructure.

On the basis of the problem outlined, a research question about a healthy lifestyle appears as one of the elements aimed at improving the situation of the elderly. In the face of an ageing population, are LGUs taking significant actions to promote a healthy lifestyle? To find the answer to this question, the following research objectives were formulated:
- presentation of demographic changes taking place in Poland,
- discussing the concept of "living in health" and indicating examples of its values,
- assessment of the possibilities of using sports infrastructure and promoting a healthy lifestyle to improve the situation of the elderly.

In order to accomplish the indicated objectives, three research hypotheses were formulated:
- H1: The level of health popularisation and promotion by LGUs that improve the situation of the elderly is varied.
- H2: The level of LGU debt has an impact on the level of LGU's commitment to promoting a healthy lifestyle.
- H3: Access to the sports infrastructure has an impact on the degree of popularisation and promotion of health.

In addition, the relationship between the level of LGU debt and access to sports and recreation infrastructure was examined.

The source of data for the analyses presented in the study is a survey conducted among the rural and urban-rural communes of the Lesser Poland Voivodeship in the period September – December 2018 in cooperation with the Regional Accounting Chamber in Krakow. In addition, the demographic data of the GUS, United Nations and Eurostat were used. Research methods used in the review part include demographic analyses as well as critical analysis of the literature. In the empirical part, the survey data were analysed using statistical tools.

An overview of the literature

Old age as a social phenomenon defines society through the specificity of age structure but also through an intergenerational culture that needs to be learned. The age of life is getting longer, so more and more generations must learn to live and function with each other and next to each other. The problem of old age and ageing and the issue of its solution are not only within the borders of the countries (permanent map). It is also associated with the circulation of information, experiences, ideas, migrations, and population flows (liquid map). Stopińska-Pająk (2018) also puts forward the thesis about the issue being resolved over countries (flight map) due to the fact that health difficulties, disabilities or inefficiency largely result from the quality of the ecosphere. The topic of "ageing Europe" should be considered taking into account not a single country but all maps simultaneously (Stopińska-Pająk, 2018).

The issue of old age should be considered, taking into account the topics connected with it, such as care for the elderly, because their level of efficiency is varied. The quality and kind of assistance provided to the elderly depends on the interaction of factors that can be grouped into three or even four levels. The first of them, micro, is associated with the support of a disabled person by family, neighbours, and friends, but also environmental help when the former are unable to cope. At the meso level, the activity of the local government is expressed, which carries out tasks commissioned from the headquarters, but also through various initiatives, it takes care of the shape of social policy, taking into account the needs of the local environment. The macro level concerns the establishment of social policy at the national level. At the mega level, it is a commitment to implement the regulations set by the fact that a given country belongs to international organisations (Szweda-Lewandowska, 2013).

Taking into account the factors determining the specifics of society, attention is directed to geographical and demographic reasons, such as size (population), population density, structure by sex and age, birth rate or average life expectancy. Planning, decision making and implementation of a specific policy are different in the case of a "small" community and different in the case of several million. When it comes to organising public spaces for the elderly, the importance will be of, for example, population density, the share of the number of elderly people in the total population, the possibilities to meet housing needs for this group, etc. (Karwińska, 2008) will be important.

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An increasing number of people aged 50+ are becoming the subject of interest of companies operating in various industries. This group, which has enormous potential, is becoming more and more interested in actively spending free time due to growing awareness. The segment of clients aged 50+ is characterised by specific needs. The knowledge of buyers in this age group, their preferences and diverse financial possibilities can help attract new consumers. First, however, you must adapt the available offer to customer requirements. In this respect, there is still a gap/divergence in the market (Nestorowicz & Bronikowska, 2011).

Inevitable demographic changes are observed around the world. This entails the need to change their perception. This is not a distant topic for far-off countries. On the contrary, it is observed in Europe and Poland. Ageing is a challenge, but it also creates new opportunities. Opportunities for the development of new markets available to increasingly elderly inhabitants, which improve their condition, but also ensure a higher standard of living. Importantly, the changes must occur not only in the policy of European, national, but also regional and local authorities because these authorities are closest to the inhabitants and know their needs.

Ageing is mentioned when there is an increase in the share of older people in the total population. The older age in the article will be understood as age 65+. An ageing population can be considered by analysing the age of 60 for women and 65 for men. However, the UN applies a uniform age for men and women, and it is 65 years (United Nations, 2021). In order for the analyses of data collected from the Central Statistical Office (GUS) to be comparable to UN studies, the threshold was adopted of 65 years. The ageing of society will be evidenced by the increase in the number of people aged 65 and more, i.e. post-working age (according to GUS – the age at which people usually end their work, i.e. for men – 65 years and more, for women – 60 years and more – GUS). Pre-working age is understood as one in which the population has not yet reached work capacity, i.e. the age group 0-17 years (GUS, 2021b). The working age is referred to as work capacity, which for men is in the range of 18-64 years, and for women – 18-59 years (GUS, 2021b). Therefore, the age of 65 is considered to be the beginning of old age (Kujawska, 2015). However, the indication of this age is not medical but more social. Health problems appear at different ages, and it is difficult to state clearly that at age 65, the state of health and well-being deteriorates significantly. The author does not agree with the opinion of Kujawska (2015), who believes that healthy people may experience problems related to ageing around 75-80 years old. The author's observations are quite different. However, the author agrees that the most common difficulties relate to problems with the movement system. In view of these considerations, it is reasonable to raise the issue of healthy life.

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Whether extra years of life will be spent in health or in incomplete efficiency is extremely important. Healthy life years (also known as life expectancy without disability) are an important measure of the relative health of the population in the European Union (Eurostat, 2021b).

Table 1. Healthy life years

	Healthy life years at birth			Healthy life years at age 65		
	Females	Males	Difference	Females	Males	Difference
EU-28	64.2	63.5	0.7	10.1	9.8	0.3
Poland	64.6	61.3	3.3	8.9	8.2	0.7

Source: authors' work based on Eurostat [21-07-2021].

The data from 2016 presented in Table 1 indicate that the healthy life expectancy for Polish new-borns is about 65 years for women and just over 61 years for men. The EU average is 64.2 years for women and 63.5 years for men. Residents of the European Union at the age of 65 could expect, according to assumptions, about 10 years of healthy life. Whereas Poles could enjoy health for about 8-9 years.

Physical activity is a form of supporting life in health. It is one of the elements affecting physical and mental fitness. Its role in everyday life is getting more and more attention, trying to realize that the earlier you take care of your physical condition the better. The information provided by the National Cancer Registry shows that too little movement is the cause of, among others, the increasing risk of chronic diseases. A sedentary lifestyle and a poor diet contribute to the increased incidence of colorectal cancer. By exercising, you can reduce your risk of illness by a quarter, and in people who are slim even by half. The situation is similar with the prevention of breast cancer. Intense physical activity not only affects body weight, but also hormone levels. Most effectively, however, the occurrence of breast cancer is prevented by sport practiced in the period of youth (National Register of New-borns). Physical activity should become an element of a healthy lifestyle for all residents, regardless of their age. Often the authorities of LGUs have to face the challenge of providing appropriate conditions to facilitate physical activity, especially among the elderly.

Demographic forecasts are prepared for different periods depending on the institution making it. Forecasts up to 2100 can be found on the websites of the United Nations (United Nations, 2021), according to which in Poland there will be 23 033 thousand residents. According to Eurostat estimates, in 2100 Poland will have 27 524 thousand residents (Eurostat, 2021b). On the other hand, the Central Statistical Office (GUS, 2021a) does not provide such distant predictions, but "only" until 2050. Of course, one can discuss the usefulness and truthfulness of such distant forecasts, or even question them. Nevertheless, they provide a basis for further consideration, e.g. on long-term social policy.

Table 2 presents the expected changes in the population of Poland according to the GUS, the UN and Eurostat. As you can see, the most favourable for Poland are the predictions of the European Statistical Office, and the least of the UN. Big differences between the above-mentioned forecasts are visible in 2045 and 2050.

Table 2. Forecasted changes in the population of Poland [in thousands]

Year	GUS (G)	UN (O)	EUROSTAT (E)	G-O	G-E	O-E
2020	38 138	37 847	37 968	291	170	-121
2025	37 741	37 515	37 810	226	-69	-295
2030	37 185	36 945	37 398	240	-213	-453
2035	36 477	36 178	36 821	299	-344	-644
2040	35 668	35 283	36 174	385	-506	-892
2045	34 817	34 310	35 513	507	-696	-1 203
2050	33 951	33 295	34 861	656	-910	-1 567

Source: authors' work based on GUS, UN, Eurostat [19-07-2021].

Table 3 presents the GUS forecasts for changes in the population of Poland. The data it contains are ranked according to a decreasing index of population dynamics in 2050/2018. This is therefore an indication of the voivodeships in which demographic changes will be most visible. The Opole Voivodeship is noteworthy, whose population in 2050 will constitute 75% of that of 2018, and Świetokrzyskie – 79%. Slight changes in the population will apply to the following voivodeships: Masovia, Pomerania, Lesser Poland and Subcarpathia.

The problem of the impact of actions taken by local government units on the situation of an ageing society has become the subject of numerous research studies, examples of which can be found in the international literature on the subject. Among the research topics undertaken, the authors' attention was drawn to two research trends, the results of which indicate the existence of relationships between the ageing of the population and the structure of expenditure of the government and local government authorities and between the level of debt of local government units and the amount of expenditure allocated to the implementation of the tasks of these units.

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Table 3. Forecasted changes in the population of Poland by voivodeships

Voivodeship \ Year	2018	2020	2025	2030	2035	2040	2045	2050	2050-2018	2050 /2018
	in thousand									%
Masovia	5 403	5 388	5 416	5 418	5 401	5 375	5 348	5 319	-85	98
Pomerania	2 334	2 324	2 335	2 334	2 323	2 307	2 287	2 266	-68	97
Lesser Poland	3 401	3 396	3 407	3 403	3 384	3 355	3 319	3 279	-121	96
Greater Poland	3 494	3 490	3 490	3 471	3 435	3 389	3 340	3 288	-206	94
Subcarpathia	2 129	2 115	2 096	2 068	2 030	1 982	1 929	1 870	-259	88
Poland	38 411	38 138	37 741	37 185	36 477	35 668	34 817	33 951	-4 461	88
Lubusz	1 015	1 010	997	980	958	933	906	879	-136	87
Kuyavia-Pomerania	2 078	2 065	2 039	2 004	1 960	1 909	1 854	1 799	-279	87
Lower Silesia	2 901	2 867	2 826	2 773	2 709	2 638	2 566	2 495	-406	86
Warmia-Masuria	1 429	1 421	1 399	1 371	1 336	1 296	1 253	1 208	-221	85
West Pomerania	1 701	1 692	1 667	1 635	1 595	1 549	1 501	1 453	-248	85
Podlaskie	1 182	1 168	1 147	1 122	1 092	1 059	1 022	982	-199	83
Lublin	2 118	2 096	2 050	1 996	1 933	1 862	1 788	1 711	-407	81
Łódź	2 466	2 434	2 374	2 306	2 232	2 153	2 075	1 999	-467	81
Silesia	4 534	4 478	4 370	4 245	4 108	3 965	3 821	3 681	-853	81
Świętokrzyskie	1 242	1 226	1 194	1 157	1 117	1 072	1 024	977	-265	79
Opole	987	967	936	902	865	826	785	745	-242	75

Source: authors' work based on GUS [19-07-2021].

The local government unit represents the community and administrates its funds. The idea of New Public Management appeared in public administration (Eshuis & Klijn, 2012), which has influenced and continues to influence public sector reforms, introducing methods and management techniques specific to the private sector so far. Local Government Units can develop activities focused on the place promotion, treating them as a factor significantly affecting regional development. Local authorities have a central role to play in popularising and promoting health.

The results of published international studies have shown that the ageing of the population influences the elements of government and local government spending, especially in the area of social welfare, education and health, including the popularisation and promotion of behaviours influencing a healthy lifestyle of the elderly (Sanz & Velázquez, 2007; Shelton, 2008; Tepe & Vanhuysse, 2009; Krieger & Ruhose, 2013).

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Jäger and Schmidt (2016) argue that the growing number of elderly voters has contributed to the decline in public investment rates. Thus, raising public investment levels might become increasingly difficult in greying democracies. The results of the questionnaire surveys confirm the existence of specific preferences of elderly people regarding the social expenditure of local government units. Sørensen (2013) conducted a cross-section survey-data for 22 countries and estimated a regression model explaining respondents' public spending preferences. The results show that elderly people want less education spending and more health care spending. The results of a survey conducted by Cattaneo and Wolter (2009) among Swiss society also show that elderly people have a clear tendency to spend public resources on health and social security than on education.

Local authorities have responsibility for wider policy areas, which can have a significant impact on the physical activity of the local population. It was confirmed that the property and financial situation of local government units, and especially the level of their debt, have a negative impact on the amount of expenditure allocated to the implementation of tasks of these units (Oxley & Martin, 1991; Jäger & Schmidt, 2016). Thus, a research gap appears, as the impact of the level of indebtedness of local government units on the specific type of expenditure allocated to the promotion of a healthy lifestyle among the elderly was not studied.

Sainto et al. (2016) examined the cross-sectional and longitudinal associations between the area-level population ageing and the subjective well-being of older individuals. Findings from two survey projects suggested cross-validity in the positive effect of area-level population ageing on older adults' well-being. Studies carried out in various countries prove that the subjective well-being of older people could be affected by community characteristics (Gao et al., 2017; Levasseur et al., 2015; Li et al., 2005). These findings suggest that creating cohesive neighbourhoods may encourage elders to participate in social activities and promote a healthy lifestyle.

The actions of local self-government authorities undertaken in communes may therefore have an impact on the degree of popularisation and promotion of health among the elderly, which may contribute to extending the period of "healthy life". Already in the 1980s, it was confirmed that in environments with a higher elderly concentration, older residents tended to have greater activity participation (Lawton et al., 1984). Still, the literature emphasises that only a few studies have examined the impact of factors related to the place of residence on the health and healthy lifestyle of the elderly (Sainto et al., 2016; Vogelsang & Raymo, 2014).

Research conducted by O'Brien (2014) reveals that local councils have differing abilities to provide age-friendly local infrastructure. The author claims that the challenges in this topic are greater overall for regional, rural and fringe councils compared to metropolitan. As essential task of LGUs which affects the quality of life of elderly people is providing infrastructure tailored to their needs and capabilities (Maj-Waśniowska & Jedynak, 2020).

Currently, there are many changes related to the local infrastructure (Broniewicz et al., 2021). It should also be noted that access to sports infrastructure for older people is seen as one of the factors by which local authorities can influence the perception of the immediate environment as friendly to the elderly (Edwards & Tsourous, 2006; Lui et al., 2009). The results of the cited international research became the starting point for the authors to undertake their own research, leading to the verification of the formulated research hypotheses.

Research methods

The presented empirical research is based on an opinion survey carried out by employees of the College of Economy, Finance and Law of the Cracow University of Economics in cooperation with the Regional Accounting Chamber in Krakow in September-December 2018 as part of the project "Problems and challenges of local government units in the era of ageing society". The subject of the survey was the opinion of communes on the opportunities and threats that the progressing ageing of the society and the development of the silver economy bring to the implementation of communal tasks.

The survey was conducted using the CAWI method among all communes of the Lesser Poland Voivodeship. In a few cases, given the technical conditions, it was also possible to provide a survey in the form of a questionnaire on paper form containing a set of questions identical to the electronic version. During the research, it turned out that in some communes, answering individual questions required the exchange of information between physically distant departments, and the survey available at one computer station hindered the formulation of reliable answers.131 units provided full answers. The answers came mainly from rural communes (67.2%) and urban-rural (25.2%). There were 5.3% of urban communes and 2.3% of cities with poviat rights. The debt in the analysed communes was in the range of 21-30% (in the case of 29.8% of respondents), 11-20% (24.4% of respondents), 1-10% (17.6% of LGU). People in the pre-working age constituted on average 20.99% of LGU residents participating in the survey, 62.7% in the working age and 16.3% in the post-working age.

Responses to the survey were provided by representatives of Local Government Units from rural and urban-rural communes.

The conducted surveys verified the research hypotheses H1-H3 formulated earlier on the basis of the analysis of the distribution of answers to indi-

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vidual questions in the survey, and the answers "I do not know" or "I have no opinion" were omitted. For the analysis of results, the χ2 independence test was used, in which the null hypothesis about the lack of relationship between the analysed variables is tested. The H0 hypothesis should be rejected if the statistics χ2 given by the formula:

$$\chi 2 = \sum \frac{(Ei - Oi)^2}{Oi}. \qquad (1)$$

exceed the table value for the assumed level of significance and the number of degrees of freedom given by the formula r = (k-1) * (w-1), where k is number of column and w is a number of verse. A significance level of 0.05 was used in the study. During the interpretation, it should be noted that empirical values were > 5 (Mamcarczyk, 2022).

Results of the research

The H1 hypothesis was verified based on the distribution of answers that the surveyed units gave to the question What actions to improve the situation of the elderly are undertaken in your commune? One of the areas studied was the popularisation and promotion of a healthy lifestyle. Respondents provided answers to this question on a scale of 0-3, where 0 meant lack of knowledge on the subject, 1 that LGU do not take action in this area, 2 activities are undertaken to a moderate extent, and 3 that activities are undertaken to the full extent.

The results obtained indicate that the activities related to the popularisation and promotion of a healthy lifestyle are moderate in 47.9% of respondents in rural communes and 17.4% in urban-rural communes. The full range of activities is used in 10.7% of rural LGUs and 6.6% in urban-rural. 11.6% of rural communes and 1.7% urban-rural communes do not take up the activities. Therefore, referring to the research hypothesis (H1), it should be stated that there are grounds to claim that the degree of popularisation and promotion of health by LGUs affecting the improvement of the situation of the elderly is varied. There can be several reasons for this type of distribution. One of them can be the level of debt.

Figure 1 draws attention to the relationship between the level of debt of a given LGU in relation to income from 2017 and the scope of activities aimed at popularising and promoting health. A moderate level of activity is visible regardless of the level of debt. For the χ2 test, due to the appropriate number of intervals, the level of debt was divided into 3 groups, i.e. 1-10%, 11-20%, 21-30%.

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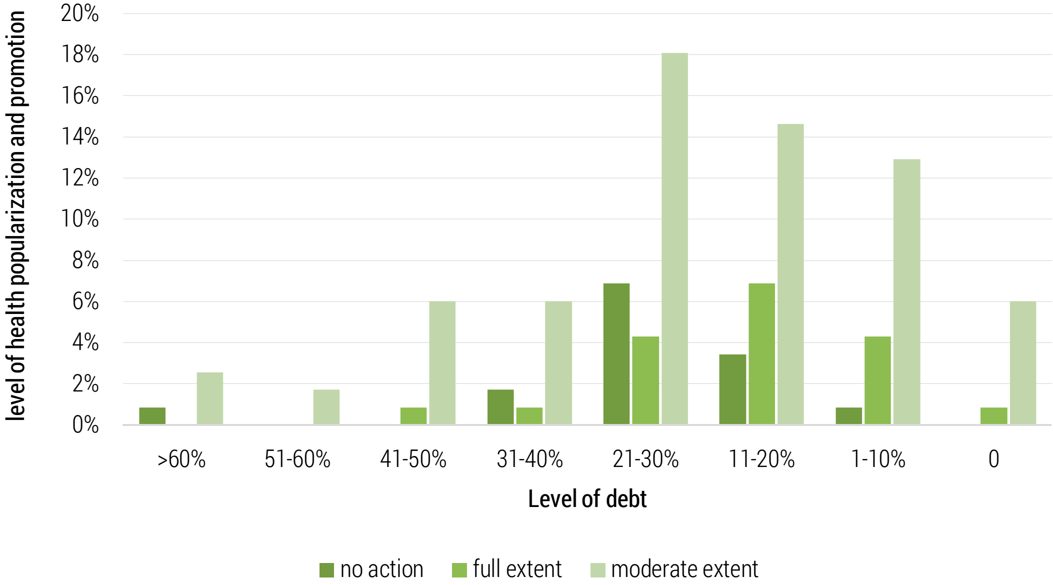

Figure 1. The level of debt versus the level of health popularisation and promotion

Table 4. Results of the χ2 test in the analysis of independence between the level of debt and the degree of health popularisation and promotion

	Ei			Oi		Ei/Oi	
debt level	full range of activities	moderate activities	sum	full range of activities	moderate activities	full range of activities	moderate activities
1-10%	5	15	20	5.1	14.9	99%	100%
11-20%	8	17	25	6.3	18.7	126%	91%
21-30%	5	21	26	6.6	19.4	76%	108%
Sum	18	53	71				

In Table 4, apart from the values necessary to calculate χ2, the share of empirical values in the expected values is also presented. The conditional formatting used allows highlighting the occurred relationships between the entities. The light grey colour indicates too few real observations in the case of LGUs taking the full range of activities and having the level of debt belonging to the group 21-30% (76%). However, too many observations (126%) are in the case of debt at the level of 11-20%.

Because the statistics χ2 = 1.1 is less than the critical value of 5.99 (for significance level $\alpha = 0.05$ and 2 degrees of freedom), the hypothesis about the independence of variables should be confirmed. This means that the level of indebtedness has no impact on undertaking activities in the field of health

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popularisation and promotion. Therefore, the H2 hypothesis should be confirmed as false.

In the next part of the survey, in order to verify the H3 hypothesis, the answer to the question, what problems most often affect the elderly in your commune? Was analysed along with the area's Limited access to sport and recreation infrastructure. Respondents again answered this question on a scale of 0-3, where:

- 0 – no opinion on this topic,
- 1- the phenomenon is not a problem,
- 2 – it is a moderate problem,
- 3 – a serious problem.

The obtained answers indicate that 34.5% of rural communes and 10% of urban-rural have no problem with access to recreational infrastructure, for 35.5% of respondents from rural communes and 11.8% from urban-rural this is a moderate problem, and only for 6.4% from rural and 1.8% from urban-rural is serious. Due to the small percentage of these last answers (Table 5), they were omitted in the $\chi 2$ analysis.

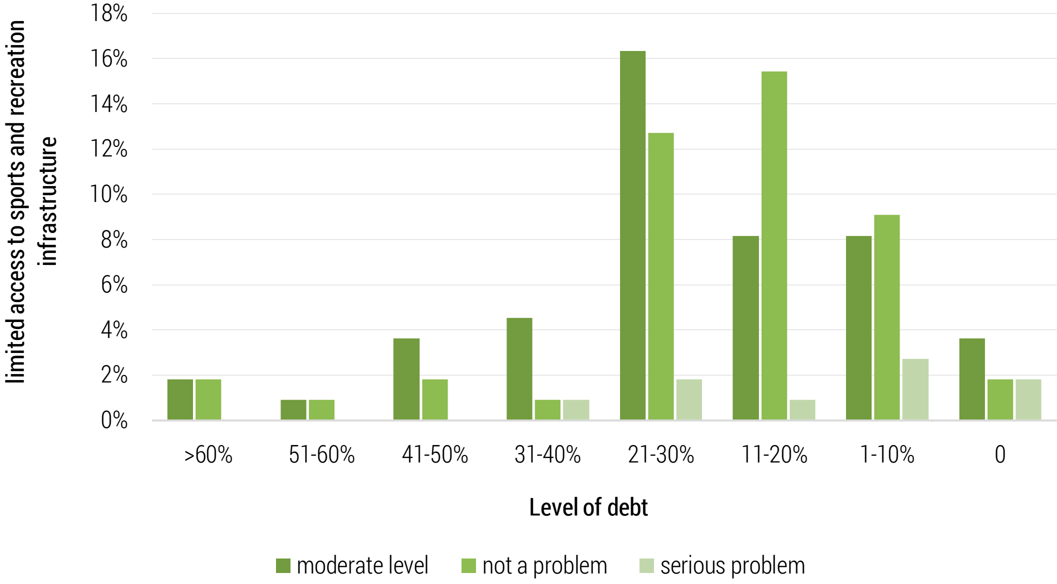

Figure 2. Level of debt and limited access to sports and recreation infrastructure

In Table 5, in addition to theoretical and expected values, the relationships between them were given. The number of LGU observations in which limited access to sports infrastructure is a moderate problem (debt 11-20%) should be 26% higher (74% light grey). Values marked in black indicate that actual observations could be about 20-23% less.

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Table 5. Results of the χ2 test in the analysis of independence between the level of debt and limited access to sports and recreation infrastructure

	Ei			Oi		Ei/Oi	
debt level	moderately affected	not a problem	Sum	moderately affected	not a problem	moderately affected	not a problem
1-10%	9	10	19	8.9	10.1	101%	99%
11-20%	9	17	26	12.2	13.8	74%	123%
21-30%	18	14	32	15.0	17.0	120%	82%
Sum	36	41	77				

Due to the fact that the statistics χ2 = 2.701, so this value is less than the critical value = 5.99 (for significance level α = 0.05 and 2 degrees of freedom), the null hypothesis about the independence of variables should be confirmed. Thus, at the significance level of 0.05, it can be confirmed that the level of debt is not associated with the problem of limited access to sports and recreation infrastructure.

Table 6. Results of the χ2 test in the analysis of independence between limited access to sports and recreation infrastructure and the degree of popularisation and promotion of a healthy lifestyle

	Ei				Oi			Ei/Oi		
infrastructure problem/ promotion a healthy lifestyle	no action	activities to the full extent	moderate activities	Sum	no action	activities to the full extent	moderate activities	no action	activities to the full extent	moderate activities
affect in moderate extent	8	8	34	50	5.7	10.3	34.0	141%	78%	100%
are not a problem	3	12	32	47	5.3	9.7	32.0	56%	124%	100%
Sum	11	20	66	97						

The data in the last part of Table 6 (Ei /Oi) indicate a greater than expected number of actual observations (141%) of LGUs that have a moderate problem with access to infrastructure and, at the same time, do not take measures to promote a healthy lifestyle. On the other hand, there are too few observations in the absence of problems with access to sports and recreation infrastructure (56%).

Statistics χ2 = 3.043, therefore, this value is less than the critical value = 5.99 (for significance level α = 0.05 and 2 degrees of freedom), so the null hypothesis on the independence of variables should be confirmed. Thus, at the significance level of 0.05, it can be confirmed that the degree of popularisation and promotion of a healthy lifestyle does not depend on access to sports and recreation infrastructure.

In view of the above calculations, it should be concluded that H3: Access to sports infrastructure affects the level of popularisation and promotion of health is false.

Discussion and conclusions

The process of ageing in rural society and its consequences have been recognised for many years. It should be noted, however, that in many European countries, there is still a period of discussion on this problem and taking strategic decisions regarding the subjective and objective scope of the policy towards the elderly. These decisions are also related to determining the method of financing the assumed policy and setting its priorities.

Undoubtedly, the problem of ageing requires the involvement of many entities, including local government units. Hence the topic of conducting actions to improve the situation of the elderly is justified. This topic is currently due to demographic data confirming the increase in the number of such people in Poland.

The results of empirical research have shown that activities related to the popularisation and promotion of a healthy lifestyle in the vast majority of respondents are moderated and do not depend on the level of debt of LGUs. In promoting a healthy lifestyle, access to sports and recreation infrastructure also plays a role, with which there is no problem, or it is moderate. The conducted analyses indicate that it does not depend on the level of LGU debt. $\chi 2$ analysis showed no relationship between limited access to sports and recreation infrastructure and the degree of popularisation of a healthy lifestyle. The result, however, raises some practical doubt. It seems that one way to encourage the local community to participate in physical activity is to ensure its access to sports and recreation infrastructure.

When answering the question posed in the introduction of the study on undertaking significant activities of local government units promoting a healthy lifestyle, it should be said that it is a moderate assessment of the possibilities of using sports infrastructure and promoting a healthy lifestyle to improve the situation of the elderly.

The assumed goals have been achieved. On the one hand, attention was paid to encouraging a healthy lifestyle, and on the other, to sports and recreation infrastructure. Co-occurrence of both will improve the situation of the elderly in rural and urban-rural communes. In particular, the lack of physical

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activity, which is part of a healthy lifestyle or insufficient amount, can lead to cancer, as noted in the article.

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The contribution of the authors

Conception, M.M., Ł.P. and P.Z.; literature review, M.M., Ł.P. and P.Z.; acquisition of data, M.M., Ł.P. and P.Z.; analysis and interpretation of data, M.M., Ł.P. and P.Z.

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POSSIBILITY OF USING EMAS ENVIRONMENTAL REPORTING REQUIREMENTS FOR ESG REPORTING IN SELECTED AUTOMOTIVE CORPORATIONS

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ABSTRACT: The lack of uniform guidelines on how ESG measures are calculated leads to a lack of transparency and problems while comparing them over time and between different entities. It can be noted that EMAS, may help in the implementation of ESG reporting. The aim of the article is to analyse the possibility of using environmental reporting required under Regulation in the field of ESG reporting and to indicate the possibilities of using existing solutions to ensure comparability of results between individual areas regarding environmental impact and organisations. This article presents the latest guidelines in the field of sustainability reporting, assesses the possibility of using the existing reporting under EMAS to report environmental indicators, and presents the current approach of selected automotive concerns to ESG reporting. The article contributes to the utilisation of existing reporting systems in order not to impose an excessive administrative burden on enterprises and to maximise synergies.

KEYWORDS: ESG, CSR, EMAS, environmental effects, sustainable reporting

Introduction

The article aims to indicate the possibility of using requirements contained in the EMAS Regulation in the field of environmental reporting as a part of ESG reporting based on selected information obtained from the automotive industry. To achieve the main objective, the following specific objectives have been indicated in the article:

- presentation of the latest framework for guidelines on reporting non-financial indicators published by the European Parliament and the Council of the European Union,
- assessment of the possibility of using existing reporting for reporting environmental indicators under EMAS,
- illustrating the currently functioning approach to reporting indicators on sustainable development by selected automotive companies: Volkswagen Group, Ford Motor Company, and MAN Truck & Bus SE.

The article tries to find answers to the following research problems:

- To what extent can EMAS environmental reporting be used in ESG reporting?
- How prepared is the automotive industry to report on sustainability?
- How useful can EMAS requirements be for ESG reporting?
- To what extent would EMAS requirements help the automotive industry meet environmental reporting requirements?

To carry out this study, the case study method was used for selected automotive industry companies by analysing non-financial reports made public at a specific time. From the point of view of a research process, the research is qualitative in nature.

A case study is an empirical study that examines a specific phenomenon in the context of real life (Lima et al., 2023). The case study method is derived from grounded theory, the aim of which is to construct new theoretical concepts capable of explaining emerging phenomena. In the field of qualitative research, grounded theory is gaining prominence as an approach to developing theory from data (Monteiro et al., 2023). A common trend in all types of case studies is to try to explain why a particular decision or several decisions were made, how those decisions were implemented, and what is the effect of implementing these decisions (Lima et al., 2023).

In this study, several steps were taken: defining the research topic, reviewing the literature, the development of non-financial reporting, and requirements and guidelines for reporting the effects of environmental activities. Then, key companies in the automotive industry were selected, data was collected, an analysis was carried out, and a table was formulated, which

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was divided according to individual elements related to the environmental impact resulting from the organisation's activities.

The development of this research should deepen the knowledge of environmental activities undertaken in automotive industry companies and indicate the possibilities of requirements contained in environmental management tools to standardise reported information on the effects of environmental activities of these organisations.

An overview of the literature

The rising importance of business information on sustainable development induces companies to become increasingly interested in developing and publishing non-financial effects of their activities in the form of ESG (Environment, Social responsibility, corporate Governance) indicators. ESG factors are a set of non-financial performance indicators intended to ensure the responsibility of the organisation and may be subject to assessment by investors and other stakeholders (Kaźmierczak, 2022). ESG refers to the way in which corporations and investors integrate environmental, social and governance issues in their business, which means that ESG explicitly covers issues related to the governance of an organisation (Gilan et al., 2021). Environmental factors refer to how an organisation uses renewable and non-renewable resources. Social factors allow for measuring how the company and its business activity affect the social environment, i.e., employees, customers, suppliers, and the local community. Corporate governance means the company's internal governance system. It consists of procedures, standards, and control mechanisms implemented to ensure effective management, improve decision-making processes, comply with the law and consider the needs of external stakeholders, especially the investors (GPW, 2021).

Unfortunately, the lack of uniform guidelines on how to calculate these metrics leads to a lack of transparency and problems with comparing them over time and between different organisations. Despite the emergence of non-financial reporting guidelines (GPW, 2021), there are no clear requirements for the specific data that information should be reported with principles related to ensuring transparency, relevance, truthfulness and non-misleading and ensuring factuality, accuracy and reliability.

With the provisions of the EU Directive on the reporting of non-financial data, the importance of business information on sustainability, such as ESG data, has increased in all EU Member States. In the literature on the subject, there are also more and more studies on various aspects of ESG disclosures. For example, Ellili (2020), Sharma et al. (2020) and Suttipun (2021) examined the extent of ESG disclosures and confirmed that, although still at a low

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level, the scope of information has increased in subsequent years. In addition, corporate governance information accounts for the largest part of ESG disclosures, followed by social and environmental information. Hence, issues related to the environment and ongoing climate change are the area that requires the most urgent action, which means that organisations with EMAS implemented will have easier reporting opportunities in this area. In addition, a number of recent studies (Manita et al., 2018; Arayssi et al., 2020; De Masi et al., 2021) examined the impact of different corporate governance mechanisms on ESG disclosure. This only confirms that ESG is gaining more and more recognition.

To identify business risks and increase investor and consumer confidence, disclosure of non-financial information is key to managing the shift towards a sustainable global economy through a combination of social justice and environmental protection. In this context, the disclosure of non-financial information helps to measure, monitor and manage business performance and, thus, in sustainability accounting (Vukić et al., 2017). Currently, those responsible for ESG reporting of organisations rely on various methods, approaches and tools that are still developed in national and international institutions and have an impact on statutory requirements but also on the content of the reports (Kocmanova et al., 2012). Although the term ESG was introduced as early as 2004 by the United Nations, there is still a lack of consistency in the features, attributes and standards defining individual ESG components (Billio et al., 2021). Thus, reports published by various organisations often face criticism because they do not fully illustrate how financial and non-financial elements are managed to create enterprise value (Hoang, 2018). In addition, given the diversity in ESG reporting, the comparability of strategic ESG results is problematic (Lokuwaduge & Heenetigala, 2016), while research by Singhania and Saini (2022) indicates significant variation in the degree of implementation of ESG frameworks in different countries.

The implementation of the ESG reporting system can be supported by environmental management systems functioning in organisations, including EMAS, which increases the awareness of management and stakeholders in the need to care for the environment and the essence of the idea of sustainable development, which is confirmed by research conducted in 22 Polish companies that have implemented EMAS (Myszczyszyn, 2017). Research conducted in 211 manufacturing companies in Pakistan also confirms that the environmental management system is a tool that really supports the long-term, sustainable development of enterprises (Ikram et al., 2019), as did Ronalter et al. (2022), who concluded in their research that both the quality management system and the environmental management system are powerful business tools for improving ESG results. Finally, Kocmanov and Simberov (2014) drew on international sources of performance indicators,

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including EMAS, when defining ESG performance indicators for companies in the processing industry.

The identified gap in the literature is largely due to the fact that contrary to the practice used in disseminating financial information, organisations enjoy a great deal of freedom and discretion in reporting non-financial information on sustainability through ESG indicators and the lack of indication of best practices used in the EMAS.

Sustainability reporting through ESG indicators

At the end of 2019, the European Commission published the Green Deal – a package of policy initiatives aimed at achieving climate neutrality by 2050. These include actions on climate, environment, energy, transport, industry, agriculture, and sustainable finance (Rada Europejska, 2022). One of the commitments of the Green Deal was the revision of the currently functioning NFRD (Non-Financial Reporting Directive), i.e. the Directive on disclosure of non-financial information (Dyrektywa, 2014) due to the lack of uniform reporting standards, and thus the impossibility of comparing data published by different entities.

The new rules were to be reflected in the CSRD (Corporate Sustainability Reporting Directive) (Dyrektywa, 2022) in the form of ESG (Environment, Social responsibility, corporate Governance) indicators. In addition, the new regulation assumes the imposition of more reporting obligations and the extension of the list of entities and areas to which it will apply (Hamada, 2022). The CSRD Directive was published on 16 December 2022 in the Official Journal of the EU, which means that ESG reporting is mandatory for all large entities from 2026 (for the trading year 2025). This provision must be implemented into Polish law within 18 months (Ministerstwo Finansów, 2022). This is, therefore, the beginning of intensive preparations for the relevant subjects.

The elements of the sustainability reporting system published so far in the area of "environment", which will be clarified by the European Commission by 30 June 2023 in the scope of "information that should be disclosed by entities in relation to all areas of reporting and sustainability issues, and information that financial market participants must disclose in accordance with the disclosure obligations set out in Regulation (EU) 2019/2088" is:

- Climate change – mitigation and adaptation,
- Water and marine resources,
- Resource use and circular economy,
- Pollution,
- Biodiversity and ecosystems.

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The indicated factors are at a high level of generality, which means that in many organisations, the approach to presenting results in this area will be very diverse. There are no specific requirements for reporting environmental effects resulting from the organisation's activities. In addition, these requirements do not indicate whether effects are to be reported at the product or process level and which benchmarks and scale should be used. It is also not indicated to what extent reporting organisations can compare their own environmental performance with that of other organisations.

By 30 June 2024 at the latest, 'the Commission should adopt a second set of sustainability reporting standards by means of delegated acts, specifying the supplementary information that undertakings should disclose where necessary in relation to sustainability issues and reporting areas, and information specific to the sector in which the entity operates' (Dyrektywa, 2022).

EMAS environmental reporting requirements

One of the tools that can help organisations prepare for reporting ESG indicators in the area of environment is Regulation (EC) No 1221/2009 of the European Parliament and of the Council of 25 November 2009 on the voluntary participation in a Community eco-management and audit scheme (EMAS), repealing Regulation (EC) No 761/2001 and Commission Decisions 2001/681/EC and 2006/193/EC. According to the requirements of this Regulation, EMAS-registered organisations 'should produce and make publicly available periodic environmental statements providing the public and other interested parties with information on their compliance with applicable legal requirements relating to the environment and their environmental performance. In order to ensure the relevance and comparability of the information, reporting on the organisations' environmental performance should be on the basis of generic and sector-specific performance indicators focusing on key environmental areas at the process and product level using appropriate benchmarks and scales. This should help organisations compare their environmental performance both over different reporting periods and with the environmental performance of other organisations.' (Regulation, 2009). Inaddition, in the reporting of environmental effects, the organisation can support reference documents, including best environmental management practices and environmental performance indicators for specific sectors, which should be developed through information exchange and collaboration between Member States. Those documents should help organisations better focus on the most important environmental aspects in a given sector. Annex IV to Regulation (EC) No 1221/2009 sets out the requirements for environmental reporting. EMAS-registered organisations are required to communic-

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ate information on key environmental performance indicators. One of the important documents produced in the organisation, which contains information on the environmental performance of the organisation, is the environmental statement (Regulation, 2009). In addition to information on the organisation itself and its eco-management and audit scheme, the environmental statement must include information on environmental aspects and impacts, environmental objectives and plans for their achievement, and the environmental performance and results of the assessment of compliance with applicable legal requirements relating to the environment. In addition, the environmental statement should include confirmation from the accredited verifier that the information contained in the environmental statement meets the requirements of the EMAS Regulation. This means that only information verified by an environmental verifier can be included in the environmental statement and made public.

Given that it is not always possible to measure the environmental performance of an organisation on the basis of data, soft indicators can also be presented, including changes in behaviour, process improvements, and other measures to improve environmental performance. Again, when reporting on these other factors, the organisation's management should take into account relevant sectoral reference documents. It should therefore indicate in its environmental statement how relevant best environmental management practices and available criteria of excellence have been applied in the definition of measures and actions and possibly in setting priorities to further improve the environmental performance of the organisation (Matuszak-Flejszman, 2019).

A sectoral reference document was created, i.a., for the car manufacturing sector – Commission Decision (EU) 2019/62 of 19 December 2018 on the sectoral reference document on best environmental management practices, sector environmental performance indicators and benchmarks of excellence for the car manufacturing sector under Regulation (EC) No 1221/2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS). The sectoral reference document (SRD) is primarily addressed to organisations that are already registered with EMAS, secondly to organisations that are considering registering with EMAS in the future, and thirdly to all organisations that wish to learn more about best environmental management practices in order to improve their environmental performance. Consequently, the objective of this document is to support all organisations in the car manufacturing sector to focus on relevant environmental aspects, both direct and indirect, and to find information on best environmental management practices, as well as appropriate sector-specific environmental performance indicators to measure their environmental performance, and benchmarks of excellence (Commission Decision,

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2019). This Commission Decision contains best environmental management practices, separately for the automotive manufacturing sector and for the end-of-life vehicle treatment sector. Best practices for the car manufacturing sector cover the issues presented in Table 1.

Table 1. Best environmental management practices for the automotive manufacturing sector

ENVIRONMENTAL MANAGEMENT
- implementation of an advanced environmental management system
ENERGY MANAGEMENT
- implementation of detailed energy monitoring and energy management systems - increasing the efficiency of energy-intensive processes - use of energy from renewable and alternative sources - optimization of lighting in automotive plants - rational and efficient use of compressed air - optimization of the use of electric motors
WASTE MANAGEMENT
- waste prevention and management
WATER MANAGEMENT
- water use strategy and water use management - water-saving opportunities in automotive plants - water recycling and rainwater collection - green roofs for rainwater management
BIODIVERSITY MANAGEMENT
- review and strategy for the management of ecosystems and biodiversity along the entire value chain - biodiversity management at the level of the place of production
VALUE CHAIN DESIGN AND MANAGEMENT
- promoting environmental improvements throughout the supply chain - working with suppliers and customers to reduce packaging - sustainable design using life cycle assessment
ENVIRONMENTAL MANAGEMENT REGENERATION
- general best practices for remanufactured components

Source: authors' work based on Commission Decision (2019).

In addition to the best environmental management practices in the Commission Decision (EU) 2019/62, you can also find indicators of the organisation's environmental performance, which can be reported as an effect achieved by organisations in the area of environmental impact (Table 2).

Table 2. Selected environmental performance indicators for the car manufacturing sector

BEMPs for environmental management
Sites with an advanced environmental management system Number of environmental performance indicators that are in general use throughout the whole organisation and/or which are reported on in environmental statements Use of internal or external benchmarks to drive environmental performance
BEMPs for energy management
Number of facilities with detailed energy monitoring systems, with an energy management system certified ISO 50001 or integrated in EMAS Implementation of regular reviews of systems, automation, repair, maintenance and upgrades Overall energy use per functional unit Share of site energy use met by renewable sources Energy consumption from fossil fuels per functional unit Implementation of improved positioning, energy-efficient lighting
BEMPs for waste management
Waste generation per functional unit Hazardous waste generation per functional unit Waste sent to specific streams, including recycling, energy recovery and landfill Establishment and implementation of an overarching waste strategy with monitoring and targets for improvements Number of sites with advanced waste management plans in place Number of sites achieving zero waste to landfill
BEMPs for water management
Water use per functional unit Sites that have conducted a water strategy review Sites that have monitoring for water use Sites that have separate water monitoring for production processes and sanitary use Water use per functional unit Share of new sites designed with water-saving devices and processes Water use per functional unit Installation of a wastewater/ rainwater recycling system
BEMPs for biodiversity management
Application of methodologies to assess ecosystem services to the value chain Coverage of relevant scope, as determined by prioritisation Number of collaboration projects with stakeholders to address biodiversity issues Inventory of land or other areas, owned, leased or managed by the company in or adjacent to protected areas or areas of high biodiversity value Plan for biodiversity friendly gardening in place for premises or other areas, owned, leased or managed by the company
BEMPs for value chain management and design
Self-assessment questionnaires sent to direct high risk suppliers Direct supplier development and training undertaken Waste generation per functional unit Packaging waste generation per functional unit Packaging waste generation per site or maintenance group Conducting LCA of the main product lines to support design and development decisions
BEMPs for remanufacturing
Level of remanufacturing Overall remanufacturing levels

Source: authors' work based on Commission Decision (2019).

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These environmental performance indicators allow the management of an organisation to report its environmental performance in specific areas, which means that organisations representing a given industry can compare with each other. This possibility can also be used by stakeholders who would like to invest or buy products of a given organisation, taking into account one of the non-financial indicators, which is the environmental impact.

It should also be stressed that, as part of the requirements of the EMAS Regulation, organisations additionally provide information related to the impact of their activities on society and environmental activities for society in their environmental statements. This is linked to the requirement to have an open dialogue with the public. This information could also be taken into account in the framework of ESG reporting in the area of 'society'.

Previous activities of selected automotive companies in the field of ESG reporting

Despite the lack of a general obligation to report non-financial data (so far, this compulsion has been "imposed only on those large undertakings which are public-interest entities and on those public-interest entities which are parent undertakings of a large group, in both cases with an average number of employees higher than 500, on a consolidated basis in the case of a group" (Dyrektywa, 2014)), as well as the lack of unified indicators with regard to the reporting of activities in the field of sustainable development, many organisations, in anticipation of the CSRD Directive, have already tried to define their own indicators in the presented projects. The following table presents the reporting structure of ESG indicators in reports on sustainability activities voluntarily published by selected automotive concerns: Volkswagen Group, Ford Motor Company and MAN Truck and BUS SE.

ESG Indicators 2020 & 2021 in the Volkswagen Group

The Volkswagen Group is one of the largest automotive concerns in the world and the largest car manufacturer in Europe, which includes 10 brands offering various vehicles – from motorcycles, through passenger cars, sports cars, to vans and trucks: Volkswagen Passenger Cars, Volkswagen Vans, ŠKODA, SEAT, CUPRA, Audi, Lamborghini, Bentley, Porsche and Ducati (Volkswagen Group Polska, 2022). The company has been publishing a Sustainability Report since 2011, while ESG indicators have also been part of the report since 2020.

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The report on ESG indicators for 2020 and 2021 presented by the Volkswagen Group includes 5 groups of indicators: Decarbonization, Circular economy, People in transition, Diversity, Integrity, Responsibility for supply chains and economy. Table 2 summarises and compares the measures included in the report for the three environmental areas (Volkswagen AG, 2022).

Table 3. Overview of the "ESG indicators" published in the ESG-Kennzahlen Volkswagen AG 2022 report with a focus on environmental indicators

Decarbonisation	Circular Economy	Responsibility for supply chains and the economy
Decarbonisation KPIs: – decarbonisation index, – average emissions of passenger cars broken down by US and EU, – number of cars produced in alternative drive technologies (gas, hybrid, electric), – carbon footprint of the product, – greenhouse gas emissions. Environmental management KPIs (for all brands and separately for the production of passenger cars and commercial vehicles): – specific emission reduction, – emissions of volatile organic compounds. Direct NO_x- and SO_2 emissions (for all brands and separately for the production of passenger cars and commercial vehicles)	KPIs circular economy: – avoided CO_2 emissions due to aluminium closed loop project, – demand for fresh water in locations in at-risk areas. Environmental management KPIs: – number of locations certified according to ISO 14001 or EMAS in the Volkswagen Group/VW AG, – number of production sites certified according to ISO 50001 in the Volkswagen Group. Energy consumption (overall and per car) – electricity, heat, fuel gases for production processes: – water, – sewage, – waste (non-hazardous, hazardous and metallic) for recycling , – waste for disposal (non-hazardous and hazardous), – chemical oxygen demand, – water intake, – sewage disposal, – number of remedial measures implemented.	– suppliers with a certified environmental management system according to ISO 14001 and/or EMAS, – buyers who have taken part in sustainability qualification activities, – suppliers who have received sustainability training, – average sustainability breaches by region, – suppliers who have completed the sustainability e-learning module.

Source: authors' work based on Volkswagen AG (2022a).

Analysing the ESG indicators presented by the Volkswagen Group, it can be seen that each of them closely correlates with the elements of the sustainability reporting system included in the latest CSRD Directive.

In the area of the environment (E), the Volkswagen Group pays particular attention to reducing CO_2 emissions into the atmosphere not only at the stage of vehicle production but throughout the entire life cycle of the products offered, which is a manifestation of the commitment to mitigate climate change, which is included in the list of environmental activities in the CSRD Directive. Also, the use of water and other resources and the circular economy listed in the Directive have been reflected in indicators concerning the consumption of utilities and the reduction of the amount of waste generated. The Volkswagen Group's monitoring of the number of locations with functioning and certified environmental management systems goes beyond the scope of the indicators set out in the CSRD Directive. On the other hand, the Volkswagen Group's current report lacks indicators relating to biodiversity and ecosystems, but they are part of the CSDR Directive, and in this respect, the Volkswagen Group will have to develop and report appropriate measures.

Looking at the summary of environmental ESG indicators, they lack indicators on the mass flow of key materials used in car production and indicators related to land use in relation to biodiversity. It should also be noted that the Volkswagen Group takes into account environmental management issues as a key performance indicator (KPI), including locations certified according to ISO 14001 or EMAS within the Group and production sites certified according to ISO 50001 at the Volkswagen Group. This means that the environmental performance indicators resulting from the requirements of EMAS and the sectoral reference document for the car manufacturing sector must be used.

The fact that the topic of ESG is treated as a priority in the Volkswagen Group is evidenced by the fact that, along with decarbonisation and integrity, it is one of the 12 initiatives of the Volkswagen Group's "New Auto" Strategy (Volkswagen AG, 2022b). During the work on the "New Auto" Strategy, the choice of issues on which the Group focuses was also considered in the context of the requirements of the financial and capital market. As a result, in 2020, 4 thematic areas were defined: Decarbonization, Circular economy, Responsibility for supply chains and business, and People and transformation, and in 2021 two more were supplemented: Diversity and Integrity. Each of the thematic areas has clearly defined objectives and milestones, possible KPIs and action packages. ESG-related measures such as the decarbonisation rate and the diversity index are already reflected in the remuneration of board members (Volkswagen AG, 2021a). All defined thematic areas are aligned into the 17 sustainable development goals (SDGs) defined by the United Nations for 2030[1], to which the Volkswagen Group is committed to supporting, and the independent Board of Sustainability (Volkswagen AG, 2021b) has been advising the Board of Directors of Volkswagen AG since 2016.

1 United Nations (2015).

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Ford Motor Company – ESG Data Book

Ford Motor Company is currently one of the largest automotive concerns in the world with more than a hundred years of history, which has developed to the current level from a family business. Currently, Ford Motor Company produces cars, sports cars, vans and trucks under the Ford and Lincoln brands. The Ford Motor Company has been reporting sustainability indicators for more than 20 years, but it is only in recent years that the company has highlighted ESG in its annual Environmental, Social and Governance Review (Ford Motor Company, 2022a).

Table 4. A compilation of the "ESG indicators" published in the Ford Motor Company 2022 ESG Overview report with a special focus on environmental factors

Supply chain management	results of supplier audits – number of non-conformities in initial audits in 2021, broken down into categories: management systems, employees, health and safety, environment and ethics and detailed subcategories
Fuel consumption of vehicles and CO_2 emissions (Scope 1, Scope 2)	average fuel consumption of Ford Corporation in the USA CO_2 emissions of Ford vehicles in the USA, Europe, Switzerland and China per 1 vehicle average fuel consumption of Ford Corporation in China CO_2 emissions of Ford vehicles in China per 1 vehicle
Car emissions other than CO_2	Ford's average NOx and NMOG1 emissions in the USA
Operational energy consumption and CO_2 emissions	energy consumption in facilities worldwide global greenhouse gas emissions from plants greenhouse gas emissions from operations around the world
CO_2 emissions of purchased goods and services	indirect emissions
Emissions (VOCs and others)	volatile organic compounds released by production plants emissions reported to Toxics Release Inventory in the USA emissions reported to the National Pollutant Release Inventory in Canada
Waste	regional waste sent to landfill by region and per 1 vehicle regional hazardous waste by region and per 1 vehicle hazardous waste according to the method of disposal non-hazardous waste according to the method total amount of waste according to the method of disposal scrap metals total amount of waste and percentage recycled
Water	global water consumption per vehicle produced global water consumption by source water consumption by region reuse from the local wastewater treatment plant discharge of process sewage

Source: authors' work based on Ford Motor Company (2022b).

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In October 2022, the Ford Motor Company published an integrated report on finances and sustainability. It refers to the company's vision for carbon footprint by 2050, which specifically defines targets for air emissions, energy consumption, waste, water consumption, materials, safety, human rights, diversity, equity and inclusion, and mobility and accessibility for all (Ford Motor Company, 2022a). The data published in the report covers the years 2019, 2020 and 2021, and specific indicators are visualised in the table below (Ford Motor Company, 2022b).

As in the case of the Volkswagen Group, the Ford Motor Company also refers to ESG as defined in the CSRD through the published data. In the area of environmental factors, data such as vehicle fuel consumption and CO_2 emissions, car emissions other than CO_2, operational energy consumption and CO_2 emissions, CO_2 emissions of purchased goods and services, emissions (VOC and others), waste and water were included. In this example, each area identifies specific environmental performance indicators (EPI) against which an organisation's environmental performance can be assessed. As in the case of VW, the indicator related to the annual flow of key materials used for production and land use with regard to biodiversity is not included here. Also, with regard to the requirements of the CSDR Directive, there are, therefore, no indicators relating to resource use and biodiversity and ecosystems.

Environmental indicators of MAN Truck & BUS

MAN Truck & BUS is an international company producing commercial vehicles, trucks and cars. It has production plants in 3 European countries: Germany, Austria and Poland, as well as in Russia, South Africa and Turkey. MAN (Krakow plant) is the only company in the automotive sector to be registered under the EU's voluntary Eco-Management and Audit Scheme (EMAS), which entails a reporting obligation on key emission factors. The Munich, Nuremberg and Salzgitter plants are also registered in the EMAS register. The ESG indicators presented cover the entire MAN Truck & BUS Group and cover seven strategic areas (MAN, 2022). These are presented in Table 5.

MAN Trucks Sp. z o.o. (Krakow plant) is an EMAS-registered organisation. In its Environmental Statement, this organisation publishes indicators for six mandatory areas, in accordance with the European Commission Regulation 2018/2026 – energy, emissions, material, water, waste and land use in relation to biodiversity in 2019-2021. These indicators are presented in Table 6.

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Table 5. ESG MAN Truck & BUS indicators published in the Sustainability Report 2021 with a focus on environmental indicators

ENVIRONMENT		
Decarbonization	**Circular Economy**	**Responsible Transport and Mobility Solutions**
– greenhouse gas emissions along the entire value chain and other indirect emissions – energy consumption in production processes – direct energy consumption (combustion fuels and gases) and indirect energy consumption, including electricity and heat – direct primary energy consumption (heating oil, natural gas, diesel, other) – Energy consumption per vehicle – Absolute indirect and indirect CO_2 emissions – CO_2 emissions per vehicle – Atmospheric impurities (sulphur dioxide, nitrogen oxides, solid particles, volatile organic compounds) – Logistic-related CO_2 emissions per vehicle produced	– production waste (broken down into hazardous and non-hazardous and broken down into recycled and recovered) – metal waste – recycling rate – water consumption – surface water consumption – reused water – used rainwater – wastewater	– number of connected vehicles – number of electric cars (orders and sales broken down into trucks, commercial vehicles and cars)

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

Table 6. Environmental performance indicators MAN Trucks Sp. z o.o. (Krakow plant)

ENERGY: – Electricity and natural gas consumption, – Share in renewable energy sources, – Fuel consumption, including: on-site diesel, petrol, other fuels.	WATER: – Water consumption per vehicle, – Amount of wastewater per vehicle, – Consumption of drinking water from external sources.
EMISSION: – Emissions of volatile organic compounds and nitrogen oxides per vehicle, – CO_2 emissions per vehicle, – SO_x, NO_x, dusts, – CO_2 equivalent.	WASTE: – Consumption of waste per vehicle: hazardous for disposal, hazardous for recovery, non-hazardous for disposal, non-hazardous for recovery [kg/vehicle], – Absolute amounts of waste generated: • Other organic solvents, washing solutions and mother liquors, • Paint and varnish removal sludges containing organic solvents or other hazardous substances, • Paper and cardboard packaging, • Other wastes not listed, • Packages containing residues of dangerous substances or contaminated with them.
MATERIAL: – surface treatment material: • varnishes containing solvents, • water-based varnishes, • diluents, • hardeners, • coagulants. – number of vehicles produced	LAND USE IN RELATION TO BIODIVERSITY: – Total area of the plant, including fenced, roofed, built-up and green area, including meadows, arable fields and uncultivated land.

Source: authors' work based on GDOŚ (2023).

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In these areas, the Krakow plant MAN Trucks Sp. z o.o. has indicated additional criteria for the assessment of environmental aspects that are important in reporting environmental effects. For example, in the area of energy consumption, the share of 'green electricity', the technical and economic possibilities of achieving significant savings (electricity, gas, etc.) and the condition of buildings, the supply network (insulation, emissions) are indicated. However, in the case of emissions from incineration/ painting processes, the technical and economic feasibility of achieving significant savings, the type and quantity of emissions and the location of the site are taken into account (GDOŚ, 2023).

As can be seen, the indicators presented in Table 6 and the information contained in the Environmental Declaration on the achieved by the Plant in Krakow MAN Trucks Sp. z o.o. inform stakeholders and the actual impact of the plant on the environment in an appropriate and clear way. In addition, this information is factual, accurate and reliable, as evidenced by the signature made by the accredited verifier on the statement in the environmental statement.

Comparison of ESG indicators

Analysing the above lists of ESG indicators reported by selected automotive concerns, it is clear at first glance that their simple comparison is not possible at this stage, which is confirmed by literature data. For instance, Piłacik (2017) stated that the lack of unified principles for preparing social responsibility reports responsibility causes difficulties in properly assessing a company's impact on, for example, the environment. Currently, making comparisons between companies is not possible due to the form and scope of presented information in the area of CSR. Sipiczki (2022) additionally highlighted the dynamic development of ESG-related products and services in the market over the last decade. As a result, there are now more than 600 ESG ratings and rankings worldwide, and although these products have similar objectives, the methods and metrics are very inconsistent and present sustainability information in different ways.

Each of the analysed companies has defined and monitored indicators useful and relevant from the point of view of its own operations and the environment in which it operates, most often responding to legal requirements or those resulting from the implemented management systems. These indicators are measured in different units and analysed from different angles (e.g. location, business units or type of product). Moreover, not every indicator has been released since the same point in time, some of which did not appear in the reports until 2021. In addition, each of these corporations in

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the presented reports in a descriptive way presents a number of activities undertaken towards the implementation of social, environmental and management goals, which are even more difficult to compare.

When analysing indicators from the environmental area, it is difficult to determine and compare data presented by organisations of the same industry. Both VW, FORD and MAN presented indicators on emissions, energy, water and waste in their ESG reports. In the case of MAN, the revised Environmental Statement presents the environmental performance in six main areas and provides additional information related to the environmental benefits achieved and the environmental objectives set for the coming years. Targets include but are not limited to reducing CO_2 emissions by 50% by 2025 compared to 2015, implementing an ISO 50001 energy management system, reducing water consumption per vehicle by 3% by 2025 compared to 2019 and strengthening employee environmental awareness. Therefore, the application of the requirements of the EMAS Regulation and the consequent obligation to publish their environmental performance annually based on 6 key environmental indicators and additional specific indicators would allow stakeholders to compare the environmental performance of these organisations.

The subject of ESG is also reflected in the group's strategies, which proves the high level of priority posed to this issue, but despite the strong involvement of all three companies in ESG activities, it is not possible to compare the presented indicators, although all the companies operate in the same industry. It should be noted that it will be even more difficult to compare organisations from different industries. This example confirms the need for a uniform framework for the reporting of ESG indicators, which is what the European Parliament and the Council of the European Union are taking.

Conclusions

The latest framework of guidelines for reporting non-financial indicators in the area of "environment" presented in the article and the assessment of the possibility of using the existing reporting to report environmental indicators under EMAS allowed for the analysis of the possibility of using environmental management tools for non-financial reporting.

The analysis shows that the depicted approach to reporting sustainable development indicators by selected automotive concerns, referred to as "ESG indicators", often have their source in the already implemented management systems functioning in these enterprises (environmental management systems, energy management systems, compliance management systems, etc.). Such an approach is in line with the guideline of the newly introduced CSRD

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Directive, which clearly indicates that "sustainability reporting standards should be proportionate and should not impose an excessive administrative burden on companies that are obliged to comply with them" (Dyrektywa, 2022). However, each of the organisations, due to the high level of generality, arbitrarily presents these indicators, taking into account the basic division. In addition, when analysing the presented indicators related to the area of environmental impact, it should be stated that all three concerns did not take into account indicators related to the use of resources and biodiversity and ecosystems.

It must therefore be concluded that the automotive industry is partly prepared for sustainability reporting.

The inclusion in ESG environmental reporting of key performance indicators (KPIs) in the form of EPIs (environmental performance indicators) based on the key environmental performance indicators contained in Annex IV to the EMAS Regulation and the inclusion of a sectoral reference document for the car manufacturing sector would increase the transparency of the information made available to stakeholders. The more so that these indicators are validated each year by an accredited environmental verifier, which unfortunately cannot be ensured in the field of ESG reporting. The introduction of more precise requirements for ESG reporting and validation requirements for reported results would make it possible to ensure their credibility and comparability. The use of environmental performance indicators and best environmental management practices contained in reference documents and the ISO 14031 standard would definitely facilitate environmental reporting within ESG for organisations.

The contribution of the authors

Conception, A.K.-W. and A.M.-F.; literature review, A.K.-W. and A.M.-F.; acquisition of data, A.K.-W. and A.M.-F.; analysis and interpretation of data, A.K.-W. and A.M.-F.

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EMERGY ANALYSIS OF POND FISH FARMING – A CASE STUDY FOR A LARGE FISH FARM IN POLAND

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ABSTRACT: The immediate goal of the article is an emergy analysis of fish production on an exemplary fish farm. Additionally, it was compared, in terms of environmental burden, with other exemplary agricultural productions. On the basis of the calculated emergy inflows, selected emergy indicators (ELR, EYR, REN) were calculated, showing the scale of use of renewable and non-renewable resources. The results show that the analysed fish production does not burden the environment and largely uses renewable resources, unlike other intensive agricultural productions. The ELR value was compared with its values for other exemplary agricultural production. In fish farming, this indicator is most often lower than 1. It is assumed that such activity does not burden the environment. Animal production requires the involvement of additional space for fodder production. Therefore the differences in the area necessary for the production of a food unit (GJ) of exemplary plant and animal products are also shown. Emergy analysis and its results can provide valuable information for decision-makers in terms of the direction of a given production.

KEYWORDS: emergy account, environment, inland aquaculture, emergy indicators

Introduction

Fishing is an important part of the global economy, consisting in acquiring fish, seafood and other aquatic organisms for consumption and processing. The scope of fishing also includes breeding or rearing that is based on the breeding of fish and other aquatic organisms in aquaculture (Hryszko et al., 2018). According to FAO data (FAO, 2022), global fisheries and aquaculture production in 2020 amounted to 177.8 million tonnes, including inland aquaculture comprising 54.4 million tonnes. Compared to 2000, the total production volume increased by more than 32%, and for inland aquaculture by over 20%. At the same time, 157.4 million tonnes of fish were used for consumption in 2020 (an increase of 44% compared to 2000), and consumption per person was 20.2 kg/year on average (an increase by approx. 20% compared to 2000). The greatest number of aquatic products per person per year are consumed in Asia (24.6 kg on average), the lowest – in Africa (10 kg), and in Europe – 21.1 kg. Unfortunately, in Poland, the consumption of aquatic products is still at a very low level (13.1 kg/person on average – data for 2019 (EUMOFA, 2021). The consumption of fish and seafood is recommended due to their high nutritional value (Januszko & Kałuża, 2019).

Polish aquaculture has a long history, with the first records of activity from around the 11th–12th century (Guziur, 2018), and Poland uses the largest areas of ground carp ponds in the European Union (Lirski & Myszkowski, 2022). Currently, aquaculture in Poland consists mainly of terrestrial freshwater fish farming and is limited to the rearing of about forty species of fish. There are three main types of activity specialising in the production of fish for consumption: low-intensity carp farming in polycultures, intensive farming of salmonids and high-intensity farming of fish in recirculating systems with water filtration and purification. Among these groups, the production of consumption carp has a significant share. In 2020, it accounted for 48% (21.15 thousand tonnes) of the total weight of produced fish for consumption (Lirski & Myszkowski, 2021a; Lirski & Myszkowski, 2021b).

The global production of aquaculture has increased in recent decades, while aquaculture systems are becoming more energy-intensive, mainly based on non-renewable sources (Kim & Zhang, 2018). Sustainable aquaculture production is the subject of intense discussion (Naylor et al., 2021), and for this to be a sustainable trend, it is necessary to combine local resources and human capital in the best possible way while reducing or eliminating negative environmental impacts (Diana et al., 2013). Fish production in freshwater ponds, like any other activity, has an impact on the environment, and without concern for sustainable development, it leads to ecological disadvantages, an increased number of diseases of farming fish, and conse-

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quently to a decrease in the economic profits of fish farms (Mavraganis et al., 2020).

Since aquaculture is closely related to the environment, the authors shall analyse the problem of its impact on the environment. Freshwater aquaculture, an example of which is the subject of analysis in the paper, is often a very complicated form of activity, including not only the farming of specific species, but a number of adaptations related to the necessary infrastructure and creating value chains. In many countries, it is most often in the form of family fish farms, which produce a variety of fish species for local and regional consumption (Hernandez et al., 2018; da Silva Maciel et al., 2022; FAO, 2018).

The immediate goal of this study is an emergy analysis of fisheries production in freshwater aquaculture (carp rearing and accompanying production of additional species) in an exemplary family fish farm located in south-western Poland. On the basis of the calculated emergy inflows (renewable and non-renewable) to the system, selected emergy ratios have been calculated (NEAD, 2022; Haden, 2003), showing the scale of using renewable and non-renewable resources. Additionally, we compare the analysed production with other exemplary agricultural types of production, which constitute the crucial basis for food consumption in many countries (e.g. wheat, buckwheat, corn, chicken, and pigs, examples of aquaculture). The purpose of these comparisons is to show the differences in the environmental load of these different types of productions. Due to the fact that animal production (including aquaculture) requires the involvement of additional land for fodder production, we also show the differences in the area actually required to produce a food unit (GJ) of sample plants and animal products.

Data and Methods

Description of the studied object

The subject of the analysis is the production of a fishing farm: the production results achieved, the amount and type of expenditures incurred, taking into account the extent of the use of renewable and non-renewable environmental resources. The analysis includes the two production years, 2020 and 2021.

The farm was established in 1985; it is located in south-western Poland, in the Opole Voivodeship (50°87’17.9”N 17°81’49.1”E). In the vicinity of the farm, there is the Stobrawa Landscape Park. The proximity of the farm’s fishing ponds and the running production blend in with the landscape, enrich biodiversity and do not disturb the natural environment. The vicinity of the ponds is also a great place for hiking.

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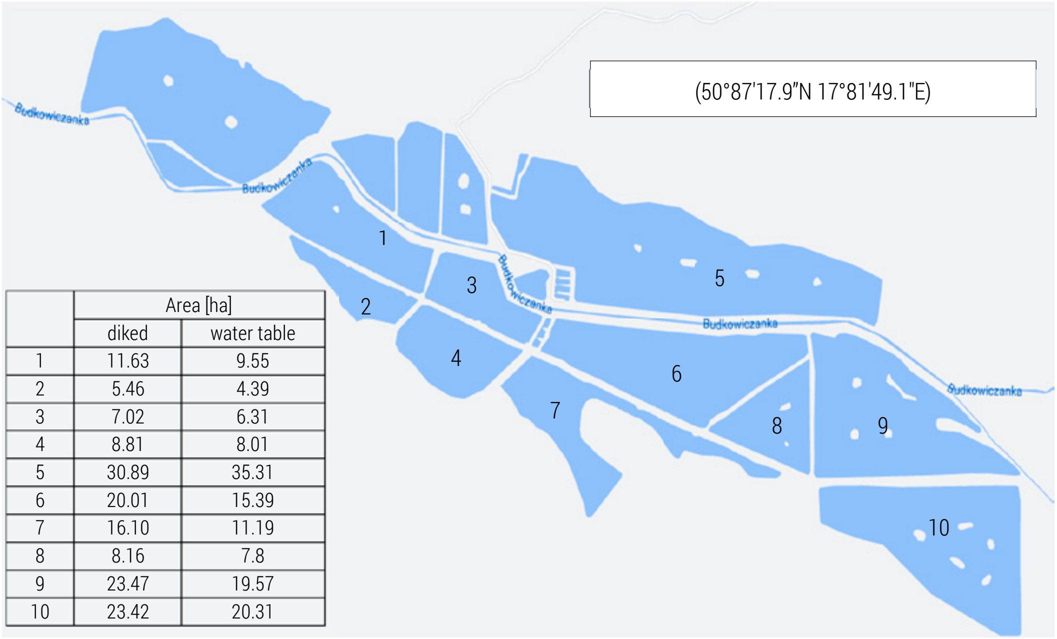
The most important and valuable assets of the farm are fish ponds with a diked area of 162.77 ha and a water surface area of 137.83 ha. The farm has a total of 10 ponds with an area of 5.46 ha to 38.89 ha with an average depth of 1.3 m (Figure 1).



	Area [ha]	
	diked	water table
1	11.63	9.55
2	5.46	4.39
3	7.02	6.31
4	8.81	8.01
5	30.89	35.31
6	20.01	15.39
7	16.10	11.19
8	8.16	7.8
9	23.47	19.57
10	23.42	20.31

Figure 1. Illustrative map of the location of fish ponds and their area

Source: authors' work based on Google Maps [04-08-2022]. The data on the area of the ponds come from the analysed farm.

The Budkowiczanka River, which is the longest left tributary of the Stobrawa River, flows through the central part of the pond area. The river supplies the ponds with water. The intake of surface water from the river is in accordance with the decision of the water permit and amounts to 10,833,960 m^3 per year. This environmental resource and the amount consumed make up the main share in the use of renewable natural resources in production. Other renewable resources included in the emergy analysis of fish production are: solar energy, wind, rainfall, and wild fish that appear in ponds with the water let in the ponds. Most ponds are filled with water each year in the spring (from March to April) and drained in the fall (from October to November) when fish for sale are harvested. The selected ponds intended for the so-called lagoon of winter-breeding (fingerlings materials), which are the basis for further production, remain flooded all the time. After being har-

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vested, fish for sale are kept in fish warehouses until the Christmas period, when they are sold. Ponds no. 3, 6 and 8 – with a total diked area of 35.19 ha and water surface area of 29.50 ha – are intended for wintering stocking material.

In addition to the production ponds, the farm is equipped with machines, devices, means of transport and buildings necessary to run production. Equipment characterised by a high level of wear and tear and the needs of the farm aimed at the improvement of working conditions and efficiency, also having an impact on animal welfare, prompted owners to purchase new equipment and machines with the use of external support in the form of EU funds. At the end of 2020, the farm obtained funds from the Fish Operational Programme (FOP) in the amount of PLN 172,013.65 (about $ 44,120.77), which was 1/3 of the net value of the new equipment purchased. Equipping the farm with modern machinery and equipment should improve the conditions, safety and organisation of work (e.g. mowing dikes, feeding fodder, and transport). It may also affect the efficiency of the production process and translate into the production results achieved. Until the end of 2020, some of the farm work was done by hand, which consumed a lot of time for the employees involved in the production process.

The type and volume of production on the farm

The analysed facility is a large commercial farm which has specialised in the production of commercial fish – carp (*Cyprinus carpio)* from the very beginning of its activity. The production is of a low-intensive rearing character. For such farms, the scope of production ranges from 500 to 1500 kg/ha, the share of natural food in the ration is high, and depending on the fertility of the pond and the stocking density, may reach up to 50%. This level of production intensification currently covers the vast majority of Polish pond farms (Guziur, 2008; Lirski & Myszkowski, 2021a; Raftowicz & Le Gallic, 2020; Lasner et al., 2020). Currently, in fishing practice, low-intensity farming is recommended as the most profitable.

The production of fish for consumption on the farm in question is carried out in a two- or three-year cycle. The two-year cycle consists in producing heavy fingerlings (at least 60 g/pc.) in the first year, which is stocked in commercial ponds in the second year. In a three-year cycle, in the first year, light fingerlings with a unit weight of up to about 60 g are produced. After overwintering in the second year, the light fingerlings are used to produce two-year-old stocking material, called steplets, with a unit weight of 200-400 g, which is used in commercial ponds in the third production season.

The current final products of the farm are commercial fish ("tradeish"), such as carp grown from stocking material as well as pike (*Esox Lucius)* and

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tench (*Tinca tinca*) flowing in with water when the ponds are filled. Additionally, fingerlings and stocking material are produced, but mainly for the farm's own production needs. Carp is the main, so-called intended production of the farm. Tench and pike flow into the filled reservoirs "by the way", along with water feeding the ponds. Owners benefit from the mercy of the environment and the gift of nature, and these species that migrate ultimately increase production, increase diversity and affect the economic result of the farm.

Every year, nearly 100% of adult commercial fish production is sold. The farm obtains the largest part of its revenues from the sale of commercial fish. Its share in total sales was over 80% in both years. The total sale of stocking material and fingerlings in the years 2020–2021 accounted for 18–19% of the total sales of the farm's production. In 2020, the production volume was 1.80E+05 kg. According to the owners, the increase in main production by 6.50+E3 kg in 2021 (see Table 2) resulted, among others, from improving work related to equipment purchased under FOP.

Data for emergy calculations of a farm production

Information on the production was obtained from the records conducted on the farm, other documents (water abstraction permits) and, additionally, through direct discussions with the owners. Data included:

- production volume,
- sold production value,
- expenditure (purchase and own) and costs related to production: own and external human labour, fodder, young stocking material, consumption of fuel and spare parts, consumption of materials for repairs, lime consumption, fees and taxes, depreciation, and insurance.

Additionally, for the needs of emergy analysis of the conducted production, the use of renewable environmental resources taken into account, such as solar energy, precipitation supplying water to ponds, wind, surface water flowing from the Budkowiczanka river and other fish species supplying ponds with inflowing water.

Using available references data on other agricultural productions (plant and animal, extensive and intensive), the ELR of these productions was compared with the fish production analysed in the article. In addition, in order to show the real scale of the area involved in a given type of production (including feed production), the total necessary area per energy unit (GJ) of the final product was calculated for selected productions. Such an analysis also shows a much greater scale of environmental load in many different productions.

The energy value (GJ) of fish production was calculated using the tables of the composition and nutritional value of food (Kunachowicz et al., 2020).

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Emergy analysis and emergy indicators

There are several approaches allowing to measure the impact of a given type of production on the environment, e.g. Cumulative Energy Intensity (CEI), Life Cycle Assessment (LCA) or Emergy Analysis (EMA) (Wang et al., 2020; Wardal et al., 2021; Flaten et al., 2019; Wilfart et al., 2013; Kim & Zhang, 2018). The method that allows to measure the relation of involvement of renewable and non-renewable resources in the production process is emergy analysis. Its application, along with the estimation of environmental loading ratios (e.g. EYR, ELR, REN) (NEAD, 2022; Haden, 2003), may allow for more optimal decision-making in the sphere of using resources available for production (Lomas et al., 2006; Sciubba & Ulgiati, 2005).

The emergy approach in the assessment of the use of the environment is based on the analysis of the use of the environment as a donor of available energy (exergy) (Wang et al., 2020; Brown & Ulgiati, 2004b) and the analysis of the path of thermodynamic transformations of energy: resources, products manufactured, services (Wang et al., 2020; Hau & Bakshi, 2004; Odum, 1996). Emergy measures the work done by both nature and people in the process of creating a product or service, and the starting point is the focus on the energy available in the environment (energy of the sun, wind, tides, etc.), which is the source and basis for the functioning of the biosphere and the creation of economic goods.

The natural environment is the provider of energy needed to produce goods and services. Accumulated in renewable and non-renewable resources, it constitutes energy available for use in the production process. From the point of view of conserving natural resources and sustainable development, it is important that the production in question uses a greater proportion of renewable resources.

The concept of emergy, introduced by Odum (1996) as the measure of the manufactured product (service) and its quality, expresses the energy of solar radiation used directly or indirectly in the production of a product or service. It is expressed in solar joules [seJ]. In EMA, solar energy has been assigned particular importance in the process of creating resources and goods. The vast majority of products and services are characterised by considerable complexity and the use of different materials, intermediate products and labour inputs. Monetary flows are also largely used. Therefore, the emergy account is often very complex, similar to the determination of cumulative energy or exergy consumption (Stanek, 2009).

The emergy of a given product (production process) or service can be expressed by the equation (1) (Sciubba & Ulgiati, 2005):

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$$U = \sum_i P_i \times \tau_i, \quad (1)$$

where: U – emergy, P_i – expresses a component used in production, expressed by its exergy in [J], mass [g] or monetary value, e.g. in [$], τ_i – solar transformity of component expressed in [seJ/J], [seJ/g], or [seJ/$].

The exergy of most substances or various products can be precisely estimated. It concerns their mass and price as well. However, it is difficult to accurately determine the solar transformity. Often its values are inaccurate, which raises a number of controversies, e.g. in the work by Hu et al. (2012).

The emergy account also has a number of advantages. It makes it relatively easy to determine the emergy of financial outlays in production. Data on national monetary equivalents (P1) (NEAD, 2022) and the share of renewable sources of emergy in their value make it possible to divide the emergy of goods obtained from purchase into a renewable and non-renewable part. In our calculations, we use the value of the monetary equivalent (P1) derived from (NEAD, 2022) for 2015 (latest available value), which is 6.09E+12 seJ/$.

The emergy account brings the contribution of all inputs to a common reference quantity, which is solar energy. At the same time, it enables the separation of components into a renewable (or partially renewable) and non-renewable part. This allows for the determination of the share of renewable components in the production process and the total level of its renewal, as well as for determining its impact on the environment (environmental loading).

The emergy account also gives the opportunity to compare different types and techniques of production in terms of their impact on the environment. This is achieved by appropriately defined emergy indicators. The most important are ELR, EYR, REN. The Environmental Loading Ratio (ELR) is a measure of the environmental pressure of a given production. It expresses the use of environmental services by a system, indicating a load on the environment. It is the ratio of the total emergy of the nonrenewable inputs to the emergy of the total renewable inputs. The lower the ratio, the lower the stress to the environment, and any production for which ELR>1 begins to load the environment. Emergy Yield Ratio (EYR) is an index measuring the ability of a system to use the available local resources. It shows the ratio of the output of a system to the external inputs from outside (purchased). The higher the ratio the higher is the relative contribution of the local sources of emergy to the system. In the productions where the streams of emergy of goods and services from purchase definitely dominate, EYR aims at the value of 1. The renewability (REN) indicator determines the ratio of emergy from renewable sources to the total emergy consumed in the production process. The higher the score, the greater the use of local renewable environmental

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resources in the production process (NEAD, 2022; Ciotola et al., 2011; Jankowiak & Miedziejko, 2009; Chen et al., 2006; Pérez-Soba et al., 2019; Su et al., 2020; Vassallo et al., 2007; Brown & Ulgiati, 2004a). An additional description of the indicators is presented in Table 2.

Often some resources used in production are partially renewable and sometimes difficult to estimate precisely. The share of renewal is described differently in the literature on the problem. The renewal of human labour can be an example. In the production analysed in this paper, labour and services are fully paid. Therefore, its renewal was assumed at the level determined by the monetary conversion factor (P1) (National Emergy Money Ratio) (NEAD, 2022).

Results and discussion

In accordance with the procedure of emergy account described by Sciubba and Ulgiati (2005), the production on the farm and the type of resources involved are presented in Figure 2. It is a diagram of an energy system that shows the relationship between components and processes within the system boundaries. The production system and its boundaries are determined by the area of the rearing ponds. The resources related to the production process, shown on Figure 2, include:

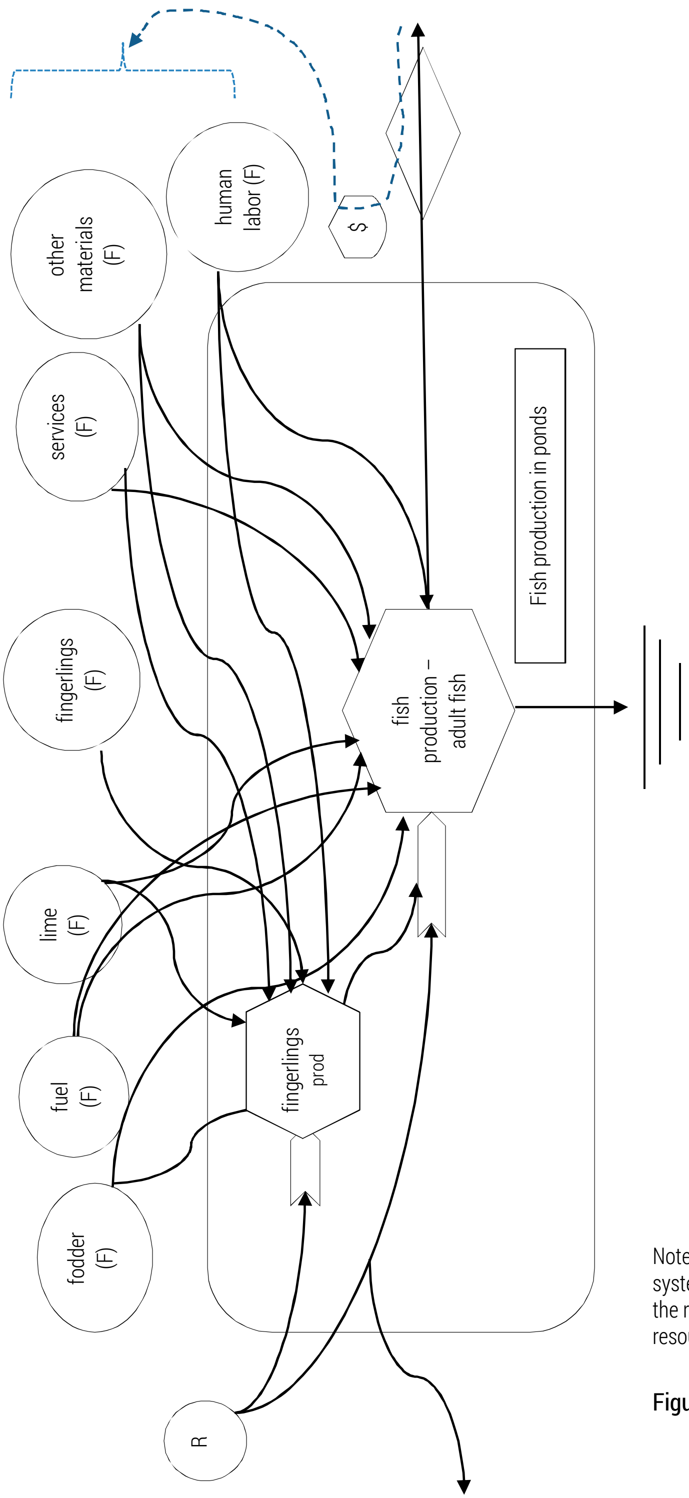
renewable from natural sources (R): sun, rainfall, wind, surface water from the river feeding the ponds, wild fish flowing into the ponds,

purchased (F): including the share of renewable (FR) and non-renewable (FN) parts, e.g. fodder, lime, services, fuel, purchased stocking material.

Further below, Tables 1 and 2 show exactly the types of expenditures and costs involved in the production of fish in 2020–2021, production results and the calculated selected emergy indicators. Table 1 summarises the share of renewable and non-renewable resources, both from beyond the system and from purchase, used in production (including their renewable and non-renewable part of resources). They are shown in energy and monetary terms. Financial costs of the conducted activity were also taken into account, including depreciation, taxes and fees, insurance.

Looking at the emergy share, the large area of rearing ponds and the area required for the manufacture of a production unit (ha/t or m^3/kg) means that the share of renewable sources is clearly greater (1.532E+18 seJ in 2020 and 1.534E+18 seJ in 2021) in relation to the share of non-renewable resources (1.163E+18 seJ and 1.269E+18 seJ). This makes the production environmentally beneficial, which is reflected in the emergy indicators discussed later.

Due to the fact that practically all the remaining resources necessary for the discussed fish farming come from purchase, their emergy shares are con-



Notes: R – renewable resources available to the system, e.g., wind, sun, rain, surface water from the river flowing into the ponds; F–purchased resources (FR and FN parts).

Figure 2. Emergy flow diagram of pond fish rearing

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veniently expressed by the use of a monetary conversion factor (P1). Among these components, the largest part is expenditure on fish fodder (45.22% in 2020 and 58.22% in 2021), labour and services (26.49% and 20.62%), depreciation of fixed assets (6.32% and 9.45%) and fuel (7.06% and 4.43%).

The amount of fodder given is a consequence of the scale and type of the farming process, as well as the experience of employees. It is difficult to reduce these costs in the analysed fish farm. In the literature dealing with the analysis of emergy fish farming, there are examples of a smaller scale of production compared to the discussed farm. In these examples, fish fodder is often a by-product or waste from other production, sometimes aggregated with ongoing fish farming. Such a situation is described in (Liu et al., 2018), where silkworm larvae are used as fodder. In small family farms, fish fodder also uses various leftover food and harvested grass (Zhang et al., 2012). In the farm, which is the basis for our analysis, the fish are fed with grain fodder, mainly wheat.

At the end of 2020, the farm received funds from the FOP, and a number of purchases of fixed assets were made, the purpose of which was to improve production activities. The effect of these measures was a reduction in spending on wages and services by over 20% and a reduction in fuel consumption by about 38% in 2021. The investments implemented also increased the value of depreciation, which influenced the overall financial result and total energy in 2021.

Emergy monetary conversion factors are often used alternately with conversion factors (solar transformities) based on energy (exergy), such as seJ/J or mass seJ/g units (Sun et al., 2021). Since financial conversion factors and a calculation based on the purchase prices of raw materials depend on fluctuations in market prices, the values of emergy of selected goods or services determined in this way may differ from the values based on energy conversion factors (Jankowiak & Miedziejko, 2009). Therefore, additionally, our analysis contains a recalculation (for the year 2021) of the streams of emergy for fodder and fuel. At that time, they accounted for over 62% of production costs. In the case of fodder, data from the study by Kuczuk (2016a) regarding the conditions of wheat cultivation were used for the calculations. We assumed that it is the basis of the fodder mixture for farmed fish. Solar transformity for conventional wheat production presented in Kuczuk (2016a) amounted to 2.96E+12 seJ/kg, and REN = 0.107. For organic wheat production 2.95E+12 seJ/kg, and REN = 0.249. The recalculations provided a similar emergy stream with different shares of the renewable and non-renewable parts. In the case of fuels, the cumulative exergy consumption of diesel oil in the amount of 47.4 MJ/kg after Stanek (2009) and the solar transformity of τ = 11.088E+4 seJ/J, adopted after Brandt-Williams (2002) were used. The emergy stream of 2.849 seJ was obtained, for which REN = 0 was assumed.

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Table 1. Emergy analysis: local renewable and purchased (FR and FN) inputs

No	Input	Renewability share	Unit	Quantity, value per production cycle (2020)	Quantity, value per production cycle (2021)	UN seJ (2020)	UN seJ (2021)	τ	UR seJ (2020)	UR seJ (2021)	Refer. τ
1	Solar energy	1	J	4.74E+15	4.74E+15			1	4.74E+15	4.74E+15	Odum (1996)
2	Rain	1	m³	1.02E+06	1.02E+06			2.59E+04	1.31E+17	1.31E+17	
3	Wind	1	J	5.35E+11	5.35E+11			2.50E+03	1.34E+15	1.34E+15	Jankowiak and Miedziejko (2009)
4	Water in ponds from river tributaries	1	m³	5.35E+13	5.35E+13			2.59E+04	1.39E+18	1.39E+18	
5	Wild fingerlings	1	kg	1.80E+02	2.88E+02			8,44E+12	1.52E+15	2.36E+15	Own calculation
	Total renewable								1.525E+18	1.526E+18	
6	Purchased fingerlings	0.00616	$	1.86E+03	1.14E+03	1.12E+16	6.89E+15	6.09E+12	6.97E+13	4,27E+13	NEAD (2022)
	Fodder	0.00616	$	8.69E+04	1.22E+05	5.26E+17	7.39E+17	6.09E+12	3.26E+15	4.58E+15	
7	Fodder*	0.107					1.42E+18	2.86E+12		1.70E+17	Kuczuk (2016a)
	Fodder**	0.249					1.19E+18	2.85E+12		3.96E+17	
8	Calcium	0.00616	$	1.99E+03	1.05E+03	1.20E+16	6.34E+15	6.09E+12	7.46E+13	3.93E+13	NEAD (2022)
9	Fuel and grease	0.00616	$	1.36E+04	9.11E+03	8.21E+16	5.51E+16	6.09E+12	5.09E+14	3.42E+14	
	Fuel and grease***	0					2,85E+16	11.09E+04		0,00	Odum (1996) (corrected by 1,68)

No	Input	Renewability share	Unit	Quantity, value per production cycle (2020)	Quantity, value per production cycle (2021)	UN seJ (2020)	UN seJ (2021)	τ	UR seJ (2020)	UR seJ (2021)	Refer. τ
10	Spare parts	0.00616	$	6.99E+03	3.64E+03	4.23E+16	2.21E+16	6.09E+12	2.62E+14	1.37E+14	NEAD (2022)
11	Other materials	0.00616	$	1.07E+04	2.42E+03	6.50E+16	1.47E+16	6.09E+12	4.03E+14	9.10E+13	
12	Depreciation	0.00616	$	1.22E+04	1.98E+04	7.36E+16	1.20E+17	6.09E+12	4.56E+14	7.43E+14	
13	Taxes and fees	0.00616	$	3.20E+03	3.26E+03	1.94E+16	1.97E+16	6.09E+12	1.20E+14	1.22E+14	
14	Social insurance	0.00616	$	3.88E+03	3.93E+03	2.35E+16	2.38E+16	6.09E+12	1.46E+14	1.47E+14	
15	Purchased services	0.00616	$	2.70E+04	1.70E+04	1.64E+17	1.03E+17	6.09E+12	1.01E+15	6.36E+14	
16	Full-time human labour	0.00616	$	8.00E+03	8.69E+03	4.84E+16	5.26E+16	6.09E+12	3.00E+14	3.26E+14	
17	Full-time human labour	0.00616	$	1.59E+04	1.76E+04	9.63E+16	1.06E+17	6.09E+12	5.97E+14	6.60E+14	
	Total purchased					1.163E+18	1.269E+18		7.211E+15	7.866E+15	
	TOTAL					1.163E+18	1.269E+18		1.532E+18	1.534E+18	
	TOTAL: *and ***						1.923E+18			1.699E+18	
	TOTAL: **and***						1.697E+18			1.924E+18	

Notes: U – emergy used; R – renewable part; N – non-renewable part; τ – transformity; No. 15 – the purchased services, e.g. desludging, service, transport, mowing, contract work for the time of catching fish; No. 16 – Full-time human labour – farm work, physical work on dikes (mowing), feeding, taking care of the physical condition of machines and devices, manual work on catching fish, guarding; No. 17 – Full-time human labour – administration and physical work by the owner; *calculation from solar transformity for conventional fodder (wheat); **calculation from solar transformity for organic fodder (wheat); ***fuel calculation taking into account cumulative exergy intensity.

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This methodology is more difficult to apply to labour and service outlays. In the case of the fish farm analysed in the study, they differ seasonally in terms of scope and duration. These are often specialised services, simple jobs also performed by family members. As the accounting documents do not reflect the exact man-hours, it is difficult to calculate their total number. Hence, in the case of work, the monetary emergy conversion factor was used. As a consequence, for the analysed fish farming, for the year 2021, also three values of selected emergy indicators (ELR, EYR and REN) were given as an alternative. The first of the values is the result of taking into account only the monetary conversion factor for fodder and fuel, and the second and third values – are the solar transformity of wheat production and the exergy consumption of the accumulated fuel. We assess the environmental sustainability of the analysed production on the basis of selected, generally used emergy indicators, listed in Table 2 (NEAD, 2022; Haden, 2003). Their estimated values have been supplemented with additional information that may be helpful for comparisons with other aquaculture systems as well as with other agricultural activities.

In 2021 in the analysed fish farming, the ELR = 0.827, EYR = 2.195, and REN = 54.7%. The value of ELR<1 proves the favourable relations between production and the natural environment. The consequence of the relatively high renewal of the analysed process is the value of EYR>2. The higher the EYR value, the higher the relative contribution of local emergy sources to the system. Therefore, this indicator shows the system's ability to use the available local resources. The values quoted above relate to calculations taking into account the monetary conversion factor.

On the other hand, when using the conversion of fodder and fuel emergy, taking into account the solar transformity of wheat grain and the cumulative exergy consumption of fuels, some differences in the values of the indicators (REN, ELR, EYR) calculated for 2021 can be noticed. Taking into account the feeding of fish with conventional fodder, the ELR value increased slightly to 1.132. On the other hand, the use of organic fodder lowered the ELR again to a value below 1, which is a result similar to the calculation taking into account the monetary conversion factor. In general, the results for both calculation methods are similar, and the differences that appear in the emergy account are acceptable. Especially if you take into account the various assumptions you make, comparing data and the values of indicators in 2020–2021, it can be seen that the completed investment (FOP) allowed reducing the share of labour and fuel-related emergy streams. However, a significant increase in depreciation made the value of the REN slightly lower in 2021. The ELR increased by 9% in 2021 but was still below 1. The changes in the prices of goods and services in those years also influenced the values of the indicators. The slight increase in production (by approx. 6 tonnes) was probably the result of various environmental impacts, but it was not a direct result of economic activities.

Table 2. Emergy measures and indicators of production in the analysed farm

Measures and indicators	Symbol/Formula/Unit	2020	2021
Total production	Y [kg]	1.80E+05	1.86E+05
Total production – energetic value	Y [GJ]	820.61	766.18
Sold production	Y[kg]	1.50E+05	1.53E+05
Value of production sold	Y[$]	5.46E+06	7.90E+06
Total emergy used	$U = U_R + U_N$ [seJ]	2.695E+18	2.803E+18
Total emergy used*			3.621E+18
Total emergy used**			3.621E+18
Share of renewable emergy (including U_{FR})	U_R [seJ]	1.532E+18	1.534E+18
Share of renewable emergy (including U_{FR})*			1.699E+18
Share of renewable emergy (including U_{FR})**			1.924E+18
Share of non-renewable emergy (including U_{FN})	U_N [seJ]	1.163E+18	1.269E+18
Share of non-renewable emergy (including U_{FN})*			1.923E+18
Share of non-renewable emergy (including U_{FN})**			1.697E+18
The purchased emergy (services and raw materials for production)	$U_F = U_{FR} + U_{FN}$ [seJ]	1,17E+18	1.277E+18
The purchased emergy (services and raw materials for production)*			2.096E+18
The purchased emergy (services and raw materials for production)**			2.096E+18
Renewability	$REN = (U_R/U) \cdot 100$ [%]	5.68E+01	5.47E+01
Renewability*			4.69E+01
Renewability**			5.31E+01
Environmental Loading Ratio	$ELR = U_N/U_R$	7.594E-01	8.276E-01
Environmental Loading Ratio*			1.132E+00
Environmental Loading Ratio**			8.819E-01
Emergy Yield Ratio	$EYR = U/U_F$	2.303E+00	2.195E+00
Emergy Yield Ratio*			1.728E+00
Emergy Yield Ratio**			1.728E+00
National Emergy Money Ratio (P1) – monetary conversion factor	P1 = U/GDP [seJ/$]	6.09E+12	6.09E+12
Total emergy used per 1 kcal of production	U/GJ [seJ/GJ]	3.28E+15	3.66E+15
Total emergy used per 1 kg of production	U/Y [seJ/kg]	1.501E+13	1.509E+13

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Measures and indicators	Symbol/Formula/Unit	2020	2021
Renewable part of emergy (including U_{FR}) per 1 kcal of production	U_R/kcal [seJ/kcal]	7.832E+09	8.389E+09
Renewable part of emergy (including U_{FR}) per 1 kg of production	U_R/Y [seJ/kg]	8.533E+12	8.257E+12
Consumption of cereal fodder (wheat)	kg	476645.0	537160.0
Cereal consumption per 1 kg of fish production	kg	2.65	2.89
Fodder consumption per production area	kg/ha	2928.33	3300.12
Average wheat yield in Poland	kg/ha	4470.00	4570.00
Arable land area required for fish production on 1 ha	ha	0.66	0.72
Total production/area	Y/ha [kg/ha]	1103.09	1140.96

Notes: *calculation from solar transformity for conventional fodder (wheat) and fuel with cumulative exergy consumption taken into account; **calculation from solar transformity for organic fodder (wheat) and fuel, taking into account the cumulative exergy intensity.

Figure 3 shows the compared values of ELR indicators for various agricultural production: plant and animal, including aquaculture. It can be noticed that the extensive and medium-intensive fish farming system is characterised by the lowest ELR indicators presented. It is also beneficial to combine farming with other production that can be a source of fodder (Liu et al., 2018). The remaining productions shown have an ELR>1. In the case of plant production, the intensive use of mineral fertilisers and plant protection products affects (often significantly) the increase of the value of the indicator (Jankowiak & Miedziejko, 2009). The work of the machines used and fuel, treated as streams of non-renewable emergy, also play a significant role. Examples of organic production often show lower ELR ratios compared to conventional production. However, in organic production, higher labour inputs and lower production efficiency are more common. Figure 3 also shows the so-called theoretical production (light gray color) under domestic conditions (Poland). In that case all goods and services necessary for production are purchased. This would mean the lack of direct participation of renewable emergy streams in the production process. An example of such production can be very intensive, caged poultry farming.

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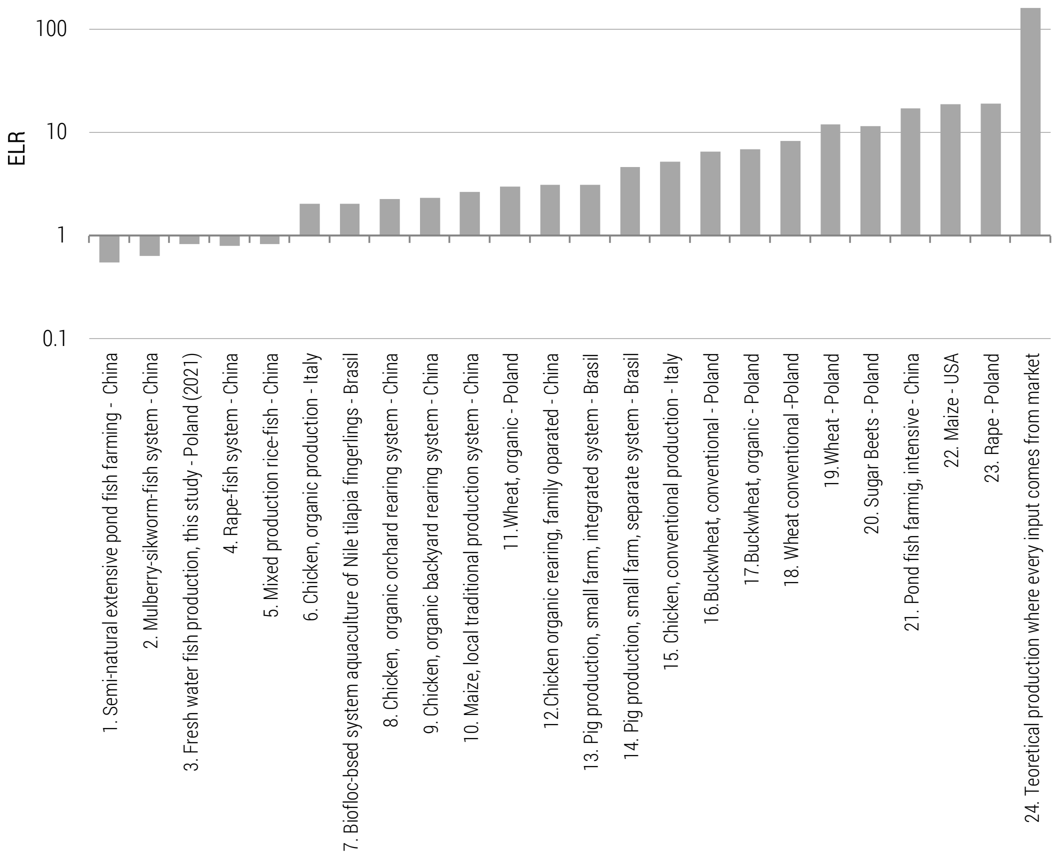

Figure 3. ELR values for typical agricultural and fishing productions

Source: authors' work based on Zhang et al. (2012; 2013); Liu et al. (2018); Su et al. (2020); Castellini et al. (2006); David et al. (2021); Kuczuk (2016a; 2016b); Hu et al. (2012); Cavalett et al. (2006); Jankowiak and Miedziejko (2009); Miedziejko & Jankowiak (2010a; 2010b); Martin et al. (2006).

Each agricultural production requires the involvement of a specific area of land. At a given scale of the production, the area is the greater, the more extensive or ecological production is. Land, especially in densely populated and urbanised countries, is expensive, which has an impact on potential plans for the development of agricultural production. Using data available in the literature, in Figures 4 and 5, there are estimated areas marked (black colour – basic production area, the white colour of bars – additional area needed for fodder production) occupied by exemplary plant and animal production, including aquaculture, related to 100 GJ of final products. It can be seen that by far the smallest area is occupied by the plant production shown in the chart and intensive animal husbandry (poultry, pond fish farming), which often takes place with extremely limited livestock areas. Virtually in all of the larger-scale animal productions shown, the basic cost is fodder (most often cereals and cereal mixtures), which requires the involvement of additional space. Therefore, Figure 5 also presents the added approximate size of the areas necessary to meet the fodder needs (white part of the bars). Verified in such a way, Figure 4 highlights the possible total area used for a given type of livestock production. It is clearly visible that plant production requires a much smaller area per 100 GJ of consumer product produced. The production of animal products for consumption requires not only livestock buildings or ponds but also a forage area. This exemplifies how large the scale of animal production is.

Pig and fish farming requires relatively the largest total area for production. In the case of poultry, it depends on the type of system: organic or conventional. The organic way of poultry farming significantly increases the area necessary for keeping the livestock. In the pond farm analysed in the study, it was estimated that for the production of 100 GJ of fish product, approximately 14 ha of forage area is required. It should be noted that in the low-intensity pond fish farm analysed in this study, the fodder provided constitutes about 50% of the nutritional requirement of the fish. The rest is supplemented by organic matter in the ponds.

In the case of the analysed fish production, one should pay attention to other aspects. The areas with ponds are often facilities for various forms of recreation and generate biodiversity. However, the ecosystem services provided by this type of production are more difficult to measure than a typical production-focused service, which is the provision of a consumer product. (Turkowski, 2021; Mathé & Rey-Valette, 2015; Hill et al., 2021). Moreover, as noted by Silvano et al. (2005), "a landowner with incomplete knowledge of the ecosystem services provided may therefore give them less weight than direct market benefits".

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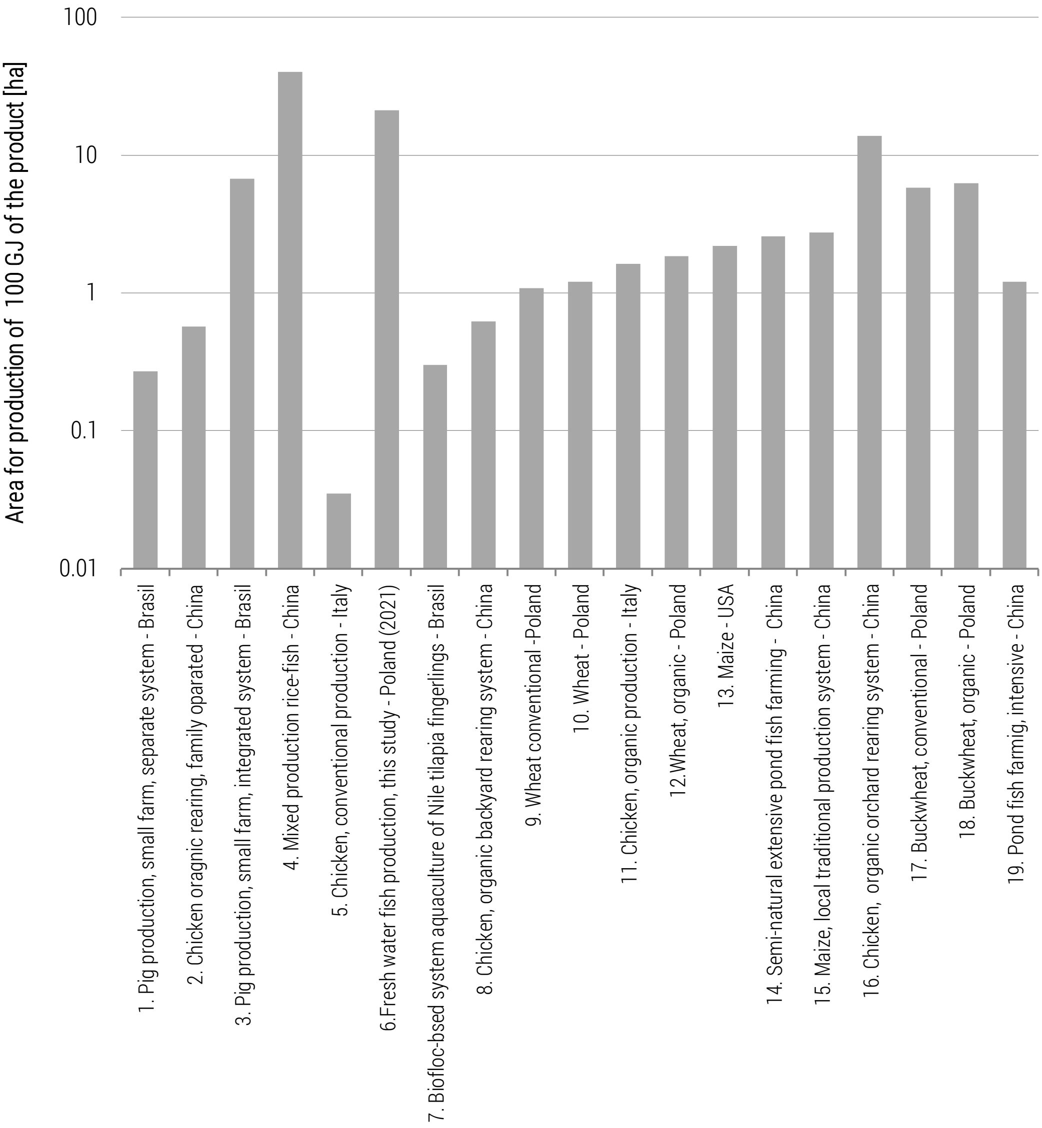

Figure 4. Main area for 100 GJ of the selected final products

Source: authors' work based on Cavalett et al. (2006); Hu et al. (2012); Su et al. (2020); Castellini et al. (2006); David et al. (2021); Zhang et al. (2012; 2013); Kuczuk (2016a; 2016b); Jankowiak & Miedziejko (2009); Martin et al. (2006).

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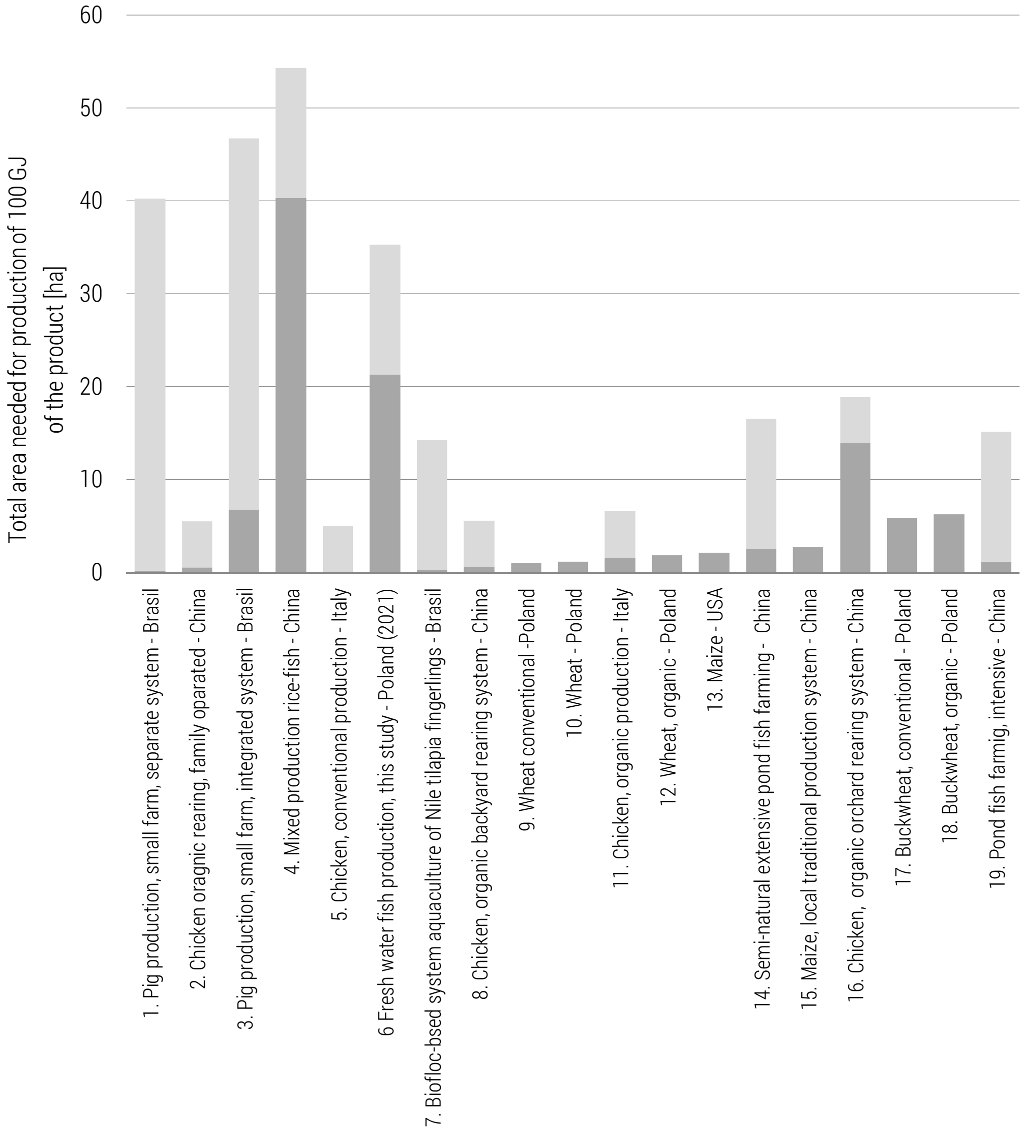

Figure 5. Area for production of 100 GJ of chosen final products, including additional area needed for fodder production purposes (white color)

Source: authors' work based on Cavalett et al. (2006); Hu et al. (2012); Su et al. (2020); Castellini et al. (2006); David et al. (2021); Zhang et al. (2012; 2013); Kuczuk (2016a; 2016b); Jankowiak & Miedziejko (2009); Martin et al. (2006).

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Conclusions

The conducted research allows for the formulation of the following conclusions:

Fish farming is an environmentally beneficial production due to the high involvement of renewable resources. This is indicated by the ELR parameters obtained: 0.7594 in 2020 and 0.276 in 2021, EYR: 2.301 in 2020 and 2.193 in 2021 and REN: 56.8% in 2020 and 54.7% in 2021. The ELR value of the analysed production was compared with its values for other, exemplary agricultural products. It can be seen that for the fish farms used as an example, the ELR is usually lower than 1. It is assumed that such activity does not negatively impact the environment.

Determination of emergy streams based on monetary conversion factor provides results vulnerable to fluctuations in the prices of goods and services. Therefore, for the production analysed in the study, additional alternative values of the above indicators were determined. The emergy of fodder and fuels was additionally determined by the use of solar transformity and renewability in wheat production (as a fodder base) and cumulative exergy consumption for fuel. The obtained results differ slightly from those obtained from monetary conversion factor. Despite these differences, they also show the environmental benefits of fish production.

The basic surfaces (without forage) necessary to produce 100 GJ of final products were compared. The smallest areas are related to intensive poultry production and intensive fish farming. Pig farming also requires a relatively small area. Extensive and ecological productions cover an area relatively larger, usually more than 1 ha per 100 GJ of production. The production of fish discussed in the paper requires about 21 ha per 100 GJ of fish produced.

If the area needed to secure fodder for the livestock is added to the areas dedicated to livestock production, the actual need for an area for livestock production can be noticed. The plant production itself requires much less space. Animal production, along with the fodder area, often requires the involvement of more than 10 ha per 100 GJ of the final product. The pond fish farm analysed in the study also requires over 30 ha/100 GJ of the product.

The practical significance of such an analysis is important information for producers, public administration and decision-makers in terms of undertaking rational production activities that take into account the problem of the use of environmental resources.

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The contribution of the authors

Conceptualisation, A.K., J.Pospolita; methodology, A.K., J. Pospolita; data validation, A.K., J. Pospolita; literature review, A.K., J. Pieczonka; investigation, A.K., J. Pieczonka; data acquisition, J. Pieczonka; analysis and interpretation of data, A.K., J. Pospolita and J. Pieczonka.

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Agnieszka WARTECKA-WAŻYŃSKA

THE IMPACT OF ONSHORE WIND FARMS ON THE TOURIST VALUE OF THE ENVIRONMENT IN THE OPINION OF POLAND'S INHABITANTS. ANALYSIS OF SECONDARY EMPIRICAL RESEARCH RESULTS

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ABSTRACT: In Poland, after several years of stagnation, onshore wind energy is becoming an important subject of interest for state and local authorities and society. An optimistic outlook for wind turbine investments is therefore emerging. The aim of the present paper is to discuss the social conditions that are an expression of public awareness that supports the construction of wind farms and to understand social opinions on the influence of wind farms on the local landscape, especially on the tourist values of the landscape.
To characterise the topic under study, the methods of literature review, statistical analysis, and secondary document analysis were used. Results of the nationwide empirical studies contained in the reports indicated a high level of public awareness of Polish society accepting investments in onshore wind farms. They do not diminish its tourist and recreational values and do not limit the development of tourist traffic.

KEYWORDS: wind energy, public awareness, tourism landscape

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Introduction

Poland's meeting climate and environmental goals for renewable energy sources (RES) and reduction of CO_2 emissions, and conditions for implementing Poland's energy policy strategy until 2040, is associated with the need to develop onshore wind energy. This need is becoming even more urgent in light of the effects of the COVID-19 pandemic, Russia's aggression in Ukraine, and the related economic sanctions against Russia. While there are specific resolutions and plans in this regard, implementing them is not easy. The difficulties are caused by the lack of appropriate regulations. Therefore, the development of wind energy in Poland is supported by social conditions such as a high level of public awareness of the country's inhabitants approving of the need to increase the use of wind energy. The aim of this paper is to present issues related to the state of Polish public awareness, knowledge, and interest in wind energy development in Poland and to identify behaviours that approve of its development. The paper also discusses the significance of social opinions on the impact of wind turbines on the tourist values of the landscape of a given geographic area, which are the energy investments that can limit the development of tourist activities. They can reduce resident income and local budgets obtained from the tourism economy.

However, the results of nationwide empirical research presented in the reports used for this paper show that the Polish society exhibits a high level of awareness and approves of investments in onshore wind farms. Wind farms have a positive impact on the natural and cultural values of the local landscape. They do not negatively affect its touristic and recreational value (Ministry of Climate and Environment, 2020a; 2020b). Public acceptance of wind energy should thus do more than just foster climate objectives and also encourage political authorities to create legal frameworks that would facilitate investment in renewable energy sources, especially onshore wind energy.

In our paper, we used the results of nationwide empirical studies collected using a diagnostic survey based on CATI and CAPI techniques. These results were published in reports by the Ministry of Climate and Environment (2020a; 2020b). Therefore, the method of secondary materials analysis was used. We also used the methods of literature review and statistical analysis. The results of nationwide empirical research on wind energy and its impact on the tourist landscape presented in the paper allowed for the formulation of the conclusions of a cognitive and practical character.

The analysis of the problem under analysis was juxtaposed with the foundations of the theories of behavioural economics and new institutional economics. These theories describe people's organised behaviour towards activities in their environment, such as windmill investments, for instance.

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Literature review

Tourist landscape

Without going into the details of various definitions of landscape, it should be emphasised that, in general, the landscape is a system isolated in a specific spatial unit, which consists of elements of the natural, economic, social, and cultural subsystems. The landscape of a particular geographical space is formed by tangible and intangible values of human activity concerning nature, culture, and historical heritage. They are important elements in the socioeconomic development and living conditions of the inhabitants of a particular area (Armand, 1980; European Landscape Convention, 2006). The landscape is a source of aesthetic experiences for humans, and it has a beneficial effect on their psychophysical health. It undergoes constant changes due to long-term natural and anthropogenic processes related, among others, to human economic activity. As part of the landscape ecosystem, humans, through their activities, not only improve and beautify the landscape but also destroy and degrade it, especially its natural values (Simmel, 2006; Urry, 2002).

Elements of the landscape, such as nature, economy, and cultural heritage, are not only protected, but they are resources used in the current and future socio-economic development of a specific area, including the development of the tourism economy. They create supply and demand values that foster tourist and recreational activities of various social groups, are of interest to tourists, and motivate them to travel. The natural and cultural values of the landscape satisfy the relevant needs of tourists and, from the economic point of view, constitute goods that are consumed by tourists. As objective and subjective elements and features of the landscape, they create its identity and tourist attractiveness and influence the tourist image of the area. The tourist image of the landscape of an area is a cognitive category, expressing knowledge describing subjective associations manifested in the opinions and emotions of tourists. Tourist values and the image of the landscape of a specific geographic space add to its tourist attractiveness, understood as a function of objective and subjective natural and cultural values, tourism development, and communication accessibility of this space.

Providing (supplying) tourist values of the landscape of a particular area that increases its tourist attractiveness is connected with appropriate land development. Development here means human activity adapted to the natural and socio-cultural environment of an area to the needs (demand) of tourism (Gaworecki, 2003).

The management of landscape values must conform to the principles of sustainable management, taking into account maintaining the balance of

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economic, social, and natural objectives of the area (Richling & Solon, 2011). These principles, among others, include:

- the principle of equal access to landscape potential,
- the principle of a high level of protection of landscape functions,
- the principle of regionalization,
- the principle of ecological effectiveness and economic efficiency,
- the principle of prevention; – the principle of precaution,
- the principle of socialisation and public participation in the planning process (Sasinowski, 2007).

Landscape management aims to achieve spatial order and eliminate ecological barriers. It combines the activities of landscape system protection with the progress of civilisation and economy and leads to a gradual reduction in landscape disproportions. It minimises functional, ecological, economic, and social conflicts according to the criteria of rationality, optimality, and management knowledge (Zimniewicz, 2008). The presented idea of managing the landscape values of an area with conscious use of scientific knowledge undoubtedly favours the development of tourist and recreational activities together with the simultaneous development of wind energy (Badora, 2014).

Wind energy

People transform the landscape of their surroundings by introducing new elements with positive or negative characteristics. Tourists look for areas suitable for recreation and leisure. They prefer places with landscapes of nature or different cultures compared to the place of their permanent residence. Examples of the development of a specific area with suitable landscape values using emerging wind farms become problematic and debatable (Marcinkiewicz & Poskrobko, 2015; Ryszkowska et al., 2018). Wind farms are devices that generate electricity using wind turbines driven by wind power. Electricity generated by wind turbines is considered to be environmentally clean as no fuel is burned to generate it. Wind turbines are divided into different types based on

- application (household, street, industrial power plants),
- power (micro, small, large),
- location (onshore, offshore).

Furthermore, wind power plant complexes with accompanying infrastructure are called wind farms, connected to the power grid. Wind farms can be located onshore or offshore (Regulation of the Minister of Economy of May 4, 2007).

Conventional energy sources (hard coal and lignite, oil, natural gas), which were a progressive innovation a century ago, have now brought nega-

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tive consequences in the form of environmental degradation (air pollution) and climate warming (Chodkowska-Miszczuk, 2014). These situations have contributed to the interest of international organisations and individual countries in renewable energy sources. According to a directive of the European Parliament and the Council of Europe as of April 2009, renewable energy was supposed to account for 20% of total energy consumption in European Union member states by 2020 (Mroczek et al., 2013). In Poland, this level was to be 15% (Statistics Poland, 2020). The 2015 Paris Agreement calls for a complete phase-out of fossil fuels in the European Union by 2050 (Sobieraj, 2017). However, in Poland, the achievement of even a not-too-exorbitant plan according to which alternative natural energy was expected to reach 15% in 2020 failed. Electricity in Poland has been generated from: – hard coal and lignite – 78.2%, – natural gas – 7.2%, – renewable (alternative) sources – 12.8% (Statistics Poland, 2020). In other European countries, energy based on renewable energy sources accounts for 54.6% in Sweden, 41.2% in Finland, 40.3% in Latvia, 36.1% in Denmark, and 33.4% in Austria. Alternative energy in Poland comes primarily from:

- wind (7.6%),
- biomass (3.0%),
- hydropower (1.2%),
- biogas (0.7%),
- photovoltaics (0.3%) (Statistics Poland, 2020).

In the present paper, the subject of the analysis is onshore wind energy, whose development in Poland is not limited by social but by formal and legal issues. The so-called 10 H distance law introduced in 2016 in Poland did not favour the development of wind energy (Act from 20 May 2016 on investments in wind power plants). According to this law, it became impossible to build turbines at a distance of less than ten times their height from the nearest buildings. Hence, it was colloquially known as the 10 H act for modern wind turbines. These provisions resulted in limiting the construction of turbines even to about 2,000 meters from buildings. Given the dispersed development of space in Poland, almost the entire area of the country has been eliminated from such investments. This situation has virtually contributed to the stagnation in the renewable energy market, restricting investors from building wind farms. Instead, it has led to a dominant role for the coal lobby (hard coal and lignite) in the energy industry. At the same time, it should be emphasised that due to the high cost of coal mining and the increase in the price of CO_2 emission allowances (from 5-6 € per tonne to 44 € in three years), we experienced an increase in energy prices. This increase affected large, medium-sized, and small enterprises and households, thus leading to an increase in the prices of goods and services. This situation caused the Polish authorities 2021 to take action, liberalising the legal regulations for the

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construction of onshore wind farms (Król, 2022). The relaxed distance bill, known as the 10 H Act, now provides for wind turbines to be located on land with a minimum distance of 500 meters from buildings. The location of new onshore wind turbines will also depend on the decisions of local governments. Local authorities, as part of their development plans, may waive the 10 H rule requirement and agree to a closer location provided a minimum protection zone of 500 meters from buildings is maintained. New onshore wind farm investments would also need to be consulted with the local community. Unfortunately, this bill has not yet entered into force ("Cztery piąte ankietowanych," 2022). A report by the Union of Polish Rural Gminas (Związek Gmin Polskich RP) shows that about 35% of Polish gminas invest in renewable energy development on their territory, including wind energy. Renewable energy sources are often created by local governments in areas of former obsolete state-owned farms from the period of Communist rule, with wind power plants being an important part of the budget of these governments ("Jedna trzecia gmin," 2016).

The conditions being created for onshore wind energy provide ample investment opportunities for state and private investors to build and operate wind farms. They also allow Poland to meet its climate and environmental targets for the development of Renewable Energy Sources and the reduction of CO_2 emissions. It offers cheaper energy to the economy and inhabitants of Poland and will stop dirty energy from coal.

The need for wind energy development in Poland is also expressed in the public awareness of Polish society. Polish residents admit that wind energy, which is cheaper and cleaner, will improve the environment, reduce carbon dioxide emissions, bring additional revenue to local governments, and increase the competitiveness of the Polish industry (Chodkowska-Miszczuk et al., 2016). Still, it will not reduce the tourist value of the landscape.

This is evidenced by studies on the impact of wind farms on the landscape and tourism carried out in many European countries. For example, similar to Poland, the development of wind energy in the Czech Republic (Franta'l & Kunc, 2011) was delayed for economic and political reasons. It was not until 2005 that favourable conditions emerged for investment in wind turbines, supported by legal and financial foundations. This situation has created arguments to discuss and seek answers to the question of whether wind farms can destroy the visual values of the natural and cultural landscape that is conducive to tourism. Franta'l and Kunc (2011) emphasise that the construction of wind turbines cannot be approached negatively in advance. And, one should not succumb to unfounded and unscientific opinions about their negative impact on the tourism landscape. These authors concluded, based on their empirical research, that wind farm activity in an area is received positively. Such farms are seen as a symbol of clean energy

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which promotes environmental protection (70%) and thus tourism. They can create positive aesthetic values of the landscape that enhance its tourism value (35%). Only 6% of respondents considered the construction of wind farms as an investment that negatively affects the image of the tourist landscape. Local communities have been particularly positive about wind farms. Residents surveyed in areas where wind turbines operate emphasised that these investments bring a clear economic benefit to landowners, investors, and local authorities. They can be a source of funding for the development of local infrastructure and its promotion, which is conducive to the development of tourism and recreation in the area. Therefore, residents perceive wind farms as a source of clean, renewable energy. They are seen as a contrast to industrial developments in the form of factories, mines, power poles, and cell phone towers, which, more figuratively and visually, harm the landscape.

The issue of the impact of wind farms on the tourist image of the landscape and the number of arriving tourists has also been the subject of scientific analysis in Portugal. For example, the results of one such empirical study conducted among the residents of a rural gmina of tourist value in the areas with wind farms and among tourists indicated that wind turbines do not have a negative impact on tourist demand (Silva & Delicado, 2017). Although there were opinions among tourists that the wind turbines pollute the rural landscape that is rich in cultural heritage sites, these imperfections are offset by the environmentally clean energy produced by the wind farms, favouring rural nature and material culture. According to tourists, the motivation for coming to a given locality is its natural and cultural heritage values. Wind farms are not a significant obstacle to visiting a tourist destination. Residents and tourists surveyed also emphasised that investment in wind farms is of great economic importance to residents and local government. Taxes paid by wind turbine investors can be partly invested into the development of local infrastructure favouring tourists and the local community nature trails, bicycle routes, supporting sports and recreation activities, and promotion of the area (Silva & Delicado, 2017).

There is also empirical research in which results show tourists' negative attitudes towards wind farms. An example, such research was conducted in Iceland by using a direct interview method among 47 tourists. The results of this research show negative opinions of tourists towards wind farms which, in their opinion, destroy the natural and historical values of the area. Therefore, they are not favourable for various forms of tourism and recreation. Investments in wind energy degrade the tourism and recreational attractiveness of a given site, its tourism image, and economic significance (Sæþórsdóttir et al., 2021).

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Social awareness in the context of behavioural economics and the new institutional economics

Public awareness is a set of widespread and accepted people's views, beliefs, and ideas about given facts and phenomena. It becomes a model of thinking and appropriate behaviour for members of a given community (Sztompka, 2002). The behaviour of a human or a social group is understood as specific actions related to needs and motives that encourage meeting these needs. Public awareness is determined by socio-cultural values and norms functioning in a given community of people (Sztompka, 2002).

Taking into account the subject matter of the paper, it was assumed that the public awareness of the Polish inhabitants in relation to wind energy concerns their knowledge and interests in the subject and their beliefs about the importance of wind energy. Furthermore, behaviours toward wind energy are any actions resulting from the state of public awareness that any person or group of persons can undertake to positively or negatively affect wind energy development.

Within economics, the issue of public awareness and people's behaviour toward wind energy can be referred to as two mainstreams, i.e. behavioural economics and new institutional economics. Behavioural economics assumes that human factors such as emotions, interactions, and formal and informal social norms that are often overlooked in the standard model of economics underlie actual human behaviour. They influence the formation of public awareness of humans, their behaviour, and decision-making (Thaler & Sunstein, 2009; Thaler, 2015). They also determine the positive or negative behaviours of individuals related to the operation of wind farms in their area of residence. Behavioural economics thus assumes that humans, as subjects with their own dignity, are both personal, thinking, and economic subjects who make rational economic decisions under conditions of uncertainty. People are becoming aware of the need to know the determinants that can influence their behaviour regarding, for example, investment activities in wind farms and their decision-making in terms of the use of wind energy.

The new institutional economics fits in behavioural economics, with its basic assumptions also supporting the functioning of wind energy. This economics assumes that the decisions of personal entities (human beings) and economic entities (enterprises) are influenced by different determinants. They are of economic (benefit, loss) and non-economic (including social) nature (cultural, historical). These determinants are institutionalised. They are formed by formal institutions supported by legal norms (e.g., local government, local residents' associations, wind energy investment enterprises) and informal institutions rooted in traditions, customs, trust, and morality

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(Ostrom, 1990; Hodgston, 2015). Within wind energy production, these institutions include informal neighbourhood groups that form social capital. The combination of formal and informal institutions develops the efficiency and effectiveness of social and economic activities that favour or disfavour wind energy production.

Given the theoretical and cognitive context of the importance of wind energy in Poland, it should be emphasised that it is and will be an important example of a renewable energy source which can eliminate fossil sources used for electricity generation. The social potential of a high level of public awareness and approving behaviour of Polish residents towards investments in wind energy is a favourable determinant of its development. A kind of development that would not destroy the value of the landscape and would not reduce demand and supply in the tourism sector.

Methodology

This paper aims to determine the level of public awareness in Polish society regarding the impact of wind farms on the tourism value of the landscape in a given area. This opinion is understood as a form of social awareness of the Polish population regarding onshore wind farm investments. Would it provide answers to the following questions: Does onshore wind energy reduce the tourist value of the landscape? Does it reduce tourist activities (supply) and the number of tourists visiting an area where windmills are present (demand)?

The realisation of the adopted objective entailed the analysis of secondary resources such as reports from nationwide empirical surveys and literature on the subject. We also used empirical data from reports on research conducted by the Ministry of Climate and Environment on the awareness and environmental behaviour of Polish residents regarding wind energy (Ministry of Climate and Environment, 2020a) and from a report on wind energy in Poland (Ministry of Climate and Environment, 2020b). This research was commissioned by the Ministry of Climate and Environment and carried out by PPS Spółka z o.o. (Partner in Business Strategies). Due to the ongoing COVID-19 pandemic, the study was conducted using the computer-assisted telephone interview (CATI) technique. The nationwide sample of respondents aged 15 years and older in both surveys was randomly selected and is representative of demographic characteristics such as gender, age, and place of residence. The maximum estimation error for a random sample of 1,000 individuals is +/- 3.1% (Ministry of Climate and Environment, 2020a).

The paper takes into account selected results of empirical research related primarily to the awareness and behaviour of Polish residents towards

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onshore wind energy. Furthermore, the method of critical analysis of the related literature and secondary materials, mainly statistical materials published by Statistics Poland, were also used in the research.

It should be noted that an increasing number of contemporary researchers use secondary data collected by other researchers to achieve different cognitive goals. Nowadays, the analysis of secondary empirical data is an established research method in the social sciences (Frankfort-Nachmias & Nachmias, 1996).

There are three primary reasons for the growing interest in using the method of secondary materials analysis: – general (in secondary materials, data are often collected in different scientific areas, which promotes a more comprehensive and deeper analysis. In primary research, an individual researcher is not able to collect broad and multifaceted information on the problem under study); – methodological (the results of research conducted by one researcher can be combined, supplemented, and compared with data collected by other researchers); – economic (primary data collection is very expensive). Using already existing data is much less expensive than collecting new data (Goodman, 1992). A similar research approach was also used in the study of the topic of public awareness and behaviour of Polish residents towards onshore wind energy and its impact on the tourist values of the landscape. Given the adopted research methodology, it should be stressed that a quantitative and qualitative analysis of the problems studied was conducted in the paper.

Research results and discussion

Surveys of environmental awareness and behaviour regarding onshore wind energy show that Polish residents have very positive attitudes to its development. It turns out that 85% of respondents surveyed supported the development of onshore wind farms. The behaviour of Polish residents towards onshore wind farms in general and with regard to their education is shown in Figure 1.

Analysis of the data in Figure 1 shows that people with vocational education predominated among those supporting the development of onshore wind farms (89% of positive indications). High approval levels for onshore wind farms were also found among those with secondary (84%) and higher education (87%). More than half of the positive indications (65%) supporting the development of onshore wind farms in Poland were found among people with primary and junior high school education.

The results of other empirical studies also showed support for onshore wind energy development in Poland. For example, “It is also encouraging to

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note that survey participants support the development of wind energy in Poland and that their majority would not mind another windmill park being built in their neighbourhood" (Ryszkowska et al., 2018).

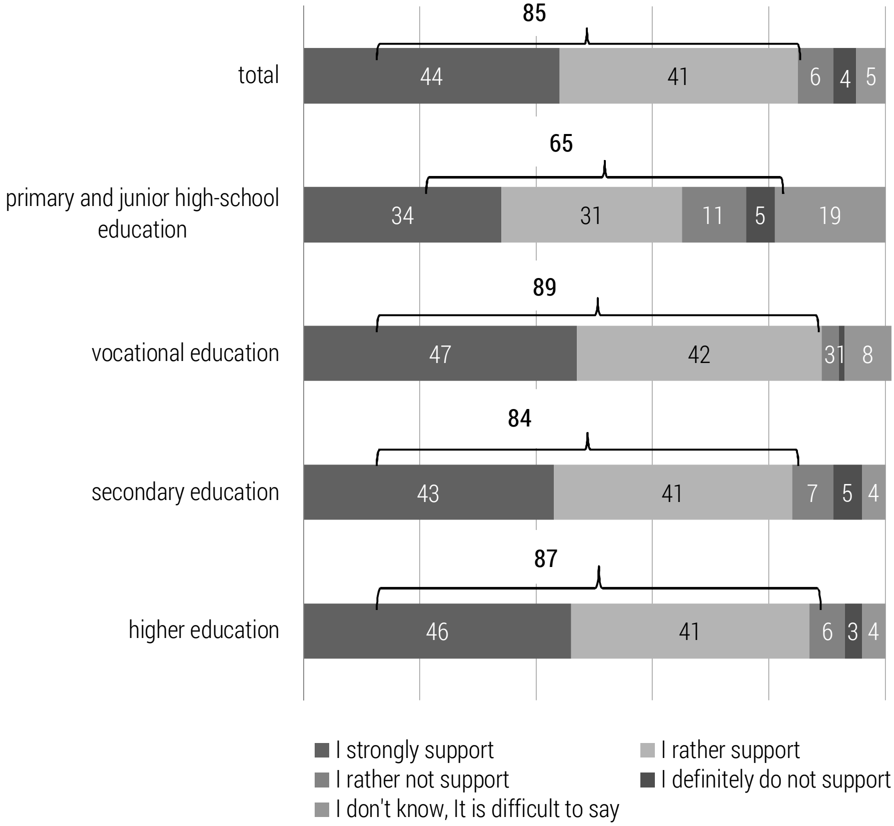

Figure 1. Attitudes towards onshore wind farms in Poland in the opinion of respondents in general and by their level of education [%]

Source: author's work based on Ministry of Climate and Environment, 2020b.

The positive attitudes of Polish residents towards wind energy in the country were not so pronounced for wind farms located near their homes (Figure 2).

The data presented in Figure 2 shows that 75% of the people surveyed would support onshore wind farms located near their residences. This is 10% less compared to the acceptance of wind farms in general in Poland. It was found that as the level of education of the respondents increased, so did their acceptance of building an onshore wind farm in the area where they lived. These results indicate a symptom of an important phenomenon called the NIMBY syndrome. NIMBY issues refer to a set of different behaviours of

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a local community towards an investment made near their place of residence. This attitude expresses opposition to the location of development at a particular site while accepting the development in general. Therefore, the object of the opposition is not the development itself but its location and the associated risks (Bednarek-Szczepańska & Dmochowska-Dudek, 2015; Wolsink, 2000). Thus, the results of the above surveys indicate that investments in wind power plants, in general, are desirable and can be completed, but it would be better if they were not close to the place of residence.

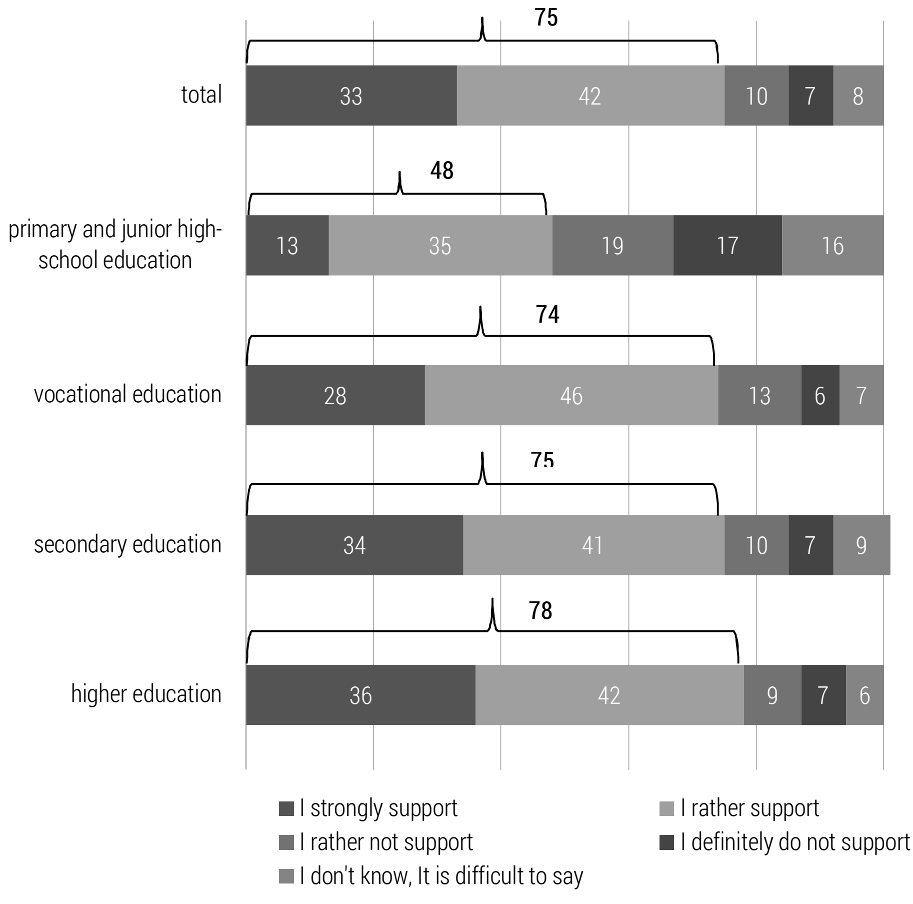

Figure 2. Attitudes towards onshore wind farms in the area of residence of respondents by their level of education

Source: author's work based on Ministry of Climate and Environment, 2020b.

The development of onshore wind farms in an area is not only influenced by the residents but also by the local government. In Poland, 24% of residents reported they lived near onshore wind farms. Among the respondents with wind farms in their area of residence, 54% positively evaluated the actions of local authorities and wind farm investors at the stage of construction (aspects of the new institutional economy). Onshore wind farms have varying impacts on the natural and social landscape elements of the local area. Although the electricity generated by wind turbines is considered green energy, there are opinions that say it can negatively affect the natural values of the area and the health of people. Some studies indicate that wind turbines generate infrasound and low-frequency noise. They negatively affect the life of birds, bats, insects, and human health (PSEW, 2008; Pawlas, 2009).

Among the factors affecting human health, the acoustic and optical effects generated by rotating turbines are most often mentioned. In addition to noise in the audible range, wind turbines generate infrasound, i.e. waves with a frequency lower than audible and low-frequency noise (up to 500 Hz). Infrasound waves are very long waves, spreading over many kilometres and penetrating even through concrete walls of buildings (Pawlas, 2009.) Among the optical (visual) factors burdensome to health, the following are mentioned: the stroboscopic effect and the so-called „shadow flickering effect". However, studies on the impact of these effects on human health are fragmentary, and their results are often questioned ("Wielka Brytania, Australia," 2015).

Another example of a threat to wind turbines is their failures and the resulting threats to people in the form of personal injury and fatal accidents. Frequent accidents were wind turbine blade breakage, fires caused by an electrical short circuit or overheating of the propellers ("Elektrownia wiatrowa," 2023).

Some research results indicate that wind forms pose a threat to birds passing by because the rotor blades cut through the air at over 150 km/h. For this reason, wind farms should not be located on seasonal bird migration routes (PSEW, 2008). World environmentalists, including those from Scotland and the USA, drew attention to this problem. It has been found that Scottish power plants contribute to the extinction of endangered bird species (including falcons, eagles and low-flying merlins). The American non-governmental organisation Center for Biological Diversity has calculated that the turbines of a single local wind power plant kill up to 1.3 thousand flying birds of prey annually (PSEW, 2008).

However, it should be noted that in many other studies, the negative impact of wind turbines on nature and people has not been confirmed. According to USA Today, wind farms kill between 214,000 and 368,000 birds a year. By comparison, 6.8 million are killed in collisions with cell and radio towers. Cats alone kill between 1.4 and 3.7 billion birds (Bujalski, 2021). This problem is illustrated in detail in Figure 3.

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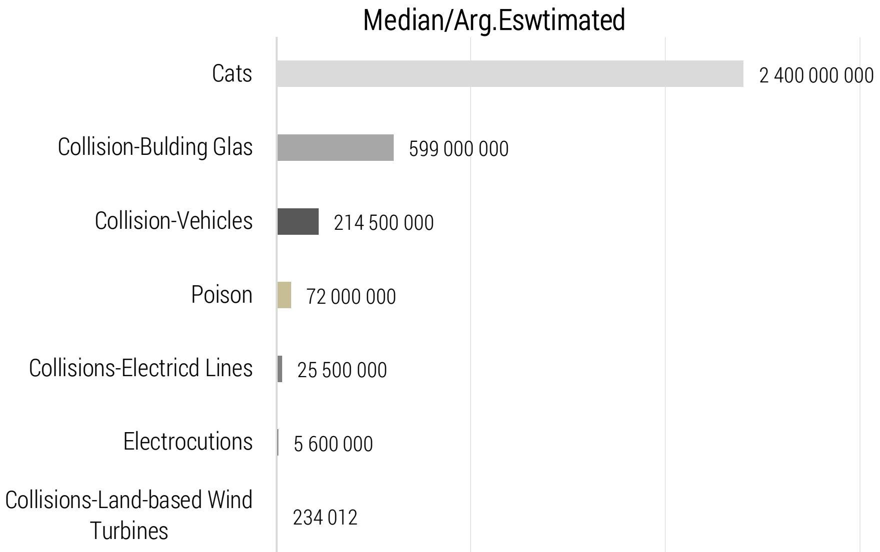

Figure 3. Wind Turbines Are Not Killing Fields for Birds. Annual estimated bird mortality from selected anthropogenic causes in the U.S. As of 2017

Source: author's work based on Feldman (2019).

Figure 3 shows the median value (middle value) of the causes of killing birds. The data from the U.S. government agency Fish and Wildlife Service shows that cats kill 2.4 billion birds a year. Another 599 million die by collisions with buildings, 214.5 million by collisions with vehicles, 72 million by poisoning, 25.5 million by collisions with high-voltage lines, 5.6 million by electrocution, and only 234,000 by wind farms. Therefore, most birds die because of cats and the fewest because of collisions with wind farms. Unfortunately, it is difficult to find similar studies for Poland (Feldman, 2019).

The presented characteristics of factors related to the operation of wind farms and their impact on the landscape of the natural and social environment conducive to tourism is not an exceptional and unique position. There are also supporters of opposite views, who believe that the results of some studies do not confirm the thesis that the location of wind farms contributes to lowering the natural and social values of a given area. They believe that wind turbines interfere with the landscape in the same way as all other buildings (Mordue et al., 2020).

Scientists from the Polish Academy of Sciences believe that the vast majority of literature information and their own research results indicate that there is no convincing evidence of the negative impact of onshore wind farms on the natural environment and its values, as well as on human health and well-being (Jasiński et al., 2022). The results of their research indicate

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that at a distance of 500 m from the wind farm, the noise level is below 40 decibels. Such noise does not cause negative health effects, even for sensitive people. The authors of the monograph "Wind power plants in the human environment" (2022) state that the levels of infrasound noise from wind turbines are lower or comparable to the noise associated with typical natural sources of infrasound (e.g. wind, waves, heavy rain) or noise from common equipment, such as vehicles, loudspeakers, engines, household appliances, airplanes). They emphasise that already at a distance of about 85 m from the wind turbine; the noise level is close to 50 decibels, which corresponds to the standards for permeable noise levels in single-family housing during daylight hours. They also indicate no risk to human health from wind turbines in the case of electromagnetic and vibration impacts (Jasiński et al., 2022).

The issues of the impact of wind turbines on the terrestrial landscape were included in the discussed studies (Figure 4).

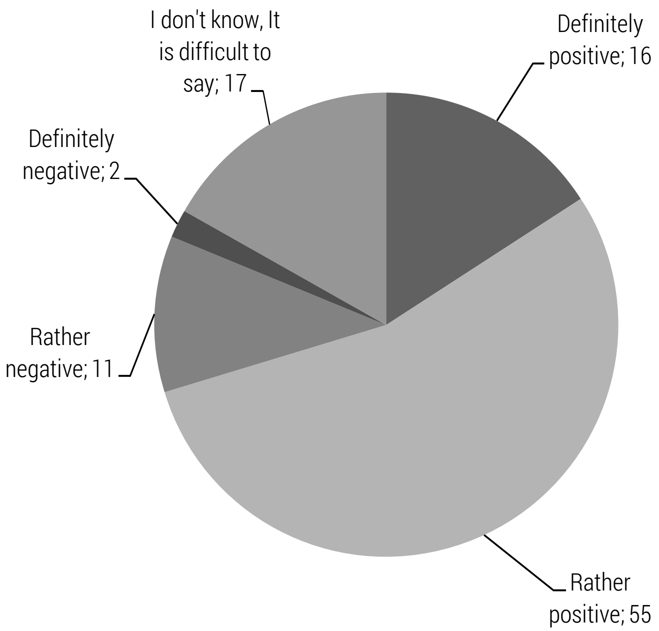

Figure 4. Impact of onshore wind farms on the landscape and the environment according to respondents [%]

Source: author's work based on Ministry of Climate and Environment, 2020b.

Analysis of the data in Figure 4 indicates that respondents have positive opinions (71%) regarding the impact of onshore wind farms on the natural and social environment of residences of places where wind turbines are located.

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In the opinion of Polish residents, onshore wind farms definitely have a positive impact on the landscape and the environment. Only 13% of the respondents expressed negative opinions, and 17% had no opinion (Figure 4). The positive opinion on the problem studied depended on the age of the respondents (Figure 5).

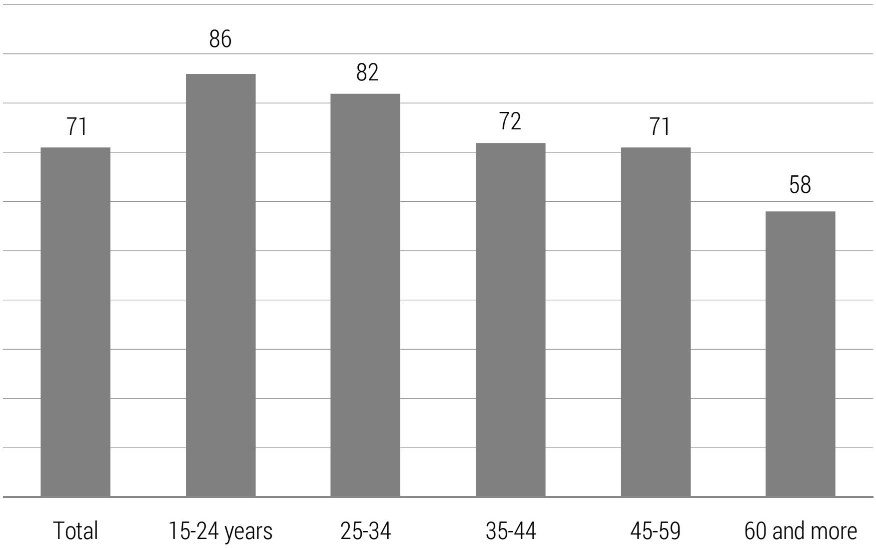

Figure 5. The positive impact of onshore wind farms on the environment and landscape as a function of the respondent's age [%]

Source: author's work based on Ministry of Climate and Environment, 2020b.

Analysis of the results by age of the respondents indicated that the greater the age range, the lower the percentage of positive opinions. Despite this fact, however, more than half of the indications were positive (58%) in the oldest age group (60 and older).

In general, it should be emphasised that the presented results confirmed the willingness of Polish residents to use clean wind energy that does not have a negative impact on the landscape of the area with wind farms. This energy does not destroy the natural and cultural values of the area, and thus it can be assumed that it does not discourage tourists from visiting these areas (Franta'l & Kunc, 2011). The opinions about wind farms expressed in the survey exemplify the public awareness of wind energy problems in Polish society (Łucki & Misiak, 2010). At the same time, they are manifestations of specific behaviours and actions toward the use of this energy (aspects of behavioural economics). One example of this behaviour is respondents› willingness to spend money for the opportunity to use wind energy. This issue is illustrated in Figures 6 and 7.

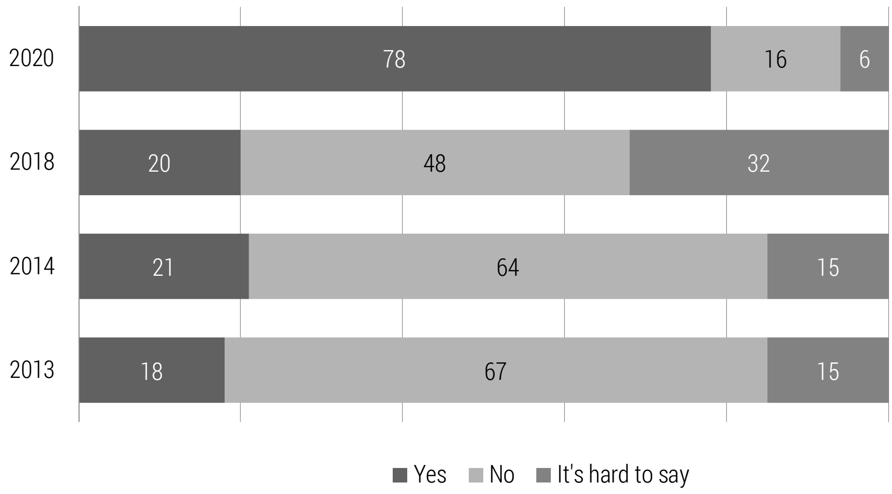

Figure 6. The willingness of Polish residents to use wind energy in 2013-2020 [%]
Source: author's work based on Ministry of Climate and Environment, 2020b.

Figure 6 shows that in 2020 compared to previous years, the residents of Poland were more willing to use clean energy and renewable energy sources, including wind energy. While only 18% of them expressed an inclination to do so in 2013, 78% of respondents decided to use such energy in 2020. Those determined to use renewable energy sources, including wind energy, are willing to spend more money on such installations. The problem is shown in Figure 7.

The data in Figure 7 shows that in 2020, the largest number of respondents (26%) said they would be willing to pay between 6 and 10% more for clean energy compared to their current energy bills. In contrast, 24% of respondents were willing to pay more than 20% more for this energy. This was the second most frequently indicated range (Figure 7).

Renewable energy sources, including wind energy, are an important subject of interest for Polish society (Biernacki et al., 2016). This is supported not only by the empirical evidence but also by the motivation for appropriate pro-environmental behaviour of consumers. The cited research shows that in 2020, 95% of Poland's population would declare energy savings at home (Figure 8).

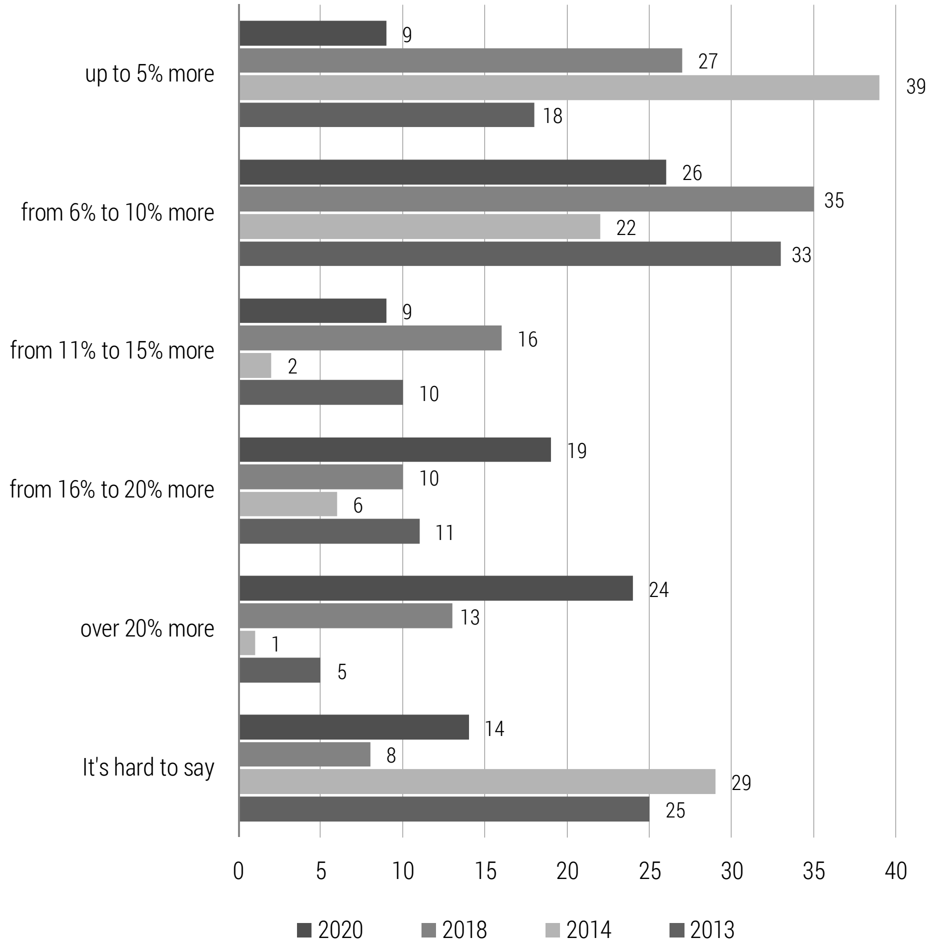

Figure 7. The willingness to pay extra money for clean energy (wind energy) compared to the current bills [%]

Source: author's work based on Ministry of Climate and Environment, 2020b.

The Polish residents surveyed planned to take additional measures in their homes to increase energy efficiency and reduce energy bills. How such actions were taken is illustrated in Figure 9.

An analysis of the data in Figure 9 shows that among those planning additional actions to increase energy efficiency and reduce household electricity bills in 2020, the use of renewable energy sources was overwhelmingly cited (57%).

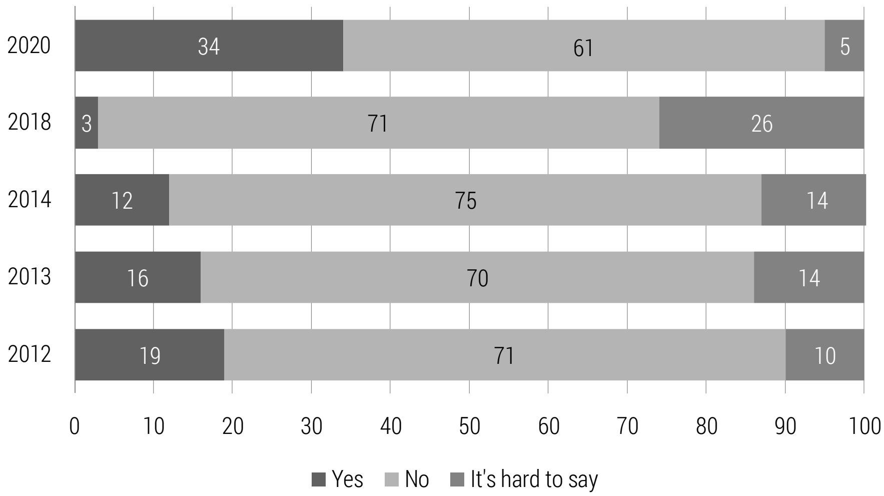

Figure 8. Planned additional behaviour aimed to increase energy efficiency and reduce electricity bills [%]

Source: author's work based on Ministry of Climate and Environment, 2020b.

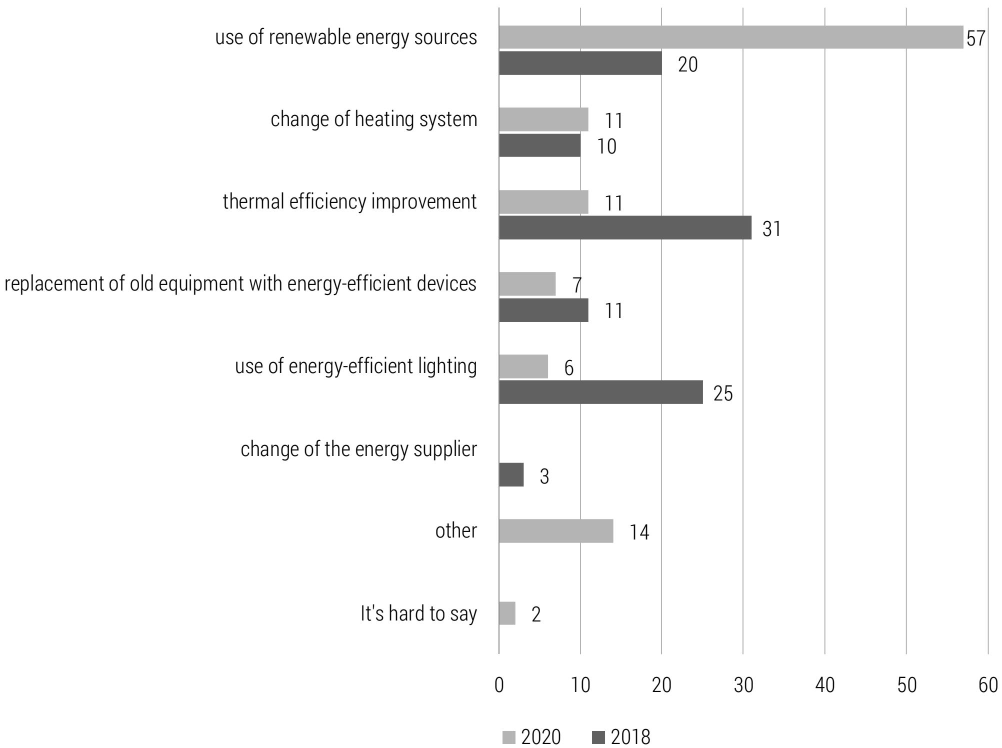

Figure 9. Planned behaviour to increase energy efficiency and reduce electricity bills [%]

Source: author's work based on Ministry of Climate and Environment, 2020b.

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Renewable energy sources, especially wind energy, are an important factor in protecting the environment (Franta'l & Urbankowa, 2014). The research results discussed in the present study demonstrate the role of social conditions enabling clean energy development and decarbonisation of the economy.

A high level of public awareness of Polish society approving investments in wind farms and the associated positive behaviour of the inhabitants confirm the need to care for nature, improve air quality, and thus the need to use renewable energy sources (Łucki & Misiak, 2010). As shown by the results of the study, these priorities do not support the thesis that the location of wind power plants decreases the natural and cultural values of the landscape of a given area, conducive to tourist and recreational activities (Chodkowska-Miszczuk, 2016). Local people and local authorities who approve of the development of renewable energy based on wind turbines are of the opinion that tourists also view wind turbines positively as a sign of an active attitude towards the protection of the environment. Some gminas advertise wind turbines as tourist landmarks on walking or cycling routes (e.g. a trail of wind turbines in the Darłowo gmina). They organise information meetings to broaden knowledge about environmental protection and renewable energy sources. There are gminas that consider the presence of wind turbines in their area an additional tourist attraction that supports the promotion strategy of the locality (Sikora & Wartecka-Ważyńska, 2015).

In conclusion, it is important to emphasise that there is no perfect landscape of the area conducive to tourism and recreational activities. In terms of tourism, landscapes are characterised by positive and negative natural, cultural, social, and economic values. The landscape with wind turbines as a source of clean energy is becoming more and more tolerated and accepted in the public mind, according to the research presented here. It ceases to be an obstacle to the development of tourist and recreational activities of many social groups. Wind turbines are an accepted architectural element and a new value to our spatial landscape. They create cognitive, educational, and economic values that are absorbed by the local community and tourists. Overall, it follows that Poles see the need for onshore wind energy development and are aware that these are beneficial without compromising landscape values ("Cztery piąte ankietowwanych," 2022).

Conclusions

The need to reduce environmentally degrading conventional energy sources and to activate the economy after the COVID-19 pandemic represents a strong argument for wind power development in Poland. Also important is

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the country's commitment to meet climate targets for renewable energy and reduce CO_2 emissions. The development of renewable energy sources, especially wind energy, is linked to investments in wind farms. To answer the questions posed in the methodological part of this paper, we used the results of a representative nationwide survey of opinions on onshore wind farms. These opinions are indicative of the level of social awareness of the respondents on the subject under study (Ministry of Climate and Environment, 2020a). This awareness may inhibit or favour wind farm investment in a particular area with tourism and recreational values.

Based on the results of the empirical survey, the overwhelming majority of Polish residents (85%) generally expressed positive attitudes towards investments in wind farms that generate clean electricity (Ministry of Climate and Environment, 2020b).

More than half of Poland's inhabitants spoke positively about the actions of local authorities towards the construction of wind farms in their areas.

The favourable social climate for wind farms was also expressed in opinions that these farms do not harm the natural and cultural values of the local landscape and do not lower their tourist value and attractiveness (71%). Neither do they prevent tourists from coming. A positive opinion about the impact of onshore wind farms on the natural and social environment varied depending on the age of the respondents. The greater the age range, the lower the percentage of positive ratings (Ministry of Climate and Environment, 2020b).

The development of onshore wind energy was supported by the tendency of Polish residents to increasingly use this type of energy (78%), which is perceived as clean energy that is not harmful to the environment (Ministry of Climate and Environment, 2020a).

Positive social attitudes about the impact of wind farms on the tourist value of the landscape were shown by the results of studies conducted in the Czech Republic and Portugal. The study in the Czech Republic indicated that clean wind energy promotes environmental protection (70%). It does not pollute the tourist landscape but, conversely, enhances its values (35%) (Franta'l & Kunc, 2011). Wind turbines provide economic benefits to their owners, the owners of the land on which they are located, and local governments. They are, therefore, a source of additional funding for local tourist and recreational infrastructure used by residents and tourists (Portugal) (Silva & Delicado, 2017).

It should be noted that onshore wind turbines are a positive value in the tourism landscape. They are a source of clean energy that does not poison the social and natural environment and improves air quality that is conducive to tourist and recreational activities ("Cztery piąte ankietowanych," 2022; Badora, 2014).

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The high level of public awareness of Polish society toward wind farms creates a social climate conducive to investments in renewable energy sources, including onshore wind energy. Such an acceptance of wind farm investments, or its lack, thus entails the need for the local authority to run social consultations ("Ustawa wiatrakowa," 2022). It shows social acceptance for investments so much needed by humans and nature and creates social conditions to facilitate the fulfilment of Poland's commitments to the European Union regarding the share of renewable energy sources, including wind energy, in the global energy mix (Sobieraj, 2017).

Furthermore, it should be made clear that Russian aggression against Ukraine is forcing Poland and Europe to become independent of Russia in terms of energy supply. A key element of this independence should be a dramatic acceleration of renewable energy development and the expansion of wind power.

Finally, from a theoretical point of view, the issue under analysis can be related to the assumptions of social and ecological economics. The achievements of behavioural economics and the new institutional economics play a vital role in it. Social and ecological economics presents the ontological and cognitive premises for analysing and understanding the interactions between natural, social and economic systems (Spash, 2011). It thus strengthens the theoretical aspect of empirical research. However, this would open a field for further discussion.

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Marta **SZABAN** • Magdalena **STEFAŃSKA**

BARRIERS INFLUENCING PURCHASE BEHAVIOUR OF GREEN PERSONAL CARE PRODUCTS – INTEGRATING INNOVATION RESISTANCE THEORY PERSPECTIVE AND STAGES OF CHANGE MODEL

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ABSTRACT: The study aimed to identify and explain perceived barriers to green consumption at different stages of behaviour change by integrating the Innovation Resistance Theory (IRT) and Stages of Behavioural Change (SOC) model. Through 20 in-depth interviews with consumers transitioning to green consumption at various stages, several barriers were identified. The knowledge barrier played a crucial role in shaping the adaptation process at every stage of change and was recognized as an independent construct within the IRT framework. Moreover, the research revealed that barriers such as tradition, value, usage, and risk exerted a stronger inhibitory effect in the early stages of green consumption, while knowledge and image barriers evolved and had a distinct impact as consumers progressed through the stages. The study also highlighted triggers that positively stimulated green consumption. These findings have implications for green marketing and can guide targeted interventions to promote sustainable consumption more effectively.

KEYWORDS: innovation resistance theory, stages of change model, green consumption barriers, green personal care products

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Introduction

Growing environmental pressure is causing changes in human needs and values. Social ethics can no longer be neglected by manufacturers (D'Attoma & Ieva, 2020). The call for sustainability has become a major driver of pro-environmental innovations (Varadarajan, 2017). According to Diepenmaat et al. (2020), sustainability transition requires socio-cultural changes in norms and values, stimulating adaptation of new technology and sustainable consumption alternatives. Acceptance of sustainable innovations on the market is slow and requires a long-term perspective (Dearing, 2000). During the last decade, despite intense efforts causing a significant increase in public awareness and pro-environmental attitudes, there has been no significant or satisfactory change in social behaviour (Fudge & Peters, 2011; Moloney & Strengers, 2014). Identifying the sources of resistance (i.e., perceived barriers) to green consumption, as well as the mechanisms behind the behavioural change process, is, therefore, crucial and demands more attention from researchers (Joshi & Rahman, 2015). This globally observable resistance to change towards green alternatives may be compared to resistance towards innovation. In overcoming existing barriers, individuals are stimulated by external (messages from the environment) and internal factors (beliefs about the validity of purchase choices) (Joshi & Rahman, 2015). The aim of the following study is to trace purchase resistance inhibitors at each stage of change towards green consumption within the context of Fast Moving Consumer Goods (FMCG). This will be achieved by applying the Innovation Resistance Theory (IRT) developed by Ram and Sheth (1989) and the Stages of Behavioural Change (SOC) model, also known as the "wheel of change," a fundamental construct of the Transtheoretical Model of Change (Prochaska & DiClemente, 1982).

The study is deliberately focused on one category of Green Personal Care Products (GPCPs) due to the booming high volume of sales concerning personal care products recorded worldwide (Klaschka, 2016). The future of the ecosystem is largely dependent on agile intervention capable of dynamically accelerating subscriptions to GPCPs consumption. Consumer barriers to this category of green products have not yet been exhaustively explored by researchers, whereas the green food market has already lived to see hundreds of studies focusing on the analysis of barriers and motives determining consumer behaviour (Bryła, 2016; Buder et al., 2014; Kushwah et al., 2019). In recent publications, there has been a call for shifting the research burden on green consumption of FMCGs from food to non-food products (Niedermeier et al., 2021a, 2021b).

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This presented article is organised in the following manner: in the “Theoretical foundations and research questions” section, we give an overview of the sufficient literature and discuss the background theoretical approaches, followed by a proposal for research questions. In the “Methods” section, an overview is given of the research methods. Next, in the “Results’ section, the analysis and results of the research question testing are presented. Afterwards, in “Findings and Discussion”, we discuss the main findings of the study and highlight the theoretical as well as practical implications. The paper ends with “Conclusions and future research”, where implications for theory, as well as practice, limitations and recommendations for further areas of research, are indicated.

Theoretical foundations

Innovation Resistance Theory (IRT)

Barriers to sustainable consumption are the subject of intense research and discussion (Niedermeier et al., 2021a; Tan et al., 2016). As early as 1990, Bänsch proposed a list of quite universal and timeless factors determining and limiting green consumption, i.e. doubts about authenticity, image, aesthetic aspects, habits, availability, price, lack of efficiency and of faith in the relevance of such consumer action (Bänsch, 1990). It is puzzling that despite the passage of more than 30 years, these barriers continue to determine green purchasing behaviour resistance, as evidenced by (Kushwah et al., 2019), regardless of the rapid growth in awareness concerning the seriousness of risks generated by unsustainable social behaviour (Sandler, 2012). However, there is a gap in knowledge on the strength and nature of the impact these barriers have, depending on the stage of change towards green consumption.

In order to better understand the resistance of consumers towards green product innovations, Innovation Resistance Theory (IRT) has been implemented in our study (Kaur et al., 2021; Ram & Sheth, 1989). This resistance to the adaptation of innovative behaviour is defined as resistance to changing the status quo by adopting an innovation, understood as a departure from existing beliefs (Kaur et al., 2021). IRT, postulated by Ram and Sheth (1989), aids in understanding how resistance to a behaviour change is formed.

The IRT theoretical lens allows us to classify barriers according to innovation by dividing them into those functional and psychological. Functional barriers come forth when the observed functions or attributes of innovation are not in perfect agreement with consumer expectations. Psychological barriers become visible in cases where perceived attributes of innovation cause

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conflict or psychological issues among consumers. Therefore, the theory allows suggesting that "resistance may occur when the innovation disrupts established routines, habits, traditions and norms of consumers, or induces conflict with consumers' briefs, values and faith" (Ma & Lee, 2019). It should be noted that there is a lack of consistency regarding opinions on the final classification of resistance barriers. According to Talke and Heidenreich (2014), the risk barrier can also be classified as a psychological one instead of the IRT authors' original assignment to functional barriers. In another study by Santos and Ponchio (2021), additional factors beyond the IRT construct were identified. The study positively verified the effects of emotional barriers when studying opposition to digital banking services. Thus, in identifying the barriers determining resistance, the category of products or services containing a certain degree of innovation is of great importance (Santos & Ponchio, 2021).

Stages of Change Model (SOC)

When analysing resistance to a green product such as innovations, following the research by Cornescu and Adam (2013), four pillars of determinants which may influence attitudes or behaviours should be taken into account: (1) perceptions of innovation characteristics, (2) consumer psychological characteristics, (3) propagation mechanisms (nature of the market and propagation channels) and (4) the influence of opinion leaders. However, to obtain a better comprehension of the mechanisms shaping resistance and change processes, this analysis should take place at multiple levels, separately analysing groups of individuals according to the status of their current intentions and behaviours, which has not been done in earlier studies. This objective can be achieved via the Stages of Change Model by dividing consumers according to the stage of change towards green consumption.

Stages of Change Model (SOC), conceptualised as the central organising construct of the Transtheoretical Model (TTM) (Bridle et al., 2005), was developed by Prochaska and DiClemente (Prochaska & DiClemente, 1982). The rudimentary premise of the TTM model is that individuals undergoing behavioural change continually analyse the advantages and disadvantages of undertaking such change (Prochaska et al., 1988). According to this model, often called the "wheel of change", people do not modify their behaviour in dynamic and decisive terms. This change is a cyclical process at the level of 5 stages of change (SOC): (1) pre-contemplation, (2) contemplation, (3) preparation, (4) action and (5) maintenance. At each of these stages, they experience different internal and external stimuli, depending on the nature and strength of the impact, convincing them to change their behaviour or discourage them from progressing. The SOC model is used to segment a certain

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population into groups on the basis of the status of the person subjected to the process of change (Arnaudova et al., 2022) and is often applied as a separate tool beyond the context of the Transtheoretical Model (Lacey & Street, 2017). In the research by Gatersleben and Appleton (2007), it has been indicated that perceptions of personal and external barriers change as individuals progress and move on the "wheel of change" from pre-contemplation to action. Resistance to change at each stage requires developing a different intervention depending on the context and motives behind it. This leads to the assumption that different variables shape behaviour at each stage of change. Thus, the optimal intervention should respond to the specifics of the clusters.

In some studies, it has been indicated that combining continuous models as well as stage models can aid in the explanation regarding the process of behavioural change (Forward, 2014). Therefore, the aim of our study is to explore determinants shaping the process of change towards green product consumption through the utilisation of the IRT and SOC models. In the past, the two constructs have been applied individually when comparing IRT barriers with green consumption (Sadiq et al., 2021), meat consumption (Arnaudova et al., 2022), or with the usage of the SOC model – vegetable consumption (Ahn & Kim, 2012), cycling to work (Gatersleben & Appleton, 2007) and undertaking physical activity (Romain et al., 2018). To the researchers' knowledge, the two constructs have not been applied simultaneously to analyse the determinants of green consumption. Integrating the complementary aspects of these two theoretical frameworks provided the basis for assigning barriers from the IRT construct to all phases of the SOC change process. An in-depth qualitative study makes it possible to verify the adaptability of the two theoretical frameworks in the field of green consumption and to provide answers for the posed research questions arising from an analysis of literature on the subject.

Research questions

In tandem with the growing debate about the barriers inhibiting green consumption, many current researchers are calling for more qualitative and experimental design studies to identify factors that may reduce the green gap found between attitudes and behaviours (ElHaffar et al., 2020). Moreover, despite the existing research verifying the influence of IRT barriers on green product purchase intention (Sadiq et al., 2021), no attempt has been made to explore the specifics of these barriers or the strength of their impact at different stages of transition towards green consumption. Closing an intention-behavioural gap would not be possible without an attempt to understand the

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complexity of that behavioural process and the nature of the phenomena by applying a qualitative method (Wiederhold & Martinez, 2018). The objective of this study, therefore, is to subject this process to in-depth analysis and make inferences based on an analysis of the various stages of the process in order to understand the barriers in the adoption of sustainable consumption that determine each stage with the application of SOC and IRT theories.

To address this gap in research and contribute to scientific literature as well as the knowledge of marketers, this research is an attempt to obtain a more concise understanding of the factors that shape consumer resistance and purchase intentions at different stages of change (SOC) towards green consumption and within the context of one FMCG category (Figure 1). To better comprehend the issue, a qualitative study was proposed, guided by four main research questions:

- RQ1: Which IRT barriers can be identified within the context of green FMCG consumption?
- RQ2: Which inhibitors of green purchase behaviour are present at different stages of change (SOC) towards FMCG consumption?
- RQ3: Why do some barriers seem to be stronger at different stages of change (SOC) towards green FMCG consumption?
- RG4: What other factors than those within the IRT theory construct are the source of resistance at all stages of change (SOC)?

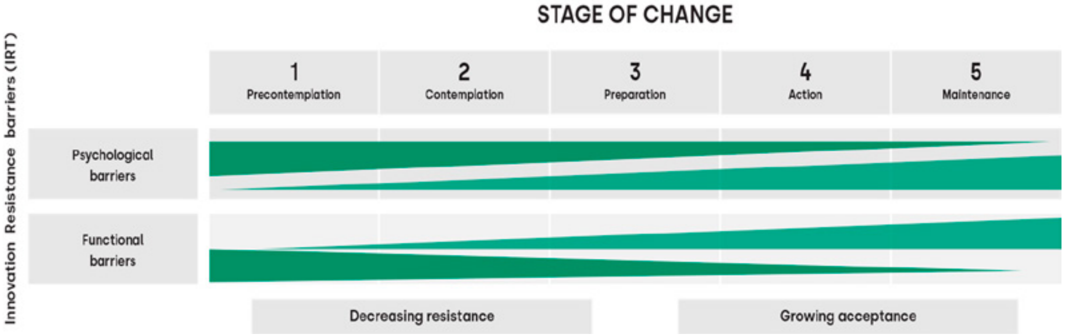

Figure 1. Integration of SOC and IRT – a conceptual model

The study is focused on analysing barriers to a selected category of FMCG products, as suggested by previous research in which discrepancies have been indicated in the obtained results depending on the green categories studied (Liobikienė & Bernatonienė, 2017).

Globally, the dominant FMCG category adapting to intense market changes is Personal Care Products (PCPs). Interest in GPCPs has experienced an increase due to various concerns connected with conventional PCPs, such as environmental, health-related and ethical concerns, respectively (Cervellon & Carey, 2020). Many cases involving recognisable manufacturers have been reported, where PCPs were linked to causing ovarian cancer (Jacob et al., 2018), hormone disruptions (Fujii et al., 2013; Koniecki et al., 2011) or migraines, asthma and dermatitis (Steinemann, 2017, 2018). Emerging green alternatives are often free of any residual chemicals, fertilisers or pesticides and genetically-modified organisms, etc. (Goyal & Jerold, 2021). GPCPs are interpreted as those being of natural composition, produced in an environmentally-friendly way, and free of chemical additives and synthetic colours (Klaschka, 2016; Moscato & Machin, 2018).

As far as GPCPs are perceived as innovations on the market (Lin et al., 2018), the process of adapting to a more sustainable purchasing behaviour can be compared to adopting an innovation. This may be understood as a product innovation adaptation (Melander, 2017) or even social innovation adaptation (Jaeger-Erben et al., 2015), both intending to lessen environmental impact. This adaptation requires changes in day-to-day behaviour and disrupts consumption habits, while "innovation that is successful does not comprise of bowing down to the resistance of consumers, but rather comprehending its reasons and creating marketing strategies used to address them" (Ram & Sheth, 1989, p. 13).

Methods

Due to the fact that the main objective of this study is to broaden knowledge on barriers hindering consumers at five stages of the green consumption adaptation process, and given that there are no qualitative studies in which the phenomenon would be analysed using IRT combined with the SOC behavioural change model, a qualitative study was chosen in this case. To interpret meaning from the barriers experienced by individuals at different stages of adaptation in the process of green consumption (Willig, 2017), semi-structured, in-depth interviews were performed.

Despite the belief that results from qualitative research analyses are non-generalisable and limited by the subjective interpretation of the researcher (Damaskinidis, 2017), there is consensus indicating that this type of research generates insights into understanding context-specific determinants (Bell et al., 2022).

Participants were recruited using purposeful sampling: intentional identification of information-rich cases having first-hand experience with the phenomena under study (Palinkas et al., 2015). Since purposeful sampling carries the risk of potential bias or sampling error, interviews were continued until data saturation was achieved (Saunders et al., 2018). Also, Glaser and Strauss (1967) emphasise that in qualitative research, data is accumulated until theoretical saturation is reached, i.e. when new respondents consistently begin to repeat previous observations/inferences. Although Creswell (1998) indicates that qualitative interviews should be conducted among 20-30 respondents, there is a lack of evidence and grounds for such samples. Therefore, in the case of this type of research methodology as in applied in that research, one can rely on the idea of sample saturation (Olejnik & Stefańska, 2022). Non-probabilistic (non-random) selection methods were used: selection based on respondent's availability. Research questions were directed at understanding attitudes and consumers' perceived barriers to green consumption adoption and the stimulants that determine change, but researchers also paid attention to the context of statements to capture factors not consciously expressed.

This study was conducted with Poland-based participants over a two-month period. Participants were residents of both the metropolitan city and adjacent smaller cities. Each respondent, in order to take part in the study, had to meet certain assumptions verified at the stage of the recruitment questionnaire, i.e. age 27-54, no direct associations with the cosmetics industry, responsibility for purchases of the product category under study in their household, and represent a certain stage of change towards green consumption of the category under study. The recruitment survey included an explanation of the specifics regarding the GPCPs product category under study. The participants' perception concerning the stage of readiness towards behavioural change in the consumption of GPCPs was assessed using the SOC scale, adapted from Cunha et al. (2015).

Table 1. Stages of change (SOC) towards Green Personal Care Products Consumption

TTM Stages of Change (SOC) towards green consumption	Do you use green personal care products? Cunha et al. (2015)
SOC 1 (Pre-contemplation)	No, I am not thinking about making a change from conventional personal care products to greener ones
SOC 2 (Contemplation)	No, but I am considering buying greener personal care products, however, I am still not convinced
SOC 3 (Preparation)	No, but I have decided to change my habits in this area and buy greener personal care products, however, I am wondering how to do this
SOC 4 (Action)	Yes, I am in the process of changing my habits in this area but I am experiencing difficulties
SOC 5 (Maintenance)	Yes, I have already changed my habits and buy green personal care products regularly

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With the intention of verifying the interview script, a pilot survey was carried out beforehand among three groups of students. The script was also consulted with two experts on qualitative research methods. The final version of the script obtained approval from the Commission of Ethics.

The sessions began by introducing and explaining the trial. This was followed by open-ended questions aimed at understanding consumers' experiences with GPCPs, and reasons for rejecting or subscription to green alternatives. There were questions from the IRT theoretical framework within the scenario structure, but respondents were free to shape their statements. Moreover, participants were encouraged to explain the context and background of their statements as the researchers intended to capture the broader background and hidden motivations.

Table 2. Sample characteristics

Participant	Sex	Education	Stage of change	Age Group	Category involvement
1	Male	Higher education	(2) Contemplation	24-34	No
2	Female	Higher education	(5) Maintenance	35-44	Yes
3	Female	High School	(2) Contemplation	35-44	No
4	Female	Higher education	(5) Maintenance	24-34	Yes
5	Female	Higher education	(4) Action	24-34	Yes
6	Female	High School	(2) Contemplation	24-34	No
7	Female	High School	(4) Action	45-54	Yes
8	Male	High School	(1) Pre-contemplation	45-54	No
9	Male	Higher education	(2) Contemplation	35-44	Yes
10	Male	Higher education	(4) Action	35-44	Yes
11	Male	Higher education	(4) Action	35-44	Yes
12	Female	Higher education	(3) Preparation	45-54	No
13	Male	Higher education	(1) Pre-contemplation	24-34	No
14	Female	Higher education	(5) Maintenance	24-34	Yes
15	Female	Higher education	(4) Action	24-34	Yes
16	Female	Higher education	(4) Action	35-44	Yes
17	Female	Higher education	(5) Maintenance	24-34	Yes
18	Female	Higher education	(5) Maintenance	35-44	Yes
19	Female	High School	(3) Preparation	24-34	Yes
20	Male	Higher education	(2) Contemplation	35-44	No

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In addition to open-ended questions, graphic presentations of the product category under study were used in the interview in order to liven up the discussion. Each of the interviews lasted 40-60 min. The researchers double-checked the method of coding to minimise bias and find validation of the findings (Spiggle, 1994). Interviews took place online via video platforms. The audio versions of the interviews were recorded and then transcribed. NVivo12 was used in this study. Transcripts were subsequently analysed by content analysis. Important factors and common themes in individual transcripts were identified and coded. Transcripts were compared with each other to observe similarities and differences regarding each answer.

Results

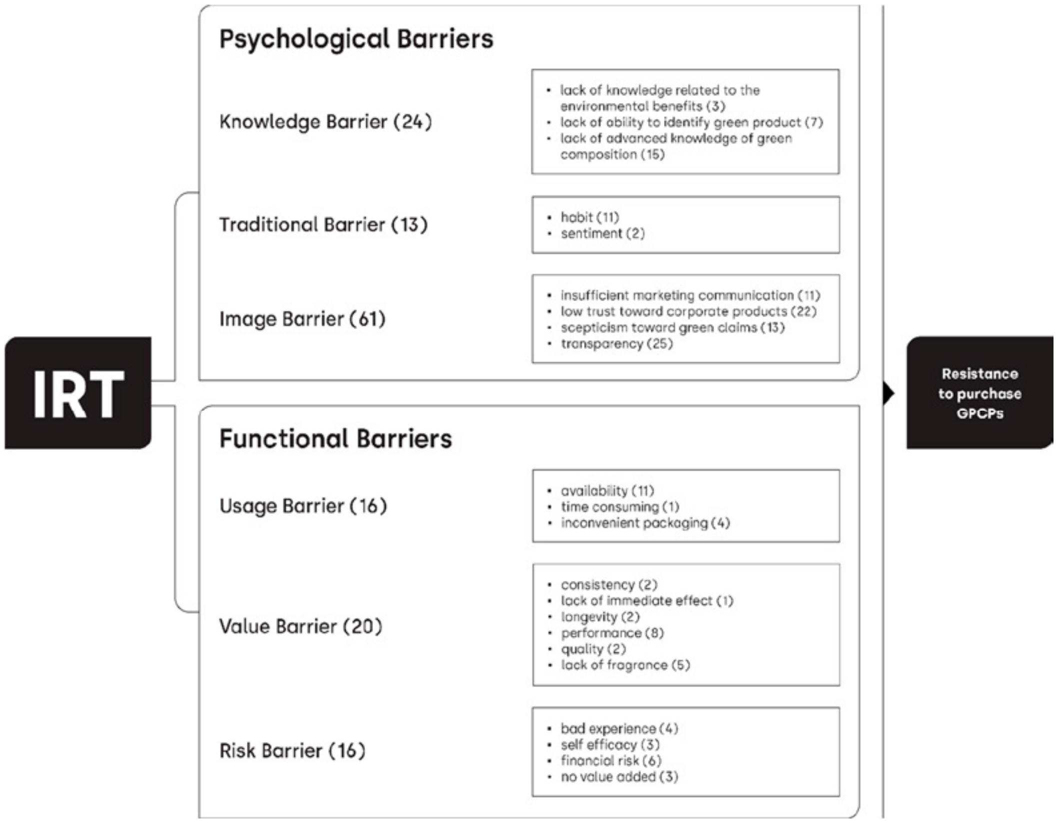

Figure 2. General IRT barrier themes identified and the number of references coded

On the basis of the IRT proposed by Ram & Sheth (1989), data were analysed thematically. This evaluation was based on semi-structured, individually performed interviews among 20 respondents declaring different SOC towards GPCPs consumption. Using NVivo12, overall emergent themes were formed from 18 subthemes (Figure 2). In the study, the existence was confirmed of all IRT barriers: psychological (traditional, image) and functional (risk, value, usage). An additional psychological barrier identified in our research was the knowledge barrier, which proved to be crucial and most influential at all stages of change following the image barrier.

Psychological barriers

Psychological barriers refer to consumer reactions to attributes connected with an innovative product as a result of internal psychological conflicts arising from established traditions, social norms and usage patterns (Ram & Sheth, 1989). This conflict stems from certain asymmetries that create uncertainty about the consequences of adapting innovations (Kuisma et al., 2007). In the current study, the knowledge barrier was also identified as a key inhibitor of FMCG product green consumption.

Knowledge barrier

The knowledge barrier was categorised by previous researchers as part of the traditional barrier within the IRT construct (Kushwah et al., 2019). This was interpreted to mean that attachment to traditional products led to a lack of anticipated knowledge needed to shift from conventional products to those green (Botonaki et al., 2006).

Whereas in this study, few levels of the knowledge barrier were identified relating to different aspects, stronger at different stages of change. In this research, the knowledge barrier comprises three subthemes: lack of knowledge related to the environmental benefits, inability to identify green products, and limited understanding of green composition. The first two are characteristic for the first initial stages of change (non-buyers), and the third for consumers at later stages of change (occasional buyers, regular buyers). The latter are eager to purchase green alternatives and rarely experience the barrier of tradition. However, consumers suffer from a lack of expert knowledge on the composition of green alternatives allowing them to make optimal purchasing choices within the green category. In other studies, it has been confirmed that the knowledge barrier has an impact on both non-buyers of green alternatives (Xie et al., 2015) and buyers (Bryła, 2018). In light of these findings, it is proposed to isolate the knowledge barrier as a crucial, separate construct of the set of psychological barriers in IRT theory. Its multifaceted nature and intensity of impact require more attention from researchers and isolated in-depth analyses as another side of the coin is the usefulness of green information perceived by consumers (Keller & Staelin, 1987). This is understood as information quality, which is another critical aspect being a hugely important piece of the puzzle of the complex mechanisms that shape sustainable knowledge. Green information should be designed to be "complete, persuasive and credible" (Kumar et al., 2021). Understanding these different perspectives will improve the properly conducted stage targeted interventions by design, distribution and application of tailored information among consumers experiencing knowledge barriers at varying degrees and intensities.

It should be noted that the number of references to the knowledge barrier in all interviews, regardless of the stage of change, was high, which further reinforces the belief that more focus is required on the significance of the knowledge barrier in shaping green consumption. Previous studies examining the impact of environmental knowledge on purchase intention have yielded conflicting results (Eze & Ndubisi, 2013; Ramayah et al., 2010), highlighting the need for more conclusive findings (Joshi & Rahman, 2015). Environmental knowledge and consciousness are often assumed to drive green consumption (Schlegelmilch et al., 1996). Gaps in information negatively affect purchase behaviours (Connell, 2010). Researchers often attempt to address this issue by employing quantitative methods that rely on established scales to assess subjective knowledge levels related to the environment and the specific product category. However, these approaches may provide only a superficial verification. During individual interviews, it was revealed that the issue is much more complex. With regard to the product category, it was discovered that distinguishing a GPCPs from a conventional one requires consumers to have almost expert knowledge of biotechnology: the ability to read the formulation and understand which ingredients or packaging parts may be detrimental both to health and the environment.

> *"First of all, I'm guided by the fact that I do not exactly know what ingredients are out there in cosmetics, but I try to choose those that have the shortest possible composition on the back, so that's kind of a determinant for me"* (Participant 1: Action stage).
>
> *"I bought this green cosmetic some time ago; at least it seems to me green... It is manufactured by a company named "Grassy". The package graphics suggests that it's kind of natural. The first striking features are the long references to nature"* (Participant 12: Preparation stage).

Interpreting green alternatives properly requires a great deal of commitment targeted at finding answers to a countless number of questions. Respondents at higher stages of change towards GPCPs consumption often search for information on expert blogs, vendors channels and publications.

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Therefore, buying and properly selecting a theoretically low-engagement product becomes extremely absorbing and time-consuming.

During interviews, consumers at higher stages of change (action, maintenance) were also mostly characterised by higher overall engagement in the personal care product category (respondents product category involvement level was assessed by the researchers based on analysis of statements referring to a products' search experience and the extent of dedication to the process of search). Consumer knowledge from higher stages of change was significantly greater; however, they still perceived a lack of self-awareness and the inability to verify the product's level of greenness and naturalness.

> *"My knowledge may not necessarily be comprehensive. There is a blog called "SrokaO" – cosmetic analysis, and there is really large database of these cosmetics.I independently type and search for the cosmetic product online to verify its composition, specifically checking whether it contains natural ingredients or is predominantly chemical-based. "* (Participant 5: Action stage).

Indeed, in research carried out among green consumers, it has been shown that they tend to engage in seeking information on the social-environmental criteria of brands (McDonald et al., 2009). However, this is dependent on the product category. In this study, it has been confirmed that GPCPs consumers, being at the last two stages of change (maintenance, action), perform such an analysis at both the product and manufacturing brand levels.

It was surprising that none of the 20 respondents recognised international certifications that guarantee the greenness of a cosmetic product.

> *"The certificate's name holds no value for me since I can easily put an "eco-certificate" or a "super quality" label on any package as well. A certificate is just a word, so it is absolutely necessary to have some more industry-specific specialised knowledge to know what's behind it, whether it really has any super value added there or not"* (Participant 4: Pre-contemplation stage).

> *"I certainly don't consider myself as an expert, because you see, even now you're asking about certificates which I didn't pay attention to. I'm more guided by the formulation description on the labels"* (Participant 6: Action stage).

Scholars have proved that knowledge of green products promotes consumer intention to purchase such items (Wang et al., 2019). However, a huge challenge remains in disseminating knowledge about green products to consumers. Understanding the composition described on the back of the package is the most ambiguous aspect for every consumer, yet it is the most frequently indicated element of the package from which respondents consciously derive their information.

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Tradition barrier

The tradition barrier is concerned with consumer reluctance to make changes in his/her routine through behavioural change. This may be related to habit, sentiment and/or satisfaction with traditional products. It is, therefore, negatively related to one's intention to adopt such an innovation (Antioco & Kleijnen, 2010). According to the results of this study, the tradition barrier negatively determines the purchase intention of green alternatives at the initial stages of change (contemplation, pre-contemplation, contemplation) and weakens the transition process.

> *"When I go to a shop, I don't have the time to consider whether something is organic or bio, whether it benefits the environment, or if it's better for my skin. I'm accustomed to purchasing products, especially those advertised by well-known brands whose advertisements I encounter daily."* (Participant 8: Pre-contemplation stage).

At the maintenance and action stages, it no longer negatively determines purchase intentions toward green categories. It has an inhibitory effect on consumers only toward selected subcategories of products for which suitable green alternatives have not been found or to which they are strongly loyal.

> *"You know, when it comes to color cosmetics, I've been using the same tested products for several years, and that's what I stick to. I don't switch them, even though I'm aware that the ingredients may not be ideal. But they work well for me, and I don't feel the need to change everything."* (Participant 7: Action stage).

The traditional barrier manifests differently depending on the customer's position on the "green wheel of change.". At the initial stages (pre-contemplation, contemplation, preparation) it is, along with the knowledge barrier, tradition and image barriers, that effectively build resistance. In contrast, at the maintenance and action stages, the traditional barrier appears as a slight limitation in intention towards a narrow range of products, typically fulfilling needs closely tied to visual day-to-day appearance, such as color cosmetics. Consumers explain this by the lack of green alternatives on the market that fully satisfy the need for efficiency and performance. Therefore, first and foremost, consumers are looking for "green quality" to meet their individual needs without sacrificing functional aspects. The concept of green equilibrium is crucial, as it allows for personal gain without necessitating complete sacrifice. . It is nevertheless more important than environmental gain (Chwialkowska & Flicinska-Turkiewicz, 2021).

Image barrier

The image barrier refers to an unfavourable image (Mani & Chouk, 2018), meaning attitudes and feelings towards a product, brand and even the place of manufacturing. An image barrier can be caused by a lack of trust in a green product and manifests itself as consumer scepticism towards the category (Sadiq et al., 2021). This barrier often arises from a series of green-washing cases observed and experienced by consumers in their daily consumption. In this study, the image barrier was identified under four subthemes: perceived low transparency, scepticism about green products, low trust in corporate green products, and perceived insufficient marketing communication.

At each stage of change, individuals consistently expressed a significant influence of brands' perceived lack of transparency in creating green communications. Scepticism about green claims was similarly shaped. Significantly, the findings of this study highlighted a prominent association between the perceived lack of transparency and corporations offering green products. Consumers particularly attributed this concern to corporations at the advanced stage of behaviour change (action/maintenance). This conscious group of green consumers often highlighted the aspect as inhibiting some of their choices in terms of the category under study but also concerning the overall sustainable consumption practised by them. What is more, the study noted negative sentiments emerging when discussing green alternatives offered by corporations.

> *"This is my understanding: if a corporate manager perceives an opportunity for profit, why not seize it and capitalize on it? Well, that's not a sound corporate assumption, because only if you completely changed all your products and removed the old line (unsustainable), it's basically a tabula rasa. From now on, all my products are super awe****, chapeau bas. But if you introduce one green line, I don't trust it. Sorry, you're just being a crackpot to me and trying to scr*** me over. Not an option, I'm just not going for it"* (Participant 15: Action stage).

> *"When it comes to the corporate aspects, so like probably most people, I'm not too trusting of them and their 'eco' labelling (...), they're just doing the bare minimum required – just what they need to do to get a certificate or some sort of label. Nothing more! So it's probably not exactly for ideological reasons being done, but rather for commercial ones"* (Participant 16: Action stage).

Respondents almost unequivocally (regardless of the SOC) prefer products offered by smaller manufacturers (employing up to 20 people) or local companies over corporate ones. Moreover, they prefer to pay more for locally crafted GPCPs. The rationale behind this usually included the word 'support smaller' in the statements made by respondents. This is what 18 out of 20 of the respondents answered during the study.

> *"I am more convinced by smaller companies, especially if the (green) brand is new, I believe they want to make a name for themselves on the market. They really exemplify their work. And yet, the number of people*

who work there, has this idea of putting out a good quality product rather than going for quantity. Quality, I hope, plays first fiddle for such a small company" (Participant 11: Action stage).

"I find myself more drawn to these niche green brands, especially small companies and Polish brands, for instance. I also like a product to be Polish, rather than manufactured by a large corporation. I prefer smaller, niche green cosmetics brands. It seems to me that by supporting a smaller entrepreneur, I am somehow helping them more than those who are sure to stay on the market" (Participant 20: Maintenance stage).

One might therefore be tempted to conclude that there is a rather negative attitude towards big manufacturers offering GPCPs alternatives, whereas there is a very positive attitude towards small craft producers.

This observation stands in contrast to the reports from other studies in which general trends have been analysed on the perception of products offered globally. The general perception of global brands has tended to be very positive due to global availability, colourfulness and diversity of offerings, innovation, and success on the international market as evidence of high quality. Research conducted by Davvetas and Diamantopoulos (2016) revealed that consumer preferences for choosing local brands are largely influenced by the specific product category. This highlights the importance of employing category-specific strategies in the management of brands on a global and local scale. Results from the interviews lead to the hypothesis that responses towards local green FMCG brands are much more positive than towards global brand offerings. This goes along with greater acceptance of paying a premium for green products locally manufactured.

The study uncovered an additional barrier that significantly impedes sustainable consumption, namely the presence of ineffective green marketing communication. This barrier exerts a substantial influence, acting as a formidable force against the adoption of sustainable behaviors.This barrier, in turn, is extremely effective in inhibiting purchase intention at the initial three SOC phases (pre-contemplation, contemplation, and preparation).

"There should be some kind of info in the shop, you know, like from the manufacturer or store, letting you know that this product comes in eco-friendly packaging. It could say something like "Make the right choice – protect the planet." (...) Something very striking like that. Then I would think about it, lean towards it" (Participant 13: Pre-contemplation stage).

The study findings highlight the importance of enhancing green marketing communication on green products, particularly among consumers who hold pro-environmental values. Insufficient exposure to such communication underscores the necessity for more robust efforts to effectively convey the green aspects of products (Alsmadi, 2007).

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Functional barriers

Functional barriers pertain to patterns of product usage, their perceived value, and the associated risks related to using specific products (Ram & Sheth, 1989, p. 7). The study identified several functional barriers, which are discussed below.

Usage barrier

The usage barrier is the result of incompatibility between user values, acceptance conditions and previous experience (Talwar et al., 2021). The usage barrier in this study consisted of barriers in the perceived form of lower availability and increased consumption of time to search for products at points of sale.

> *"While at the hairdresser's, she suggests that for my hair, the green shampoo brand X would be the most suitable (..). So you know, occasionally, being at some store, I ask around, and they don't have it. The same thing happens at the second store, and even at the third one. As it turns out, the product is exclusively available in select pharmacies, limiting its accessibility. .In such a situation, one would need to order the product online. As a result, time passes, and the topic fades away and is forgotten"* (Participant 6: Contemplation stage).

Value barrier

Value barriers result from a consumer's unfavourable assessment of the difference in the value of new products compared to traditional ones (Laukkanen, 2016). In this study, the value barrier consists of subthemes resulting from perceived worse consistency than in conventional products, lack of immediate effect, worse performance, worse quality, worse smell and comfort of use.

> *"But when it comes to the wooden toothbrush, I am not perfectly satisfied either, because it is very soft. So there is no ideal solution for me. I would love to look for a green one, but one that would give me satisfactory performance"* (Participant 3: Pre-contemplation stage).

The value and usage barrier most actively affects the purchasing behaviour of consumers at the early stages (contemplation, pre-contemplation, preparation), who perceive lower availability, performance or functionality of green alternatives as a significant problem. This is due to the fact that these consumers have not yet taken effective targeted action to purchase GPCPs, and their use is mainly inhibited by the barrier of existing habits. Participants who are at the later stages of change (maintenance, action) do not experience the abovementioned barriers or perceive them as minor impediments that

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do not affect their green purchasing behaviour. These findings are in line with those obtained by Reinhardt et al. (2019), who discovered that non-adopters state performance improvement as significant adoption triggers more often than adopters.

Noticeable consumer self-determination in these latter phases (action, maintenance) of change determines, to a large extent, the trajectory regarding the impact of usage and value barriers. Driven by incentives that appeal to their product expectations (health and environmental advantage), consumers effectively execute their intentions through engaging and informed choices. Such consumer self-determination, as a variable positively influencing the acceptance of innovations, was described by Chung and Liang (2020). The barriers they perceive the most, and which may condition their choices, are most closely related to image perception.

Risk barrier

A risk barrier constitutes the range of risks a consumer associates with using an innovative product (Laukkanen et al., 2007; Ram & Sheth, 1989). In this study, verifying the risk barriers to GPCPs consumption, four sub-themes were identified: financial, lack of self-efficacy in offsetting environmental, related to bad past experiences with this product category, and lack of added value regarding green alternatives over traditional ones.

> *"Green products are often more expensive. Many people certainly pay attention to the price. I pay attention to that too, because everyone has a certain amount of money to spend at any given time or in any given month. So, I look at that price and I try not to buy something if I don't know it (...) because I have a fear that I'm going to get an allergy on my face or whatever. Thus, I prefer something I know and can associate with, for example, something that someone has recommended to me and I have confidence that it will be a good product"* (Participant 8: Preparation stage).

It is natural that consumers with limited budgets remain more cautious in their choices. Price sensitivity often determines the choice and is one of the key factors 'holding back' green purchases (Nguyen et al., 2019). The lack of recommendations, which is crucial in the surveyed category's market, often magnifies the financial risk associated with this decision. According to the majority of the respondents, "recommendation" emerged as a critical factor, perceived as the most potent lever for overcoming all the barriers identified in this study, thereby facilitating the consumption of Green Personal Care Products (GPCPs).

Some consumers, mostly at earlier stages of the change process, do not believe in their self-efficiency when protecting the environment as individuals, as well as advantageous and long-term influence on health as one of the promises of GPCPs.

> *"I buy a 75 ml tube of toothpaste once in a while, so it is a product used in very small quantities. (...) My impression is that my environmental impact by buying this organic product is negligible here. (…) My impression in relation to personal health is that this impact is negligible"* (Participant 14: Pre-contemplation stage).

Individuals demonstrating low self-efficacy in adapting a particular behaviour will be less likely to engage in that situation-specific task (Bandura, 1977). In the pre-contemplation phase, self-efficacy tends to be low, whereas it increases with subsequent SOC phases to be strongest in the maintenance and action phases (Herrick et al., 1997).

Perceived lack of added value and past bad experiences with GPCPs emerged in the interviews as one of the risks consumers want to avoid.

> *"While I may not be well-versed in numerous organic products, I did have an experience with bath salts labeled as 'bio' that claimed to be healthy and made from natural ingredients. However, I didn't perceive any noticeable effects on the water's softness or the sensation on my skin after using them in the bath."* (Participant 9: Pre-contemplation stage).

The aforementioned risk barriers were more strongly articulated by respondents at the early stages of change. Consumers who have minimal experience with the product category, tend to express risk barriers more strongly. This can be attributed to their limited familiarity with green products and their associated risks. As they progress through the stages of change and gain more exposure and knowledge, their perception of risk may evolve and become less pronounced.

Triggers to green consumption

Reinhardt et al. (2019), in a very extensive qualitative study referring to a number of innovations, determined three general categories of triggers that increase the chance of innovation adaptation, namely: increasing the attractiveness of an innovation (regarding performance or price), barrier reduction (acquisition of knowledge and self-restricted use) or changes in the social system.

In this study, several important triggers were also observed in relation to adapting innovations in the form of GPCPs consumption: green word-of-mouth (WoM), parenting, general category involvement, current diet: vegetarianism/veganism, marketing communication, storytelling and openness to experience.

It was observed that respondents, regardless of the SOC towards green consumption, declared great sensitivity to green WoM. Undeniably, such

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a recommendation exerts a substantial influence on green consumer choices, as indicated by respondents' statements, and possesses the potential to effectively mitigate all the analysed barriers. This is in line with other studies (Mouloudj & Bouarar, 2021).

Parenting is another revealed factor having the potential to positively stimulate this particular green product consumption. In previous research, it has been indicated that the relationship between parenthood and green consumption shows a rather inverse correlation. According to Migheli (2021), parenting negatively affects green consumption in general. In the case of the category under study, however, this relationship may be reversed due to aspects of increased health safety concerning green personal care product alternatives for children.

The level of general involvement in the personal care products category, as well as dietary choices such as vegetarianism or veganism, were observed to be factors influencing consumers' attitudes and intentions to purchase green alternatives. These findings suggest that these factors play a role in shaping consumer preferences for environmentally friendly options. This phenomenon can occur due to higher awareness and knowledge among individuals who are more involved in the personal care products category. Additionally, dietary choices like vegetarianism or veganism reflect a broader commitment to sustainability, leading to more positive attitudes and intentions towards purchasing green alternatives. Further research is needed to explore these factors in depth. Several respondents stressed that information about green products comes to them as a result of marketing activity by manufacturers. It should be noted, however, that in the research, isolated cases of people were registered at the initial stages of change who incidentally chose green products encouraged by green storytelling on packaging. For consumers, facts and evidence are hugely important in breaking down barriers, but stories are often more easily remembered because of their power to fascinate. Empirical evidence (Lundqvist et al., 2013) points to the enormous impact of well-designed marketing stories.

Discussion

In the literature on green consumption, much consideration has been focused on the study of psychological and social factors affecting green consumption. The integration of IRT and SOC brings new knowledge about consumer attitudes and behaviours at different stages of adaptation towards green products. Proper qualification of consumers according to their position on the "wheel of change" towards green consumption will allow more efficient and effective implementation of sustainable strategies as resistance

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reduces the effectiveness of sustainability interventions and generates consequences for policymakers, companies and consumers (Gonzalez-Arcos et al., 2021).

In Figure 2, the synthesised results of our study are presented. This leads to a discussion about results for other researchers. First and foremost, it is crucial to highlight that the integration of Stages of Change (SOC) and Innovation Resistance Theory (IRT) concepts introduces a novel perspective on the architecture of barriers. . While analysing the results of the research, ones may notice that the general conclusion refers to the functional barriers within the IRT construct that disappear at the last two stages of change. Psychological barriers, on the other hand, remain but assume a different form, mainly related to a higher level of awareness. At the initial stages (pre-contemplation, contemplation), the image barrier mainly accumulates around general scepticism about green product alternatives and the lack of convincing marketing incentives to stimulate change. Thus, unaware consumers do not feel the need to modify their behaviour. Habitual resistance and limited knowledge about green product alternatives and their potential positive influence on the environment as well as personal health generate high perceived risks related to the transformation.

Some types of psychological barriers, such as tradition, are noticeable at the first stages of the change process, while during stages of action and maintenance, they are not observed in the same vein. Tradition serves as a psychological barrier that emerges from the clash with customers' preexisting beliefs. (Ram & Sheth, 1989). In their research, Ram and Sheth (1989) and Amberg and Fogarassy (2019) also identified that dimension. It is not clear whether this is tradition or routine due to the fact that tradition is strongly connected with emotions and celebrating moments, while routine is not based on that type of self-reflection. In our research, respondents mentioned habits and sentiment, suggesting both possible sources of inhibitors and interpretations. This further indicates that the barrier may be perceived as a routine, and – to change attitude – customers have to break repeated patterns of behaviour (Herbig & Day, 1992).

Image is shaped by customers' knowledge and experience with a particular subject or object influenced by the connotations that external target groups associate with specific companies and brands (Burmann et al., 2008). This suggests consumer acceptance of innovative GPCPs (knowledge and emotions) is influenced directly (through own experience) or indirectly (from WOM or media). The weak positioning in consumers' minds, accompanied by their scepticism without support from communication, is an inhibitor during the three stages from pre-contemplation to preparation. In advanced stages of change, the image barrier evolves and intensifies, particularly regarding the lack of trust in corporate green product manufacturers,

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their perceived lack of transparency, and their real contribution to sustainable production. Consumer suspicion increases with greater knowledge and experience. Hence, there is a need to develop communication strategies targeting this group of consumers based on alternative arguments. Examples of such arguments include providing evidence of environmentally friendly actions, transparency regarding product composition, and the credibility of certifications and independent evaluations.

Therefore, the image barrier is multi-faceted, variable for almost every stage of change towards green consumption, and requires separate consideration depending on the consumer's progress. Identifying and describing these facets requires additional effort from the scientific community and poses an intriguing challenge for future research.

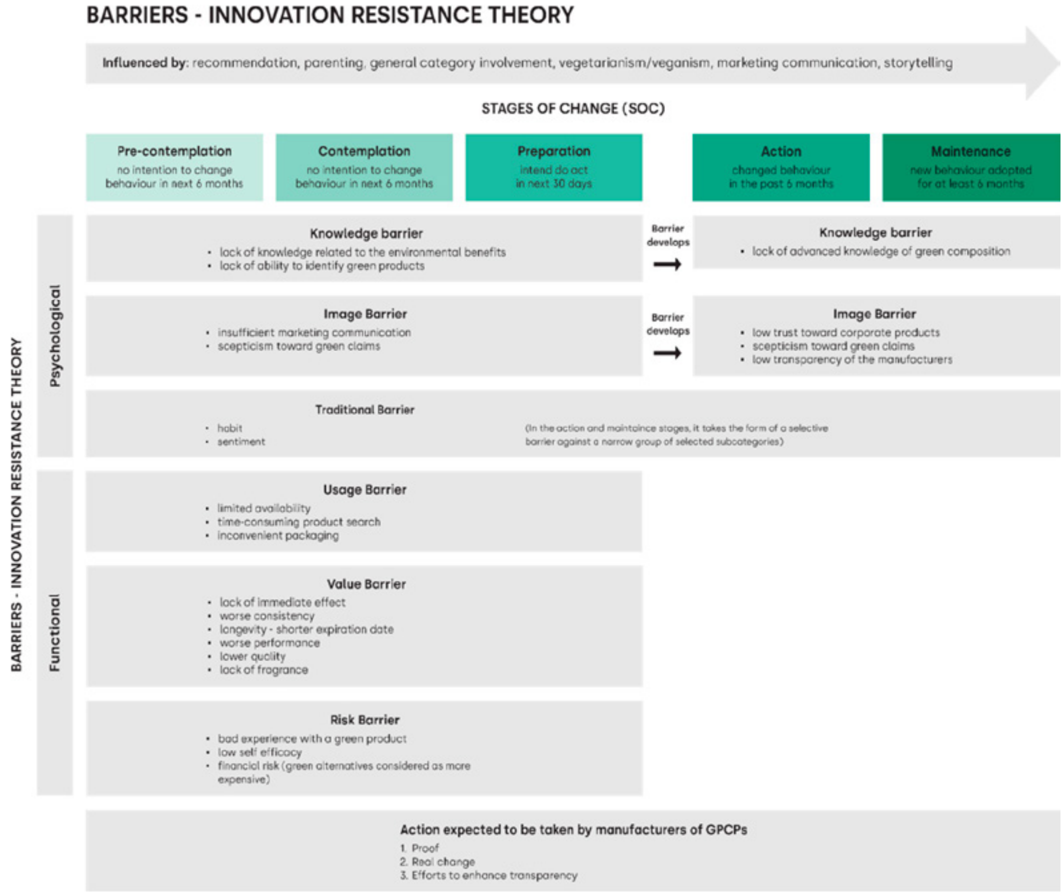

Figure 3. Barriers exist at each stage of change towards GPCPs consumption. The figure includes environmental stimulants and action expected to be undertaken by manufacturers

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Functional values, such as value barriers, strongly refer to benefits delivered by GPCPs. According to Chen and Deng (2016), environmental awareness as well as price sensitivity are intertwined and have a significant impact on the level of green purchases. Among other types of values described by consumers is trust in green cosmetics' effectiveness. In their research, Amberg and Fogarassy (2019) noticed that consumers will not use natural cosmetics if they are not as effective as their chemical complements. However, the quality of GPCPs is perceived as a barrier that can be weakened by price due to there being a correlation assumed between product price and quality (Wang et al., 2019).

The knowledge barrier is significantly evolving throughout SOC phases. Being aware can be defined as a process of change that progresses as knowledge increases through information and learning (Fiske, 2008). Naturally, environmental knowledge increases as the awareness increases (Safari et al., 2020) and vice versa. Some researchers use knowledge and awareness interchangeably in certain contexts (Kwatra et al., 2014). Knowledge is a moderator of the relationship found between practices of green innovation and consumer resistance to such innovation (Khan et al., 2022). According to Kao and Du (2020), providing information with high-quality features in advertising messages influences consumers' positive perception of a green brand. Based on that research, we argue that information should include a real reliable proof. Creating effective green marketing messages for first SOC segments may therefore require a completely different strategic approach focused on education and providing quality evidence of product sustainability (e.g., comparative advertising, content backed by factual sources, and expert support). Marketing is seen as the basic channel in promoting green consumption, but selective marketing is suggested to increase the share of the population subscribing to green consumption (Nelson et al., 2009). The selection of appropriate marketing triggers should reflect the specifics of these consumers from initial phases, inexperienced with change, clinging to their habits, but also not open to dynamic and categorical change. It is also very important at this stage to stimulate social change towards green consumption. Social influence at these early stages has the potential for the strongest stimulation of the green consumption effects. "Motived by a warm glow, which can be understood as a good feeling after engaging in a pro-social behaviour" (Tezer & Bodur, 2019) is a social creation that could prove effective in stimulating change through appropriate marketing efforts. Thus, a huge role in social marketing remains to be played in properly promoting green consumption to this audience.

Consumers who are in the third SOC group (pre-contemplation) can be described as 'lost' and in need of a 'helping hand' type of intervention. These individuals are already entirely open to change, trying to implement green

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habits but get 'lost' in the process. Green marketing communications could be primarily focused on creating 'traffic signs' and 'green signalisation to help identify both the environmental and health benefits for the consumer in the pre-contemplation phase, as well as generate cues to aid in identity establishment of green products.

Finally, at the final SOC stage (maintenance, action), corporations take on a huge role. These precisely targeted and aware of consumer trust smaller manufacturers of green alternatives are incredibly sensitive to the issue of transparency as well as product composition. This consumer greatly appreciates sustainable packaging but is equally sensitive to the aesthetic issues of green packaging. GPCPs designed for conscious consumers should be based on a simplified natural and fresh aesthetic. The consumer also has noticeably higher expectations in terms of packaging innovation (e.g., reusable refill options). This segment expects to be taken seriously, as for it, GPCPs are often a category in which the consumer is very committed to buying. Therefore, in their actions, global companies should convince buyers that they have made a real, sustainable change at all stages of production. Genuine change should also be visible on the packaging by offering GPCPs, the composition and packaging of which ought to be both consistent with the idea of green change and appealing to the consumers' high expectations.

What should be strongly emphasised are certain consumer expectations directed at green product manufacturers, namely: the expectation of eco-performance proof, a real change towards 360-degree green manufacturing, and a definite increase in transparency efforts. All respondents, regardless of the SOC, declared openness to change and increased efforts to be more committed to environmental protection. However, they were not fully convinced by market agents. They were not even provided with evidence in the form of articulating the prevalence of green alternatives for health and the environment. Consumers expect a real change in the behaviour of manufacturers, including transforming the entire production process toward those sustainable and offering exclusively green innovations, completely abandoning traditional ones. Only such action has the potential to definitely increase credibility, but also positively affect transparency. Sustainability might be a significant purchase criterion if and only if consumers feel they have been convinced by authentic, mission-driven green companies.

Theoretical implications

The integration of the two concepts: IRT and SOC, brings about new ideas for consumers attitudes toward green personal care products and participation in the process of both inhibitors and stimulants that lead consumers from the stage of pre-contemplation to maintenance. Firstly, as far as psycho-

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logical and functional barriers are concerned, they take part in the SOC process until preparation. At the action and maintenance stages, some inhibitors are still present; however, functional barriers disappear.

The interviews revealed several variables demonstrating potential in moderating relationships between barriers and intention to purchase GPCPs, namely general category involvement, parenting, current diet: vegetarianism/veganism, and openness to experience. The study also revealed that consumers prioritize the health aspect over the environmental aspect when considering alternatives to GPCPs.

In the marketing literature, there is a constant search for answers to the question of how to make a shift in consumer behaviour toward that more sustainable (Kemper & Ballantine, 2019). Knowledge of the perceived barriers in the consumption of green products is of rising significance, as trade organisations are placing more and more emphasis on environmental concerns when assessing performance in line with the triple-bottom line method.

Particularly important for proposing fruitful marketing of innovation dissemination and product failure reduction (Ram, 1987) is the analysis of barriers accompanying individuals at the early stages of change: non-adopters with no intention to change. Stimulation toward sustainable consumption, however, should run parallel throughout the behavioural change process since, at each stage of change, there is a risk that relapse will occur, a phenomenon already known in psychology (Segan et al., 2006). The creators of the TTM model pointed out that the process of change is cyclical rather than linear for most people and that relapse triggers a renewed passage through earlier and later stages of change (Prochaska et al., 1992).

In this study, it has been revealed that the dominant barrier for any consumer (regardless of the stage of change) is a lack of knowledge about green alternatives. However, the intentional acquisition of this knowledge requires certain skills and commitment. Gleim et al. (2013) reported a lack of expertise as being a barrier to green consumption, as well as that the change in the number and form of product information cues can break these barriers. The standardisation and popularisation of knowledge about the certificate marks would have the potential to significantly reduce the dilemmas that consumers currently face on the 'thorny' road towards sustainable consumption. Certification systems provide guarantees of „green quality" by verifying the production process, composition and sourcing of ingredients, packaging, storage, the authenticity of labels, energy and waste management (Vila Franca & Ueno, 2020). Certificates provide evidence of sustainability – a need that remains unmet and generates strong barriers in the transition to green purchasing decisions. Above all, however, certification in the personal care market must be the subject of intense debate and promotion, just as in the food market.

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Nonetheless, a lack of systemic governmental support and that of policymakers inhibits these changes and stifles the evolution of green consumerism. While great hopes are being pinned on green consumerism as the path to a green, low-carbon economy and poverty alleviation leading to an increase in resource efficiency (*Goal 12: Ensure sustainable consumption and production patterns*, 2015) , there are still no concrete regulations or government definitions for GPCPs in the European Union, United States or Brazil (Vila Franca & Ueno, 2020).

Managerial implications

The intention-behavioural gap on the part of manufacturers is the strongest inhibitor of green consumption concerning this product category. By offering genuinely green alternatives, implementing innovations related to greener packaging, and promoting knowledge as well as evidence of how green offerings differ from conventional ones, manufacturers are among the strongest market agents with the potential to reduce inconsistency between consumer declarations and their purchasing behaviour at every stage of change towards green consumption. Lack of quality knowledge and evidence, consumer uncertainty and mistrust stunt green consumption – especially among those at lower stages of change (pre-contemplation, contemplation), who are often characterised by lower overall engagement in the personal care category. This, in turn, reinforces the barrier of tradition, that is, attachment to tried-and-true purchases. This conclusion is in line with that obtained in the research by Sadiq et al. (2021), according to which consumers with deep environmental and health concerns are more expected to use eco-friendly cosmetics, irrespective of existing barriers.

The respondent's level of knowledge about how the consumption of GPCPs alternatives can affect environmental protection was limited at all levels of change. The aspect of green packaging innovation and aesthetics appeared in almost every conversation at the higher stages of change levels, but mainly the intention to purchase GPCPs was shaped by the natural composition of the products and their beneficial effects on personal health. Thus, health consciousness proved to be a much stronger stimulant for more sustainable choices within the given context. What should be strongly emphasised are certain consumer expectations directed at green product manufacturers, namely: the expectation of evidence, real change and a definite increase in transparency efforts. All respondents, regardless of the stage of change, declared openness to change and increased efforts to be more committed with environmental protection. However, they were mostly not convinced by market agents. They were not provided with evidence in the form of even articulating the prevalence of green alternatives for health and the environment. Consumers expect a real change in the behaviour of manufacturers, including transforming the entire production line towards sustainable processes and offering exclusively green products, not a mixed variety. Only such transformation has the potential to increase credibility, but will also affect perceived transparency. Sustainability might be a significant purchase criterion if and only if consumers feel they have been convinced by authentic mission-driven green companies.

Conclusions

In this study, preliminary evidence is provided, stating that there is considerable stage-specificity across multiple green consumption behaviours. Sustainable consumer purchasing behaviour generates strong incentives to stimulate manufacturers to make a change towards sustainable industrial development (Liu et al., 2012), which, in turn, benefits environmental well-being. Companies around the world are facing the need to provide improvements in the environmental performance of offered products, often forced by other parties such as the government, customers, suppliers, consumer groups, environmental organisations and even banks together with insurance companies (Klostermann & Tukker, 1998). In order to cover sustainability demands and enhance eco-efficiency, manufacturers are implementing product innovations and offering new alternatives to conventional green solutions for customers. Green consumption patterns are also strengthened by social change, defined by sociologists as a type of social innovation. Social innovation is perceived as a "novel solution to social issues, being more effective, efficient and sustainable compared to already existing solutions, and for which the created value primarily accrues to society as a whole rather than only to private individuals" (Phills et al., 2008, p. 38).

Researchers often portray the lack of intention execution as an unthinking behaviour (Jacobs et al., 2018), but the one-on-one interviews conducted as part of this research allow to suggest that consumers of personal care products are often very thorough in their analysis of green offerings and make their final choices in a very rational and thoughtful manner. The fundamental problem is not a lack of consistency between intention and purchasing behaviour on the part of the consumer. Often, the key problem is a lack of proper attitude and behaviour among manufacturers in terms of green declarations, not translating into the final product offered to consumers. This, in turn, generates a series of image barriers that strongly influence final purchasing behaviours. In particular, the strongly functioning image barrier at all stages of change suggests that the process of change towards green consumption is strongly hampered by the actions of green-washing manufactur-

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ers, generating bad consumer experiences, but also by intuitive consumer mistrust in corporations and their intentions. Thus, there is a noticeable green ethnocentrism in GPCPs consumption which remains consistent with other studies. Hsu et al. (2017) proved that the country of origin moderates links between purchase intention and antecedences in the case of students from Taiwan. The origin of green alternatives can therefore be one of the leading factors in decision-making and product evaluation, as opposed to conventional products. Thus, in addition to cultural differences, immeasurably shaping purchasing behaviour around the world, in analyses, it is important to distinguish the impact of ethnocentrism with regard to the product's nature (green vs. conventional). The future of the ecosystem largely depends on the proper and rapid diffusion of sustainable product and service innovations (Dearing, 2000). Approaches to formulating attitude change strategies, and addressing these societal challenges, require appropriately targeted interventions considering the knowledge of the boundary conditions for the intervention (Gwozdz et al., 2020; Verplanken & Orbell, 2022). There have been a great number of emerging studies in which the effectiveness of stage-specific interventions has been demonstrated within the context of different behaviours, i.e. physical activity or healthy eating (Klöckner & Ofstad, 2017; Teng et al., 2021). Stage-targeted interventions are especially useful in addressing lifestyle modification (Md Yusop et al., 2018).

Limitations and further research

While this study makes a significant contribution to sustainable marketing, the design of this study has its limitations. Generalising the survey to other markets outside of Poland can be problematic when market specifics are considered (both in terms of marketing communications and GPCPs labelling), in particular, the different socioeconomic characteristics of the population and the green consumer consciousness more broadly built place. The sample selected for this study includes residents of one province in one country. In future research, potential similarities among other cultures and nations could be explored.

Despite the aforementioned limitations, this study improves knowledge on the inhibitors and stimulants of the overall green consumption process, thereby, it will help programming interventions more effectively, for both social and commercial green marketing strategies.

In further research, quantitative verification should be carried out with regard to the impact of individual barriers at each stage of change, optimally compared to several categories of green products in different cultural contexts in order to compare possible differences.

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More attention should be paid to the knowledge barrier and its different framings related to green consumption. Also, attitudes toward acquiring green knowledge could be examined. And when it is acquired, does having green knowledge equate to and ability to use it?

Consumers may also hide behind the knowledge barrier, and in fact, the actual barrier may be a negative attitude towards acquiring knowledge or unsatisfactory quality of the information provided. These aspects should be explored in the future through further research.

The contribution of the authors

Marta Szaban was responsible for reviewing the literature, designing the study, conducting the research, coding the results, and analysing and interpreting the data.

Magdalena Stefańska acted as supervisor throughout the research process and participated in the writing of the article (formulation of conclusions and discussion).

Authors have no conflict of interest.

Data availability

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

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RENEWABLE ENERGY SOURCES AS A WAY TO PREVENT CLIMATE WARMING IN POLAND

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ABSTRACT: The discussion on renewable energy sources, especially wind and solar energy, conducted in Poland reveals diverse positions among representatives of science, business, local government, and government. It is generally accepted that renewable energy sources are an important factor in limiting global warming. However, it is also emphasised that this energy absorbs high costs related to, e.g. the acquisition of rare metals used in the production of wind turbines, with the disposal of used parts. The article aims to present the opinions of representatives of science, economic practice, and authorities as an expression of behaviour toward the problem of climate warming and renewable energy. An example of expressed opinions is the discussion in the public space, which is created by publications in magazines and non-serial literature. As a result of using the method of analysis of secondary materials, the article shows the diversity of views on the subject under study. Opposing views on the causes of global warming have found; that wind energy can limit global warming, but it can also cause damage to the economy, landscape, and human health. The development of wind energy is determined by legal, organisational, economic, and technological obstacles that are difficult to overcome in Poland. However, the need to develop renewable energy, including wind and solar energy, is supported by 85% of Polish society.

KEYWORDS: climate, wind energy, developmental barriers, fighting global warming

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Introduction

Energy independence is a fundamental condition for the security of any country, including Poland. The European Union (EU) closely links energy independence to the fight against global warming. Therefore, efforts concentrate on increasing the share of renewable energy sources in the so-called energy mix. In parallel, great efforts are being made to decarbonise economies, thus moving away from coal, considered the main source of CO_2 emissions. It is a nuisance for the atmosphere and exacerbates global warming with all the related catastrophic visions. There are projects developed in the EU to fight against global warming called the European Green Deal and 'Fit for 55'. However, due to the war in Ukraine, an adjustment in the discussions on global warming, renewable energy sources, and energy policy proved necessary.

The purpose of this study is to learn the opinions and positions on the ongoing discussion on the role of renewable energy sources, especially wind energy, in ensuring energy independence, limiting climate warming, and identifying the barriers of these sources. The opinions expressed in the public discussion and presented in the literature and magazines are an example of the social awareness of Poles about renewable energy sources and their importance in global warming. The article answers the following questions:

- What are the positions in the discussion of representatives of science and practice on climate warming?
- What is the importance of renewable energy sources in counteracting climate warming?
- What barriers limit the development of wind and solar energy in Poland?

While developing the topic, the authors used primarily the method of analysing reports from secondary empirical research, the method of analysing selected items of non-fiction and periodical literature, which is a forum for public discussion regarding the problem under study.

An overview of the literature

It follows from observations that the climate is warming. Poland is experiencing violent winds, torrential rains, and other calamities, causing significant material damage. Catastrophic descriptions (Gates, 2021), for example, rapidly melting glaciers and rising sea levels, boost uncertainty in readers, leading them to believe that this is the truth. Over time, it gets accepted and labelled political correctness. This belief is further strengthened by the hypothesis that human activity is the cause of the warming. This is accompanied

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by aggressive propaganda from environmental organisations known as eco-warriors (Mastalerz, 2005).

Advocates of the hypothesis of anthropocentric sources of global warming very often cite the findings of scientists working for the Intergovernmental Panel on Climate Change (IPCC). These pieces of research are interesting and inspiring, but they do not come close to scientific truth. The aforementioned Gates (2021) noted that scientists still need a lot to learn about how and why the climate is changing. The reports from the Intergovernmental Panel on Climate Change show that some things, for example, how fast temperatures will rise and the exact effects of the projected temperature rises, are still uncertain. Further, the same author raises his doubts as to whether the many aspects of climate change 'that we still do not understand' (Gates, 2021) can be explained using mathematical models.

Let us add another quote. In 2014, Kleiber (2014), President of the Polish Academy of Sciences, wrote as follows when outlining the future of climate policy: "In the last century, the Earth has warmed by almost 1 deg. C, and there is virtually no doubt today that this is due to increased carbon dioxide emissions from fossil fuels. The temperature is extremely likely to rise by at least 2 degrees Celsius by the end of this century. Possibly even twice as much. The impact of such changes on people's lives would be enormous..." (Kleiber, 2014).

Referring to the comments of both these authors, one may ask how the members of the Intergovernmental Panel know that if global warming exceeds 1.5-2.0 deg. C, an unimaginable catastrophe will occur (Warren et al., 2018). Gates (2021) argues 'no absolute certainty' whereas Kleiber (2014) writes of enormous probability. What conclusions can be drawn from these? Perhaps only such one that thanks to the achievements of social science, psychology, and neuroscience, it is known that with long-term exposure to propaganda, people start recognising propaganda as truth (Stodolak, 2022).

In his work entitled "Social Theory and Social Structure" Merton (1982) noted that scepticism is one of the necessary conditions for science. It presumes that judgements, especially final judgements, cannot be made until the research has been completed on a sound empirical and logical basis. Scepticism is a virtue and, at the same time, a necessary condition for doing science.

Now, going back to the comments of Gates (2021), Kleiber (2014) and Merton (1982), quite numerous doubts can emerge as to the intentions of the proponents of the hypothesis of the anthropogenic genesis of climate change. Reading the views of members of various environmental organisations is certainly worth the trouble. Mastalerz (2005), already mentioned above, has spoken extensively on this subject. Observations of Klaus (2007) from his

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book entitled "Blue Planet in Green Shrouds" are equally interesting. According to him, humanity should first and foremost separate reality from fantasy and truth from propaganda (...). Future generations will probably discuss with a hint of amusement that at the beginning of the 21st century, the whole developed world panicked about average temperatures rising by a few tenths of a degree and considered a return to pre-industrial times. The same author further stresses that global warming is increasingly becoming the field for a fundamental ideological and political clash of our modern age. Environmentalism, an advocate of this theme, has become the dominant alternative to ideologies that are consistently and *a priori* based on human rights and freedoms. This is the world-leading view that radically and without regard to the drastic costs, intends to change people, their behaviour, their social make-up and their system of values. Absolutely everything (Klaus, 2007; Missirian & Schlenker, 2017).

The ongoing public debate on global warming makes it apparent that the promotion of the thesis on anthropogenic sources of this phenomenon is coming to the foreground (Filipiak, 2022). On the contrary, arguments in favour of global warming being a natural phenomenon are rare. They are found in earth sciences and historical records alike. If this man is the biggest 'pest", any further narrative is self-explanatory as greenhouse gases can only be eliminated or reduced through decarbonisation and the widespread use of renewable energy sources (Betakova et al., 2015; Bolwing et al., 2020).

Regardless of the presented remarks, two distinct attitudes are observed in the discussion on stopping climate change and protecting the natural environment. The first opposes climate change and does not support the rapid development of renewable energy sources. There are economic and social reasons for this, including the loss of many jobs (Palmer, 2018). The second position points to the necessity of rapidly shifting away from fossil fuels to renewable energy sources, including wind and solar energy. It is not easy to unequivocally advocate one extreme or the other. It should be emphasised that the development of renewable energy sources is imperative, both for now and in the future (Jasiński et al., 2022). However, the discussion of this topic often overlooks the issue of the raw materials needed to manufacture photovoltaic panels, wind turbines and batteries for electric cars (Bennet et al., 2021). It is, therefore, necessary to include in the discussion rare metals, such as, for example, vanadium, cerium, gallium, indium, iridium, platinum, niobium, and cobalt. As the very name suggests, these are rare and do not occur independently. They are bound with other elements, and their mining entails the destruction of the Earth's crust, often combined with environmental contamination, the use of strong chemicals, and the cost of transport over long distances. Deposits of rare metals, their extraction and

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technological sourcing create several environmental, economic and geopolitical problems (Zarzecka, 2021; Pitron, 2020; van Kamp & van den Berg, 2021).

Methodology

The article presents the theoretical and empirical aspects of climate warming, the importance of renewable energy sources, mainly wind and solar energy, in limiting this warming, and the difficulties in this area. The basis for interest in a selected topic is the public discussion conducted in Poland in the circles of science, economy, and government. Examples of this discussion are articles in journals, the Internet, published research reports, and compact publications. To recognise the problem, following the research methodology in the social sciences, the article adopts an appropriate research process consisting of several stages. In the first stage of the research procedure, attention was drawn to the need to recognise the positions expressed in the public discussion on climate warming and the role of renewable energy sources in limiting this warming. The second stage of the research procedure concerns the specification of the research problem. At this stage, attention was paid to the differences in the views of representatives of science, economic practice, and authorities regarding the selected problem. They particularly referred to wind and solar energy, difficulties in developing these sources, and the opinion of the Polish society on wind farms. The next research step was the selection of appropriate research methods useful to verify the identified problems and conduct research. The article uses the method of analysing secondary materials in the form of a critical analysis of the literature on the subject, analysis of publications in journals, the Internet, and published reports on empirical research. The article uses the results of nationwide empirical research commissioned by various institutions. The results from the report on the awareness and environmental behaviour of Polish residents regarding wind energy were taken into account. These studies were carried out as the sixth edition in 2020 at the request of the Ministry of Climate and Environment. The study used the CATI (Computer Assisted Telephone Interview) technique, i.e. computer-assisted telephone interviews. A random representative sample of the total population of Poland aged over 15 was 1015 people. The maximum estimation error of this sample was +/- 3.1% (Ministerstwo Klimatu i Środowiska, 2022).

The article also uses the results of research conducted by the Center for Public Opinion Research (CBOS) in February 2023. This study used the mixed-mode procedure on a representative named sample of 982 adult residents of Poland. People for the study were drawn from the PESEL register

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(WNP, 2023). Research reports were also used: Social Changes (PSEW, 2022); Polish Alternative Fuels Association (PSPA, 2022); Staszic Institute (Jasiński et al., 2022); Kantor Public (ClientEarth, 2022). After collecting quantitative and qualitative data using the adopted research methods, an important research step was their presentation and discussion. This stage is presented in the part of the article entitled «Research results: Analysis and discussion». At the final stage of the research procedure, theoretical-cognitive and practical conclusions were formulated. Therefore, following the research methodology in the social sciences, the principle of knowledge of the literature on the subject and the research procedure was followed (Babbie, 2001).

It should be emphasised that in modern science, more and more researchers use secondary data collected by other researchers. These data are included in empirical reports, magazines, and statistical yearbooks. The analysis of secondary empirical data is an established research method in the social sciences (Frankfort-Nachmias & Nachmias, 1996). This approach results primarily from economic and methodological reasons. Because the collection of primary data is expensive and not always in line with the methodological requirements, especially when it concerns one researcher or a small research team with limited financial resources. The adopted research methodology used in the article includes, among others, the above methodological premises.

Research results: analysis and discussion

The general benefits of using renewable energy sources have economic and social fields (reducing the use of foreign energy sources, creating new workplaces, developing wasteland to provide agricultural energy for the source), ecological (reduction of air pollution, global warming, and the total amount of waste); health (reduction of diseases affecting the environment). Indicators of energy consumption from daily sources in gross final energy consumption per year in Poland in 2010-2021 are presented in a detailed summary. In 2010 – 6.1%, 2015 – 13.7%, 2018 – 11.1%, 2019 – 12.2%, 2020 – 16.1%, 2021 – 16.1% (Rynekelektryczny, 2022). These data indicate that the share in obtaining energy sources in total energy production in Poland is still insignificant. Since 2016, the source of development of energy sources, especially wind energy, has been inhibited by the Act on Wind Farms, known as Act 10H.

The generation of electrical power in Poland is dominated by hard coal (46.4%) and lignite power plants (27.4%). When it comes to green energy, other power plants contributed 8.6% to the total energy yield, wind installations 9.7% and hydroelectric plants 1.6%. Gas power plants accounted for

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6.3% of the electricity generation mix. These figures refer to May 2022 (Rynekelektryczny, 2022). When renewables are analysed alone, wind farms accounted for 38.3% of the mix, solar PV 50.6%, hydro 5.1%, biomass 4.7% and biogas 1.3% of renewable electricity generation (Rynekelektryczny, 2023). Thus, it follows that wind and solar energy are the most popular renewables. Both sources are clean in the sense that they do not emit carbon dioxide into the atmosphere. The fact that once erected, it generates only low operating costs is also an advantage. The same is true for photovoltaic cells. Disadvantages of both of these energy sources include the fact that they disfigure the landscape, contribute to the death of birds and bats (wind farms) (Pawlas, 2009; Gamboa & Munda, 2007; Krug & Lewke, 2009), and the low concentration of generated energy produced in need for storage (photovoltaic farms).

In response to EU Climate Commissioner F. Timmermans' call to reduce dependence on traditional energy carriers such as natural gas, oil and coal, Bielewicz (2022) wrote: "Sound simple? However, the reality does not necessarily conform to this politician's wishful thinking because (...), to put it simply, the sun does not shine every time and everywhere, and neither does the wind always blow (...). For this simple reason, until we learn how to efficiently store the generated energy produced and how to efficiently transmit just when shortages occur, renewable sources will remain impractical and, in that sense (...), 'non-renewable'" (Bielewicz, 2022).

In late 2021 and early 2022, there was some confusion in the RES discussion. In particular, as a result of the war in Ukraine, some fuels, previously considered detrimental to the climate, have been given a friendly, usable status. This applies, for example, to gas, coal and the atom (Sommer, 2022b). It is interesting that when revising the renewable energy proposals, the EU allowed the use of wood (Sommer, 2022a).

It thus becomes clear that the economic interests of some European countries are more important than the slogans on the commitment to climate protection. Economic, political and electoral considerations came to the fore and climate concerns were pushed to the background. An attentive observer would surely ask whether this is about protecting the climate or rather about protecting own interests (Landeta-Manzano et al., 2018).

Despite such a pessimistic conclusion, based on past experience, the conviction might be justified that new possibilities for energy storage, safe and inexpensive use of hydrogen, generation of electricity from plastic film and many other inventions related to renewable energy sources will soon emerge. Therefore, the 2015 Paris Agreement calls for a complete phase-out of fossil fuels in the European Union by 2050 (Sobieraj, 2017).

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To say that concern for access to energy sources is a fundamental duty of every state is just a truism. These are what determine energy security, the competitiveness of the economy and the standard of living of citizens. They are not only a commodity but also a common good. Thus, energy policy focuses on issues such as the access to and volume of energy sources (both renewable and non-renewable), ways of allocating (distributing) energy, and energy consumption patterns in society (Gryz et al., 2018).

As already mentioned, the war in Ukraine questioned certain dogmas about the pros and cons of renewable energy sources and their place in Poland's energy policy. For example, the significance of RES for military purposes was pointed out due to their geographical dispersion, which is somewhat new. The need to strengthen RES was emphasised, as such decisions allow for independence from Russian gas, oil and coal supplies. An additional argument in favour of supporting renewable energy sources includes the lower installation and operating costs (compared to conventional sources) coupled with the economic and social benefits. According to the Polish Wind Energy Association (PWEA), in an optimistic scenario, the construction of wind farms could yield an increase in GDP (by 2030) of PLN 70-133 billion, whereas orders for products and services would translate into around 57-97,000 new jobs.

However, the development of the renewable energy sector and the determination of its importance in the country's energy policy, fighting global warming face various barriers (Hajto et al., 2017). These can be divided into: – technical and technological, – legal and organisational, – economic, and – social barriers. Technical and technological barriers mainly relate to mass refusals for conditions for connecting new investments to the power grid. According to the Polish Confederation Lewiatan, in 2019-2020, the field offices of the Energy Regulatory Office (ERO) received refusals to connect 1209 installations to the grid (Ciepiela, 2022). Outdated transmission and distribution networks were the reason. The storage of energy generated in the RES network used for the consumers' consumption is also problematic. Bartłomiej Pawlak, vice-president of the Polish Development Fund (PFR), draws attention to another technical and technological barrier to RES development. He stresses that while we do produce masts and blades in Poland, we do not manufacture turbines for wind farms. "Even if an assembly plant for such turbines were established in Poland, it would still increase the chances that the contractors would come from the immediate neighbourhood and not from the other side of the globe" [translated from Polish]. Moreover, the vice president emphasises that Poland does not have engines for biogas plants (Ciepiela, 2022).

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Advocates of renewable electricity point to legal and organisational barriers that do quite well in hindering its development. The six-year dispute on the 10H distance law was one of the most significant obstacles. It stipulated that the distance between a wind turbine and residential buildings could not be less than 10 times the height of the latter. It means that a windmill 150 m cannot stand closer than one and a half kilometres (1.5 km) from any house. Such a provision prevented wind investment over a significant part of Polish territory. As estimated by the Ember think-tank, the 10H rule excluded around 99% of Polish land from wind investment and limited the total installed capacity for this technology to a maximum of around 10 GW (Dyląg, 2022). It was not until 5 July 2022 that the government adopted a bill liberalising the so-called Distance Law of 2016, which restricted the possibility of locating onshore windmills in Poland so dramatically. The amended 10H Distance Law, among other things, stipulates the conditions and procedures for the locating, construction and reconstruction of onshore windmills, the principles and procedures for social consultations with the local community, and the rules for new residential developments in the vicinity of wind turbines. It has been accepted that a different distance of windmills from a residential building, but not less than 700 metres, could be specified in the Local Development Plan Identical. The amended act assumes that the investor of wind farms will offer at least 10% of the installed capacity of the wind farm to the inhabitants of the commune. The amended act retains the 10H rule in the case of national parks and in the case of nature reserves – the 500m limit. It maintains the ban on building windmills in national parks, landscape parks, nature reserves, and Natura 2000 areas. According to government estimates, the entry into force of the amended Distance Law will enable the construction of onshore windmills of total power between 6 GW and 10 GW by 2033 (Chojnacki, 2022).

Another difficulty for RES development is that small companies investing in renewable energy are not professionals in this industry and lack professional staff capable of preparing such investments in organisational terms. Therefore, they need legal and organisational assistance to implement these projects from start to finish. The implementation of onshore and offshore wind development plans necessitates streamlining the permit-issue system. Connecting renewable energy sources to the grid is also an issue. Janusz Gajowiecki, president of the Polish Wind Energy Association (PWEA), proposes a solution. He believes that energy trading companies and distribution system operators should be separated from the existing energy groups. He claims that as a result, conditions for the connection of new RES sources would be issued quickly, as the CEOs of these companies count on additional revenues (Ciepiela, 2022).

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Investors in the RES industry face significant economic barriers, such as the EUR to PLN exchange rate and rising costs of fuels, services and materials, especially steel products and rare metals. These difficulties are combined with the need to cooperate with entities with enough international experience and foreign capital. The participation of Polish companies in such investments would contribute to their development in the global RES markets. Moreover, small entrepreneurs find it difficult to finance clean energy investments and cannot always count on the support of banks that target larger investors.

Generally, social barriers are not a major impediment to the development of renewable energy sources. (Sikora & Wartecka-Ważyńska, 2015). Please note that the energy sector, and especially the renewables sector, mostly lacks young employees with adequate vocational training. This problem has been presented in Olsztyn at a conference entitled "The energy sector in Poland as a challenge for the young generation", during which Marzena Machałek, Deputy Minister of Education and Science, stressed these are especially young people that the Polish energy sector lacks. The existing generation gap thus poses a challenge for the education system at secondary and tertiary levels, for cooperation between businesses, schools, and universities, and for the transfer of knowledge and technology to education and vice versa (PulsHR, 2022).

The positive effect of social conditions for the support of renewable energy merits a mention (Cohen et al., 2014). The 2020 nationwide empirical study on environmental awareness and behaviours of Polish residents towards wind energy commissioned by the Ministry of Climate and Environment shows that Poles are very positive about the development of wind energy. It found that 85% of respondents support the development of onshore wind farms, and 76% of respondents would like to use electricity from offshore wind farms (Ministerstwo Klimatu i Środowiska, 2020; Ministerstwo Klimatu i Środowiska, 2021; Ministerstwo Klimatu i Środowiska, 2022).

Another nationwide survey conducted in 2022 by the Social Changes studio indicated that 81% of respondents support the development of onshore wind farms, and 85% believe that the Polish law should support the development and use of RES. 75% of the survey respondents believe that onshore windmills contribute to energy security and reduce dependence on fossil fuels. Among the biggest benefits of onshore wind investments, 66% of respondents cited clean air and cheaper electricity, whereas 59% mentioned energy independence. 25% of respondents thought that onshore windmills contribute to the creation of new jobs and security, whereas 22% they boosted the development of Polish companies and revenue to municipal budgets (WNP, 2022b; PSEW, 2022).

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In its turn, a study conducted in the Lubelskie Region in 2022 by the Staszic Institute on public awareness of the construction of wind farms indicated that 65% of respondents approved of the expansion of energy potential based on wind energy (PortalSamorządowy, 2022a; Fijak, 2022). These results show a high awareness of the need for energy transition, public acceptance for the construction and development of wind power and of the related benefits.

The results of the latest survey conducted by the Public Opinion Research Center (CBOS) in February 2023 entitled «Opinie o energetyce wiatrowej» indicated that 83% of Poles support the development of onshore wind energy. 10% of citizens hold the opposite position. It was pointed out that compared to the results from two years ago, the attitude of public opinion on this matter «basically has not changed». The results of these studies have highlighted that obtaining energy from renewable sources is one of the important elements of the strategy to reduce greenhouse gas emissions and strive for climate neutrality (WNP, 2023; Radun et al., 2022; Westerlund, 2020; Onakpoya et al., 2015; Pedersen & Larsman, 2009).

Energy security and fighting global warming is more than just a replacement for current fossil fuel-based energy capacity. It is also about developing many other elements and sources of electricity and electromobility. This situation is linked with, for example, an increased number of RES-powered public charging stations for electric cars. A report by the Polish Alternative Fuels Association (PSPA) shows that Poland is one of the European Union members states with the least developed infrastructure for charging electric cars. As the PSPA estimates, in just three years, thus in 2025, the number of charging points for electric cars should reach 42 000. Now, it is only one-tenth of this number (WNP, 2022a). Meanwhile, with current procedures, the construction of an electricity connection for a car charger takes longer in Poland than in any other EU country and takes one to two, and sometimes even three years. According to Maciej Mazur, PSPA managing director, such a slow increase in the number of charging points will not only result in a slowdown in the rate of production and sales of electric cars but will also lead to queues at the charging stations and cause financial penalties to be imposed on Poland for failing to meet the requirements set by the European Commission (WNP, 2022a; PSPA, 2022).

Given the current geopolitical situation and the ongoing war in Ukraine, many EU countries, including Poland, have announced an intensification of their efforts to reduce imports of fuels from the Russian Federation and replace them with, among others, green energy. At the end of March 2022, the Polish government declared that by 2030, the total installed capacity of RES would increase to around 50 GW, which is almost as much as the entire cur-

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rent energy system in Poland. The installed capacity of green energy sources now exceeds 17 GW, with half of which being photovoltaic projects (Dyląg, 2022). The Kantar Public Survey[1] conducted in June 2022 shows that 66% of the respondents believe that increasing onshore wind generation should be a priority for the government in the coming months, with 30% of them believing it should be a firm priority (PortalSamorządowy, 2022b; ClientEarth, 2022).

The energy security of any country, not just Poland, lies in its energy independence. This, in turn, is fostered by new energy sources, the construction of onshore and offshore wind farms, the development of biogas plants, and the expansion of energy storage and distribution networks. Thus, energy security has no price and cannot be treated as a commodity. It still needs to be borne in mind that the traditional economy needs to generate money, which will then support investments in renewable energy sources. Moreover, public consent and acceptance are the prerequisites for the energy transition (Landeta-Manzano et al., 2018; Pedersen & Larsman, 2009; Sklenicka et al., 2018).

Unfortunately, new modernisation investments requiring large amounts of money are needed in this area (Sobczyk-Grygiel, 2022). Joanna Wis-Bielewicz, market development director in Offshore Orsted Poland, argues that Poland has excellent wind conditions. The Baltic Sea is relatively shallow, which guarantees the high financial viability of offshore wind farm projects. She mentions plans by the Polish government to build 11 GW of offshore wind farms. However, the Wind Europe Association estimates that today's technology would allow for up to 30 GW to be built in the Polish part of the Baltic Sea (Ciepiela, 2022). Offshore windmills could therefore be the basis for the Polish energy system, with Gdynia being an investment port and Władysławowo a service port (Chojnacki, 2021; Kolendow, 2016; Sudra & Bida-Wawryniuk, 2018).

The current situation in Europe, being the consequence of the war in Ukraine with the resulting embargo on Russian gas, is well exploited by Denmark. By 2050, the Danish government plans to increase installed wind capacity in the North Sea and Baltic Sea from the current 2.3 GW to 35 GW. There are also plans to build, among other things, an energy island that will add a further 16 GW of power. Earlier than this, in 2030, Denmark wants to become a net exporter of clean energy. Investments not only in offshore windmills but also in onshore ones and the construction of photovoltaic panel farms are supposed to support these plans (Gurgul, 2021).

In contrast, Turkey presents another example of a country playing the solar energy card while reducing natural gas imports. Europe's largest solar power plant is just being built in Karapinar in the Konya province of south-

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central Turkey. It is expected to reach a capacity of 1,350 megawatts by the end of 2022, providing energy for 2 million households. When completed, the Karapinar plant will feature 3.5 million ground-mounted photovoltaic (PV) modules, will cover an area equivalent to 2,600 football pitches, and employ 3,000 staff members. The plant will contribute to savings of up to $600 million by cutting natural gas imports to Turkey. The investor has signed a financing agreement worth $812 million with eight Turkish banks and international banks. The total investment cost is estimated at one billion dollars (Wolf, 2022).

In conclusion, the importance of renewable energy sources is crucial for preventing global warming and maintaining energy security in Poland. However, wind and solar power cannot be regarded as stable energy sources. They need to be supplemented by nuclear, gas, coal and, in the future, hydrogen. However, the 'other side of the coin' must not be forgotten in renewables. What we mean are issues related to the disposal of windmills and panels, the demand for the location of photovoltaic farms, and the demand for copper and rare elements. These issues require a separate analysis. As an example, let us just mention that a photovoltaic farm from which an annual generation output comparable to that of the Bełchatów Power Plant (28 TWh) could be achieved would have an area of approximately 15,000 ha (Solecki, 2021). The figures for the copper 'equipment' for one windmill of 15 tonnes are equally surprising (Jedlak & Żylińska, 2021). The possession of strategic raw materials, i.e. rare earth metals such as silicon, cobalt, titanium, tungsten and others, will be of key importance, and the need to compete for them in third markets will emerge (Sommer, 2021).

Conclusions

The analysis of the problem of the relationship between climate warming and renewable energy sources presented in the article, presented in the social discussion of representatives of science, economy, and politics, encourages the formulation of appropriate conclusions.

It is hard to keep a fully optimistic take on making renewable energy sources a key part of an energy policy that would put a stop to global warming, given the considerations presented in this paper. As an EU member state, Poland is obliged to develop renewable energy sources. This necessitates financial resources, appropriate legal standards and a longer time frame. Renewable energy sources reduce the state's dependence on fuel imports and contribute to reducing the impact of the energy sector on the environment. Renewable energy sources have a positive impact on the labour mar-

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ket. They contribute to the creation of new jobs. The development of domestic and foreign investments related to the green technology market contributes to increasing the VAT budgets of local authorities and the state budget. Wind energy is associated with fewer negative impacts on human health than other traditional forms of energy generation. It has positive health effects as it reduces pollutant emissions. `There is also no clear evidence of negative impact on human health caused by the noise of wind turbines. It is essential for Poland's energy security and independence to overcome the barriers to RES development. Let us emphasise again that public awareness and approval foster the development of investment in renewable energy sources. Such attitudes should necessarily be used to overcome other existing barriers. It needs to be strongly stressed that in the discussion on renewable energy sources, practitioners and scientists must cooperate. Without such discussion, there is no possibility of scientific development and progress in economic activity. The public discussion conducted by representatives of science, business, local government, and government authorities on climate warming and the development of wind energy shows divergent positions. They are supported by the relevant particular interests of specific professional groups and the political authorities. Representatives of science, economy, and local government have broader support provided by society. The government authorities do not want to fully understand these arguments and public opinion. However, it is responsible for climate warming and the development of renewable energy sources in its decisions.

In the context of the presented discussions and the expressed opinions, we should emphasise that achieving energy independence and fighting global warming based on renewable energy sources, nuclear, hydrogen, and, in the interim period, on its fossil fuels, presents today a significant challenge to economic and scientific practice.

The contribution of the authors

Literature review, J.S. and K.Z.; data collection and analysis, J.S. and K.Z.; interpretation of the results, J.S. and K.Z.

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DISCUSSION AND REVIEWS

Eugeniusz KOŚMICKI

The review of the book WILD GARDENS – CREATING NATURALISTIC GARDENS

Sven Nürnberger, WILD GARDEN. Garten naturalistisch gestalten. (WILD GARDEN. Shaping Gardens in a Naturalistic Way), ss. 216, Stuttgart (Hohenheim) 2019, Eugen Ulmer KG, ISBN 978-3-8186-0716-6, www.ulmer.de

Sven Nürnberger is a prominent horticultural specialist at the Frankfurt Palm Garden (Frankfurt am Main). He works as a master horticulturist in the field of ornamental plants, dealing mainly with the cultivation and application of perennials. He creates botanical theme gardens at the Palm Garden, as well as horticultural demonstration sites. S. Nürnberger speaks at international conferences on perennials and garden design and is a recognized author published in various scientific journals, especially in the Horticultural Practice (“Gartenpraxis”) journal, where he regularly presents the results of his research. In his work, he combines observation and research into natural sites with the creation of horticultural entities based on such knowledge. This idea serves as the basis for his research assumptions adopted in the latest book: “WILD GARDEN. Shaping Gardens in a Naturalistic Way.” The author seeks gardening inspiration not only in areas located in the Northern Hemisphere, but also at many Southern Hemisphere sites. Much of his gardening inspiration can be found in the areas of: New Zealand, Australia and Tasmania, South America (especially Chile and Argentina) and the Falkland Islands. Sven Nürnberger considers Ursula Mc Hardy (1930-2011), a Scottish traveler and gardener, to be one his mentors.

The book by S. Nürnberger perfectly combines descriptions of natural habitats as the main inspiration for the creation of gardens in a naturalistic style. Chapters dedicated to such concepts are referred to as “Special Gardens.” The book consists of the following sections: “Why the ‘Wild Garden” (pp. 8-21); “Observing Natural Habitats as Inspiration” (pp. 8-21); “Vegetation Areas in the Northern Hemisphere” (pp. 22-43); “Alpine Plants on Magic Mountain. Schatzalp Alpine Garden” (pp. 44-89); “Grassland Landscapes and Mediterranean Rocky Heathlands. Botanical Garden in Würzburg” (pp. 90-97); “Vegetation Areas in the Southern Hemisphere” (pp. 98-105); “Dragon Mountains in the Garden’s Image. Frankfurt Palm Garden” (pp. 106-143); “South Hemisphere Garden in Northern Europe. Mc Hardy Garden” (pp. 144-161); “Connecting Garden Images Resembling Natural Ones” (pp. 162-181); “Diverse Plant Life Ranges in the Frankfurt Palm Garden” (pp. 161-193); “Service” (“Plants for Your Garden”; “Further Reading”; “Order Sources and Internet Information”; “Index”; “Gardens Described in this Book”) (pp. 194-216).

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In the introduction titled “Why the ‘Wild Garden?,” the author states that this book emerged from his fascination with natural processes and the dynamic interpretation of living spaces within gardens (p. 7). Furthermore, the observation and study of nature provided an inexhaustible foundation for the introduction of innovation and creativity into gardens. In the section titled “Observing Natural Habitats as Inspiration,” the interpretation of nature as a concept for gardens is undertaken, the ranges of cultivated plant life with the concept of a “Mixed Garden,” insights into plant sociology, drawing conclusions based on natural habitats, the process of creating frameworks (frames) in gardens, and the creation of their individual components. Particularly suitable for these purposes are types and species from South America and the Southern Pacific region. It is important to authentically reflect landscape experiences in the gardens being created.

In the next section titled “Vegetation Images in the Northern Hemisphere,” S. Nürnberger presents his inspirations for rock gardens and alpine areas. The Alps are young, high mountains, stretching 1,200 km in length and 150-250 km in width. They are home to many endemic species, including rock plants, pioneering trees, grassy areas, and tall perennial communities (such as *Adenostyles alliariae*, monkshoods, etc.). As many alpine plants struggle to grow in lowland areas, the cultivation needs of these plants must be taken into account. Particularly interesting are the considerations in the chapter titled “Alpine Plants on Magic Mountain. Schatzalp Alpine Garden.” Alpine plants were first introduced to the Schatzalp hotel garden in 1907. It was originally part of a luxury sanatorium for tuberculosis patients in Davos, as described in Thomas Mann’s novel “The Magic Mountain.” Since 1954, the location has been functioning as a hotel, and since 2004, Klaus Oetjen has been following the maxim of cultivating plants according to their species requirements (p. 46). Next to the hotel, plants from other regions – especially Asia – grow in the garden. Therefore, this section discusses monsoon vegetation on Mount Emei in Sichuan (China), the possibilities of using plants from monsoon areas in gardens, the concept of grassland landscapes, and Mediterranean vegetation from Southern Europe. Mount Emei is characterized by immense biological diversity (with three climatic zones and 10% of China’s total flora). It has long been a Buddhist place of worship and contains various elements such as understory perennials, subtropical valleys, and exotic perennials. Botanical collections in Germany also include well-known Mediterranean spices, gentians, wolf’s milk plants and cushion plants originating from the Mediterranean region.

The following sections pertain to grassland landscapes and rocky heathlands from Mediterranean regions. These types of plants can be found, for instance, in the Botanical Garden in Würzburg, where they occupy an area of 3,500 m^2 (for example North American prairies and rocky heathlands). Significant importance in the reviewed book is given to the discussion of vegetation areas in the Southern Hemisphere. Aspects of vegetation characteristic for this hemisphere can serve as inspiration for creating various garden areas. Notably, the natural habitats in the Dragon Mountains should be mentioned, as plant life in this region is among the richest in the world. Many plants from South Africa can thrive in Central Europe. Another important area is the Sani Pass

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between Lesotho and KwaZulu-Natal, where numerous horticulturally significant plants grow in the mountains at elevations between 2,000 and 3,000 meters above sea level. Among these plants are tritomas (Kniphofia), as well as sunroses (Delosperma), summer hyacinths (galtonias), irises, Erica species, and orchids (such as Disa and Satyrium). Dragon Mountain species are cultivated in the Frankfurt Palm Garden, including species from the Phygelius, Dierama, Watsonia, Ornithogalum, and Berkheya genera.

Other vegetation-rich areas in the Southern Hemisphere include South America (from Santiago de Chile to the Strait of Magellan), the Falkland Islands as a subantarctic archipelago in the South Atlantic, New Zealand, Australia, and Tasmania (South Pacific). The vegetation zones of Chile and Argentina evoke great fascination, even in Europe, although they are currently subject to significant anthropogenic destruction. Dry forests with honey palm trees (Jubaea chilensis) are noteworthy, as well as araucaria forests with rich understory of perennials located above the altitude of 900 meters. In central Patagonia, there are the so-called Valdivian rainforests (with rainfall between 2000-4500 mm) characterized by a diverse flora of perennials. As one moves south, forests dominated by southern beech (Nothofagus) gradually appear, along with grassy steppes and harsh conditions in southern Patagonia. The region is home to Magellanic peatlands surrounded by forests, as well as grassy steppes with species of Jarava and Pappostipa grasses.

The subantarctic archipelago of the Falkland Islands comprises two large islands (West Falkland and East Falkland) and 780 smaller islands. There is generally a lack of forests in the area and the vegetation bears similarities to a tundra (including many endemic species). The climate is cool-oceanic with weak, acidic soils. Northern Patagonia, with its Araucaria forests, Valdivian rainforests, and subantarctic regions serve as the place of origin for many attractive plants. Alpine plant communities with valuable perennials can also be found. The Argentine pampas, high Andean regions, and Patagonian steppes are home to numerous valuable grasses. A significant potential for ornamental plants, which are already being obtained in many British horticultural establishments, exists in that area. This includes the Patagonian steppe flora, as well as alpine plants. In New Zealand, Australia, and Tasmania, the following landscapes are known to exists: scrub (evergreen shrub areas), tussock - grassy areas in New Zealand with numerous perennials, New Zealand alpine plants, and various species of eucalyptus from the Tasmanian and southeastern Australian mountains (snow gums – forests of snow eucalyptus). In Scotland, near Edinburgh, Ursula Mc Hardy established the Walled Garden where she cultivated flora from the Southern Hemisphere. There, she created a series of theme gardens with plantings from many areas of that hemisphere.

The integration of garden landscapes poses a significant challenge in garden design. Such modeling is achieved using stones and dead wood. Special sites in gardens, such as wetlands, peat bogs, high peatlands, terraces made of peat, frost-resistant cacti, the edges of plantings, as well as transitions between different plantings (garden images) also require considerable effort. The Frankfurt Palm Garden can serve as an example of such a divided plant life with its impressive grasses, South African mountain meadows, tussock grass areas, tall perennial plantings, and even high peatlands.

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In the "Service" section, the author presents, among other things, a table listing of various plants suitable for different garden positions. The table includes ferns, low woodland perennials, perennial species from the Dragon Mountains, alpine species from New Zealand, South American plants for rock gardens, and more. The table provides a comprehensive overview of plant options for specific garden conditions.

The book "WILD GARDEN: Shaping Gardens in a Naturalistic Way" by Sven Nürnberger deserves the attention of Polish readers. The author takes observation and study of natural areas as the basis for creating gardens in a naturalistic manner. When designing new garden layouts, the author suggests utilizing not only the flora of the Northern Hemisphere, but also that of the Southern Hemisphere. Nürnberger demonstrates extensive knowledge of flora from regions such as Chile, Argentina, the Falkland Islands, South Africa, Tasmania, Australia, and New Zealand. Many plants from these areas are still relatively unknown in Europe. Translating this fascinating book into Polish would be a valuable resource for plant and garden enthusiasts, as well as for a wide range of interested readers.

Eugeniusz Kośmicki (Poznan)

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SUMMARIES IN POLISH

Magdalena DĄBROWSKA, Anetta ZIELIŃSKA, Grygorii MONASTYRSKYI, Mariola DROZDA

OGRANICZENIE MARNOTRAWIENIA ŻYWNOŚCI JAKO FILAR INNOWACYJNEJ FILOZOFII LEAN SOCIETY

STRESZCZENIE: Wysoki poziom strat oraz marnotrawienia żywności w dzisiejszych czasach sprawił, że problem ten nabrał globalnego charakteru. Do głównych przyczyn marnotrawienia żywności w gospodarstwach domowych zalicza się: przekroczenie terminu przydatności do spożycia, zbyt duże zakupy, zepsucie, dodatkowo zbyt duże porcje posiłków, niewłaściwe przechowywanie żywności, niesmaczność produktu, brak pomysłów na wykorzystanie posiadanych składników, a także zakupy zbyt dużej ilości jedzenia, nieprzemyślane zakupy, zbyt duże opakowanie. Negatywne skutki marnotrawienia żywności można pogrupować w trzech obszarach: środowiskowym, ekonomicznym i społecznym, które są spójne z podstawowymi celami zrównoważonego rozwoju. Celem artykułu jest przedstawienie autorskiej propozycji ujęcia filozofii *lean society* w odniesieniu do problematyki marnotrawienia żywności. W publikacji dokonano przeglądu konwencjonalnych i niekonwencjonalnych metod utrwalania żywności, identyfikacji dostępnych i innowacyjnych rozwiązań w zakresie ograniczenia marnotrawienia żywności oraz wskazano kierunki i możliwości ograniczenia marnotrawienia żywności w oparciu o założenia filozofii lean society.

SŁOWA KLUCZOWE: ograniczanie marnowania żywności, Lean Society, konwencjonalne i niekonwencjonalne metody utrwalania żywności, racjonalne gospodarowanie żywnością, profilaktyka

Hanna KOCIEMSKA, Sylwia FRYDRYCH, Ewelina SZCZECH-PIETKIEWICZ, Mariusz RADŁO, Rafał KASPRZAK, Paweł ROKITA, Radosław PIETRZYK, Krzysztof BIEGUN, Bogusław PÓŁTORAK

SKUTECZNOŚĆ ZARZĄDZANIA I ZIELONE OBLIGACJE. OCENA EMPIRYCZNA

STRESZCZENIE: Badanie ma na celu ocenę związku między efektywnością rządzenia, mierzoną za pomocą wskaźników *Worldwide Governance Indicators*, a wykorzystaniem zielonych obligacji na świecie. Zastosowano modele danych panelowych z efektami losowymi i model regresji liniowej, który pozwala nam zidentyfikować wpływ rodziny zmiennych na zielone obligacje. Znaleziono statystycznie istotną korelację między jakością rządu, mierzoną jako efektywność rządu, a wartością emisji zielonych obligacji. Tym samym w ramach *New Public Governance* wskazane jest zwiększenie efektywności funkcjonowania rządów, co może przyczynić się do większego zainteresowania inwestorów projektami środowiskowymi.

SŁOWA KLUCZOWE: wskaźnik jakości zarządzania publicznego, zielone obligacje, efektywność rządu, zielone finansowanie

Marta SYLLA

USŁUGI EKOSYSTEMÓW PRZYCZYNIAJĄCE SIĘ DO ROZWOJU LOKALNYCH SEKTORÓW GOSPODARCZYCH - RAMY KONCEPCYJNE ŁĄCZĄCE USŁUGI EKOSYSTEMOWE, KORZYŚCI I SEKTORY GOSPODARCZE

STRESZCZENIE: W artykule przedstawiono podstawowe założenia Systemu Rachunków Środowiskowo-Ekonomicznych – rachunków ekosystemowych (ang. *the System of Environmental-Economic Accounting - Ecosystem Accounting*). Celem pracy badawczej było praktyczne zastosowanie ram koncepcyjnych łączących usługi ekosystemowe, korzyści z sektorami ekonomicznymi. Analiza obejmowała lata 2012 i 2018, dotyczyła pięciu gmin w obrębie Ślężańskiego Parku Krajobrazowego i jego otuliny, leżącego w województwie dolnośląskim. Wyniki pokazują, że ekosystem pól uprawnych przynosi korzyści dla 17 i 14 procent firm działających na terenie wybranych gmin. Zastosowanie wytycznych koncepcyjnych pozwoliło na połączenie korzyści z firmami reprezentującymi pięć różnych sektorów gospodarczych. Ponadto, przeprowadzono analizę zmian pokrycia terenu w badanych dwóch okresach. Na koniec, dyskusji poddano zasadność aplikacyjną rachunków środowiskowo-ekonomicznych w kontekście zarządzania i wspierania podejmowania decyzji.

SŁOWA KLUCZOWE: rachunki środowiskowo-ekonomiczne, kapitał naturalny, rachunki ekosystemowe, usługi ekosystemowe, obszar chroniony

Elżbieta ANTCZAK, Artur GAJDOS

KLUCZOWE SEKCJE GOSPODARKI DLA TWORZENIA ZIELONYCH MIEJSC PRACY W POLSCE – ANALIZA EMPIRYCZNA

STRESZCZENIE: W niniejszym opracowaniu dokonano identyfikacji kluczowych sekcji i oszacowania regionalnego potencjału tworzenia zielonych miejsc pracy w Polsce. Wykorzystano dane z krajowego rejestru podmiotów gospodarki narodowej (REGON) oraz dane z Badania Aktywności Ekonomicznej Ludności (BAEL). W proponowanej metodzie założono, że zmiany w REGON odzwierciedlają przybliżenie zmiany zasobu GJ w sektorach działalności gospodarczej (PKD-2007) i regionach. Oceniono trendy zielonego zatrudnienia i jego przestrzenne zróżnicowanie w latach 2015-2022. Wyniki wskazały, że mazowieckie, wielkopolskie, małopolskie i śląskie są regionami z największym potencjałem dla tworzenia zielonych miejsc pracy. Zaobserwowano również, że regionalna polaryzacja zielonego rynku pracy zmniejszyła się, ale dysproporcje przestrzenne nadal są znaczne. Większość sektorów odnotowała wzrost zielonego zatrudnienia, z wyjątkiem m.in. rolnictwa. Co więcej spadające zatrudnienie w tym sektorze ma znaczący wpływ na zielony rynek pracy.

SŁOWA KLUCZOWE: zielone miejsca pracy, sektorowo-regionalny potencjał rynku pracy, sekcje PKD-2007, REGON, BAEL, województwa w Polsce

Iwona SKOCZKO, Marek GRABOWSKI

SANKCJE ADMINISTRACYJNE ZA PRZESTĘPSTWA PRZECIW ŚRODOWISKU W WYBRANYCH KRAJACH UE

STRESZCZENIE: Każdy kraj w Unii Europejskiej (UE) ma swój własny system prawa ochrony środowiska, w tym zasady walki z eco-przestępczością. Świat walczy z przestępczością środowiskową rozwijając coraz lepsze struktury, zasady i system kontroli. Ustanowienie odpowiednich norm sankcji może pomóc w zmniejszeniu przestępczości środowiskowej. Celem niniejszego opracowania jest porównanie systemów kar za szkody w środowisku we Francji, Niemczech, Włoszech, Polsce i Hiszpanii. Mechanizmy sankcji, kar i grzywien bazują na karze finansowej. Chociaż państwa starają się stworzyć możliwie najbardziej efektywne instrumenty egzekwowania zasad ochrony środowiska i kontroli jego jakości, nie zawsze jest to zakończone sukcesem. Zrozumienie i ocena wartości szkód wyrządzonych w środowisku jest trudna. Uwzględnia aspekt ludzki, ekonomiczny i ekologiczny (dążący do przywrócenia środowiska najbliżej stanu naturalnego).

SŁOWA KLUCZOWE: środowiskowe sankcje administracyjne, prawo środowiskowe, przestępstwa środowiskowe

Ksymena ROSIEK

ANALIZA MODELI OPERATORSKICH GOSPODAROWANIA WODAMI OPADOWYMI W POLSCE – W KIERUNKU MODELU ZINTEGROWANEGO ZARZĄDZANIA

STRESZCZENIE: W ostatnim dziesięcioleciu w Polsce została zmieniona definicja wód opadowych. Przestały być ściekiem. Miasta w Polsce wypracowywały różne modele zarządzania wodami opadowymi i ich finansowania. Celem badania była identyfikacja i opisanie najważniejszych elementów modeli zagospodarowania wód opadowych w Polsce z wykorzystaniem operatorów. Skupiono się nie tylko na cechach konstytuujących system, ale przede wszystkim na aspektach finansowych takich jak opłaty i inwestycje (z pominięciem fiskalnych). Udało się zidentyfikować trzy różniące się od siebie organizacyjnie modele operatorskie oraz wskazano słabe i mocne strony każdego z nich. Tak przeprowadzona systematyczna i ustrukturyzowana analiza stwarza podstawy do oceniania tych modeli i umożliwia innym miastom świadomy wybór modelu do wdrożenia.

SŁOWA KLUCZOWE: zintegrowane zarządzanie zasobami wodnymi

Dorota RYNIO, Hanna ADAMICZKA

ROLA RZEK W TWORZENIU ZIELONO-NIEBIESKIEJ GOSPODARKI MIASTA NA PRZYKŁADZIE WROCŁAWIA I GDAŃSKA

STRESZCZENIE: Celem artykułu jest analiza i krytyczna ocena wykorzystania zielono-niebieskiej infrastruktury w mieście. Badanie zostało przeprowadzone na przykładzie rzek Wrocławia i Gdańska. Istotnym elementem analizy jest określenie możliwości wprowadzenia oraz poprawy stanu wykorzystania zielono-niebieskiej infrastruktury, przy wykorzystaniu dobrych praktyk w tych ośrodkach miejskich, w szczególności odnoszących się do roli rzek. W trakcie przeprowadzonego badania sformułowano następujące pytania badawcze: Jaki megatrend rozwoju miast określają współczesne uwarunkowania oraz co jednostki miejskie w ten sposób zyskują? Czy zielono-niebieski potencjał badanych miast jest efektywnie wykorzystany? Jaki jest stan zagospodarowania zielono-niebieskich stref w przestrzeni rzeki i w jej pobliżu? W opracowaniu posłużono się takimi metodami badawczymi jak: desk research, studium przypadku, szczegółowa analiza badanych terenów wykorzystująca aktualne dane kartograficzne, indywidualny wywiad pogłębiony, analiza literatury oraz aktów prawnych. Badanie wspomaga wymianę informacji między miastami i zarządzanie rzeką w mieście.

SŁOWA KLUCZOWE: zielono-niebieska infrastruktura, rzeka, miasto, megatrendy, zagospodarowanie terenów nad rzeką

Wiktor SZYDŁO

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STRESZCZENIE: Koncepcja zrównoważonego rozwoju zyskała na rozgłosie w ostatnich dekadach. Równocześnie, neoliberalizm (główny nurt w wymiarze społeczno-ekonomicznym w państwach kapitalistycznych od połowy lat 70. XX wieku) jest pojęciem znacznie mniej popularnym w debacie publicznej. Artykuł stanowi próbę odpowiedzi na pytanie, czy paradygmat zrównoważonego rozwoju i jego najnowsza odsłona (Agenda 2030) zdecydowanie zrywają z głównym nurtem. Drugim celem artykułu jest ocena, czy Agenda 2030 adekwatnie odnosi się do koncepcji bezpieczeństwa żywnościowego. Badanie pokazuje, że Agenda 2030 jest znacznie bardziej rozbudowana w porównaniu z Milenijnymi Celami Rozwoju, jednak w dalszym ciągu nie może zagwarantować bezpieczeństwa żywnościowego zarówno w krótszej perspektywie (np. ze względu na ryzyko pojawiania się baniek na rynkach surowcowych), jak i w nieco dłuższej perspektywie (przynajmniej do 2030 r.) z uwagi na skalę zjawiska skrajnej biedy, wysokie nierówności dochodowe, problemy strukturalne w wielu rozwijających się państwach oraz nieodpowiednie regulacje na poziome globalnym. Agenda 2030 jest krokiem w kierunku bardziej sprawiedliwego i zrównoważonego rozwoju w wymiarze krajowym i globalnym, jednak nie oznacza to definitywnego odejścia od neoliberalnego paradygmatu.

SŁOWA KLUCZOWE: zrównoważony rozwój, neoliberalizm, Agenda 2030, bezpieczeństwo żywnościowe, bieda

Janina KOTLIŃSKA, Helena ŻUKOWSKA

GOSPODARKA ODPADAMI KOMUNALNYMI W GMINACH W POLSCE – KU MODELOWI GOSPODARKI O OBIEGU ZAMKNIĘTYM

STRESZCZENIE: Rozważania w opracowaniu dotyczą poziomu recyklingu i składowania odpadów komunalnych w Unii Europejskiej. Celem opracowania jest odpowiedź na pytanie, na ile możliwe jest w Polsce osiągnięcie w 2035 roku zakładanego w UE poziomu recyklingu oraz poziomu składowania odpadów komunalnych, a w konsekwencji zbudowanie do 2050 roku modelu gospodarki o obiegu zamkniętym (GOZ). Autorki będą kontynuować badania w tym zakresie. W artykule autorki: 1) dokonują przeglądu literatury w odniesieniu do koncepcji gospodarki o obiegu zamkniętym, 2) diagnozują prawodawstwo UE i Polski we wskazanym zakresie, 3) analizują strumienie odpadów komunalnych w Polsce i prezentują ich prognozy w okresie zbliżania Polski do modelu GOZ. Analizowane dane pochodzą z zasobów statystyki publicznej Głównego Urzędu Statystycznego, a dotyczą zasadniczo lat 2013-2021 i w mniejszym zakresie danych Eurostatu. W opracowaniu zastosowano metodę analizy literatury oraz regulacji prawnych, także metody analizy opisowej wybranych wielkości (analiza struktury, dynamiki, trendu) i ekstrapolację liniową. Uzyskane wyniki, co prawda zagregowane, pozwalają stwierdzić, że możliwe jest osiągnięcie w Polsce w 2035 roku zakładanego w UE poziomu recyklingu i poziomu składowania odpadów komunalnych, a w 2050 roku dojście do GOZ.

SŁOWA KLUCZOWE: gospodarka o obiegu zamkniętym, odpady komunalne, gmina, recykling, składowanie odpadów

Anna ZIELIŃSKA-CHMIELEWSKA

EFEKTYWNOŚĆ FINANSOWA VS. EFEKTYWNOŚĆ ŚRODOWISKOWA NA PRZYKŁADZIE PRZEMYSŁU MIĘSNEGO I DROBIARSKIEGO W POLSCE

STRESZCZENIE: Celem artykułu jest ocena zależności między efektywnością finansową a efektywnością środowiskową w przemyśle mięsnym i drobiarskim w Polsce w latach 2010-2020. W pierwszej kolejności przeprowadzono ocenę efektywności finansowej w obszarze rentowności, a następnie ocenę efektywności środowiskowej w zakresie wybranych elementów realizowanej polityki środowiskowej w badanych przedsiębiorstwach. W oparciu o wyniki analiz zbudowany został model ekonometryczny mierzący wpływ zmiennych binarnych na poszczególne wskaźniki efektywności finansowej. Opracowanie składa się z części teoretycznej i praktycznej. W części teoretycznej zastosowano metody analizy, syntezy, porównań i graficznej prezentacji danych. W części praktycznej zastosowano metody ilościowe: wskaźnikową analizę finansową, metodę ANOVA, panelowe modelowanie ekonometryczne oraz metody jakościowe - studia przypadków. Z badania wynika, że dla efektywności finansowej w obszarze rentowności statystycznie istotne są wartości wskaźnika rentowności sprzedaży netto. Dla efektywności środowiskowej najważniejsza jest konsekwentnie realizowana, przejrzysta polityka środowiskowa. Praktyczna implikacja badania wskazuje na konieczność wsparcia finansowego dla przemysłu mięsnego i drobiarskiego w Polsce. Społeczną implikacją badania jest potrzeba wdrożenia i promocja zrównoważonej konsumpcji.

SŁOWA KLUCZOWE: efektywność finansowa, efektywność środowiskowa, przemysł mięsny i drobiarski, Polska

Urszula MOTOWIDLAK, Daniel TOKARSKI

ANALIZA RODZAJÓW I SKUTKÓW MOŻLIWYCH BŁĘDÓW W PROCESIE WDROŻENIA EKOLOGICZNEGO OPAKOWANIA WIELOKROTNEGO UŻYTKU W OBSŁUDZE LOGISTYCZNEJ E-COMMERCE Z WYKORZYSTANIEM FMEA

STRESZCZENIE: Jedną z ważniejszych cech procesu logistycznej obsługi e-commerce jest jego niezawodność. Uzyskuje się ją przez właściwe zaplanowanie procesu, a następnie zadbanie, aby jego przebieg odbywał się zgodnie z opracowanym planem i wszystkimi procedurami. Jak pokazują dane, większość problemów powstaje w fazie projektowania i przygotowania produktów oraz procesów do wdrożenia. Wykrycie potencjalnych przyczyn, niezgodności może pomóc w uniknięciu wystąpienia niepożądanych zdarzeń. Celem artykułu jest identyfikacja oraz ocena ryzyka dla procesu i produktu w zakresie możliwości wykorzystania opakowania wielokrotnego użytku w obsłudze logistycznej e-commerce realizowanej przez ARVATO Polska Sp. z o.o. z siedzibą w Warszawie, z uwzględnieniem działań zapobiegawczych i korygujących w odniesieniu do ryzyka. Poprzez zastosowanie metodologii badawczej w postaci mapowania ryzyka wskazano 13 potencjalnych czynników ryzyka oraz sformułowano rekomendacje na rzecz uniknięcia i złagodzenia konsekwencji zakłóceń. Wśród zidentyfikowanych czynników ryzyka najistotniejszą okazała się być sama jakość opakowania, w tym odpowiedni materiał do produkcji opakowania i poziom elastyczności opakowania. Wnioski z badania mogą mieć praktyczne zastosowanie do poprawy funkcjonowania efektywnej kosztowo i przyjaznej dla środowiska logistyki e-commerce. Znaczenie tych analiz wzrasta w zakresie oceny rozwiązań innowacyjnych, za jakie można uznać wykorzystanie ekologicznego opakowania zwrotnego w obsłudze logistycznej e-commerce. Ich celem jest identyfikacja i wyeliminowanie ewentualnego niepowodzenia opakowania na rynku.

SŁOWA KLUCZOWE: e-commerce, ekologiczne opakowania wielokrotnego użytku, łańcuch dostaw, zrównoważony rozwój

Adriana DOWBYSZ, Bożena KUKFISZ, Mariola SAMSONOWICZ,
Dorota MARKOWSKA, Piotr JANKOWSKI

ŚRODOWISKOWA OCENA CYKLU ŻYCIA LAMINATÓW POLIESTROWO-SZKLANYCH WYKORZYSTYWANYCH W OKRĘTOWNICTWIE I ICH ZACHOWANIE W WARUNKACH POŻARU

STRESZCZENIE: Celem pracy jest ocena wpływu procesu produkcji laminatów poliestrowo-szklanych na środowisko oraz ocena ich zachowania w warunkach pożaru. Ocenę cyklu życia przeprowadzono zgodnie z normą ISO14040/44, stosując metodę CML-IA 2000 Baseline. Badania kalorymetryczne przeprowadzono metodą kalorymetru stożkowego zgodnie z normą ISO 5660. Badania przeprowadzono przy gęstościach strumienia promieniowania cieplnego równych 25 kW/m^2 i 50 kW/m^2. Wyniki wykazały, że zgodnie z wymaganiami międzynarodowego kodeksu stosowania procedur prób ogniowych badane laminaty w tej postaci nie spełniają wymagań dotyczących niektórych zastosowań. Ocena cyklu życia wykazała, że proces produkcji laminatów oddziałuje w największym stopniu na tok-

syczność wody morskiej (88.3%), przy największym udziale nienasyconej żywicy poliestrowej i włókna szklanego.

SŁOWA KLUCZOWE: laminaty poliestrowo-szklane, ocena cyklu życia, kalorymetr stożkowy, międzynarodowy kodeks stosowania procedur prób ogniowych

Katarzyna CHROBOCIŃSKA, Aleksandra LOTKOWSKA

SKUTECZNOŚĆ MARKETINGU ŻYWNOŚCI EKOLOGICZNEJ

STRESZCZENIE: Głównym celem opracowania była ocena uzyskiwanych wyników ekonomicznych oraz skuteczności marketingu w wybranych spółkach zajmujących się produkcją i dystrybucją żywności ekologicznej. W badaniach posłużono się metodą sondażu diagnostycznego. Badanie przeprowadzono w popularnych social mediach w 2021 r. Wzięło w nim udział 686 respondentów. Wyniki badań wskazują, że dotychczasowa strategia marketingowa nie była skuteczna. A zatem istnieje jeszcze pewien obszar wykluczony informacyjnie, który należy uzupełnić. Wobec tego należałoby skonstruować skuteczny marketing produktów, który mógłby opierać się o spersonalizowaną reklamę w social mediach i cyfrowy handel. Wyniki badań mogą przyczynić się do spopularyzowania i pogłębiania wiedzy na temat zachowań nabywców żywności ekologicznej. Określenie uwarunkowań procesu zakupowego i motywacji zakupowych wspomoże interesariuszy w budowaniu skutecznej strategii marketingowej ekożywności. A to może pozytywnie wpłynąć na rozwój i dywersyfikację na rynku żywności ekologicznej, której produkcja może przyczynić się do poprawy stanu środowiska naturalnego oraz jakości życia, a także promocji lokalnych producentów żywności.

SŁOWA KLUCZOWE: żywność ekologiczna, marketing ekożywności, skuteczność marketingu

Lidia KŁOS

WIEDZA PRODUCENTÓW ROLNYCH W ZAKRESIE RACJONALNEJ GOSPODARKI WODNEJ – STUDIUM PRZYPADKU (POLSKA)

„Wtedy się wodę szanuje, kiedy jej w studni brakuje"
/przysłowie polskie/

STRESZCZENIE: Woda jest uważana za najbardziej krytyczny zasób dla rozwoju rolnictwa na całym świecie. Nasilające się pogodowe zjawiska ekstremalne wymagają racjonalnego gospodarowania zasobami wodnymi w rolnictwie, które jest najbardziej narażone na skutki zmian klimatu. Artykuł pokazuje stan wiedzy producentów rolnych w wybranych aspektach racjonalnego gospodarowania wodą w produkcji rolniczej. W tym celu wykorzystano pilotażowe badania ankietowe przeprowadzone w wybranych powiatach woj. zachodniopomorskiego, zrealizowane w ramach projektu pod nazwą: Wsparcie dla Tworzenia Lokalnych Partnerstw ds. Wody (Wsparcie dla tworzenia LPW, SIR, 2020).

SŁOWA KLUCZOWE: gospodarka wodna, produkcja rolna, racjonalne wykorzystanie wód

Tetiana VITENKO, Nataliia MARYNENKO, Iryna KRAMAR

CHARAKTERYSTYKA SKŁADU OSADÓW ŚCIEKOWYCH DO UŻYTKOWANIA ROLNICZEGO

STRESZCZENIE: Artykuł koncentruje się na badaniach przeprowadzonych na osadach ściekowych w Tarnopolu na Ukrainie, ze szczególnym naciskiem na ich skład mikroelementowy oraz implikacje dla ich usuwania i wykorzystania. Badanie ujawniło zanieczyszczenie bakteryjne zarówno w starych, jak i nowych obiektach składowania osadów ściekowych. Stwierdzono, że osad ma potencjał jako nawóz ze względu na zawartość składników odżywczych i materii organicznej, chociaż może być konieczne dostosowanie do określonych warunków glebowych. Ustalono jednak, że dopuszczalne limity dla zastosowań rolniczych są przekraczane przez stężenia metali ciężkich, co wskazuje na zanieczyszczenie wynikające ze składowisk odpadów, starych rur i intensywnego rolnictwa. Zgodnie z obowiązującymi przepisami osad jest uważany za odpowiedni tylko do kompostowania. Wyniki badań podkreślają znaczenie monitorowania, przetwarzania i zarządzania osadami ściekowymi, ponieważ mają one kluczowe znaczenie dla zapewnienia bezpiecznej utylizacji, łagodzenia zagrożeń dla środowiska i przeciwdziałania potencjalnym zagrożeniom dla zdrowia.

SŁOWA KLUCZOWE: osady ściekowe, oczyszczanie ścieków, metale ciężkie, skład fizyczny i chemiczny osadów ściekowych

Sylwia PANGSY-KANIA, Aleksandra ROMANOWSKA, Marcin BUDZYŃSKI, Katarzyna WIERZBICKA, Joanna PRYSTROM

ANALIZA PRZYCZYN WYPADKÓW DROGOWYCH W WOJEWÓDZTWACH W LATACH 2014-2021 W ASPEKCIE KOSZTÓW SPOŁECZNO-EKONOMICZNYCH – W KIERUNKU IMPLEMENTACJI ZRÓWNOWAŻONEGO ROZWOJU

STRESZCZENIE: W artykule podjęta została problematyka bezpieczeństwa ruchu drogowego (brd). Zmniejszenie liczby ofiar rannych i śmiertelnych w wypadkach drogowych wpisuje się w cel Agendy 2030 na rzecz zrównoważonego rozwoju. Celem prac badawczych była ocena przyczyn wypadków drogowych w podziale na województwa. Analiza była prowadzona w kontekście zróżnicowania rozwoju społeczno-gospodarczego, który determinuje koszty jednostkowe ofiar śmiertelnych i rannych w poszczególnych województwach. W opracowaniu zawarta została analiza opisowa, dzięki której ukazana została dynamika zmian w latach 2014-2021 w województwach oraz przedstawione zostały zmiany względem różnych czynników. W artykule przeprowadzona została analiza zależności brd od rozwoju społeczno-gospodarczego województw. Szereg czasowy determinowany był dostępnością danych. Z badań wynika, że wraz z gęstością (demograficzną) dróg o ulepszonej nawierzchni spada liczba wypadków. Natomiast wraz z gęstością zaludnienia i PKB na mieszkańca liczba wypadków rośnie. Zależności mają odwrotny kierunek, jeżeli za zmienną zależną przyjęty został wskaźnik (demograficzny) śmiertelności lub wskaźnik ciężkości wypadków (ofiar śmiertelnych na 100 wypadków). Analizowane w artykule straty społeczno-ekonomiczne, należące do pośrednich skutków wypadków drogowych i oparte na kosztach utraconej produkcji w wyniku przedwczesnej śmierci albo niezdolności do pracy osób rannych z powodu wypadku, zostały oszacowane na podstawie danych GUS. W wycenie kosztów jednostkowych zdarzeń drogowych skorzystano z metody PANDORA. Analiza pozwoliła na pogrupowanie województw z punktu widzenia generowania najwyższych i najniższych kosztów społeczno-ekonomicznych wypadków drogowych ze zwróceniem szczególnej uwagi na koszty jednostkowe ofiar śmiertelnych. Oryginalność wyników badań odnosi się uaktualnienia badań na poziomie województw.

SŁOWA KLUCZOWE: Agenda 2030, zrównoważony rozwój, wypadki drogowe, koszty społeczno-ekonomiczne, województwa

Mariola MAMCARCZYK, Łukasz POPŁAWSKI, Paweł ZIENIUK

DZIAŁALNOŚĆ JEDNOSTEK SAMORZĄDU TERYTORIALNEGO NA RZECZ POPULARYZACJI I PROMOCJI ZDROWEGO STYLU ŻYCIA WŚRÓD STARZEJĄCEGO SIĘ SPOŁECZEŃSTWA WIEJSKIEGO – NA PRZYKŁADZIE POLSKI

STRESZCZENIE: W pracy postawiono trzy cele, które zostały zrealizowane: przedstawienie przewidywanych zmian w populacji Polski, omówienie pojęcia „życie w zdrowiu” oraz prognoz dotyczących tego zagadnienia. Obiektami badań były gminy wiejskie i miejsko-wiejskie województwa małopolskiego. Jako metodę badawczą zastosowano analizę statystyczną zebranych danych ankietowych. Poziom popularyzacji i promocji zdrowia przez Jednostki Samorządu Terytorialnego (JST) jest zróżnicowany. Poziom zadłużenia ma wpływ na podejmowanie działań w zakresie popularyzacji i promocji zdrowia, ale nie wpływa na dostępność infrastruktury sportowo-rekreacyjnej. Dostęp do infrastruktury sportowej nie wpływa na poziom popularyzacji i promocji zdrowia. Starzenie się społeczeństwa powoduje zmiany i konsekwencje we wszystkich dziedzinach życia społeczno-gospodarczego. Działania niektórych samorządów są niewystarczające i brak jest konsekwencji w ich postępowaniu w tym zakresie.

SŁOWA KLUCZOWE: prognozy demograficzne, starzenie się ludności, aktywność fizyczna, zdrowy styl życia

Aleksandra KAMIŃSKA-WITKOWSKA, Alina MATUSZAK-FLEJSZMAN

MOŻLIWOŚCI WYKORZYSTANIA WYMAGAŃ EMAS W ZAKRESIE SPRAWOZDAWCZOŚCI ŚRODOWISKOWEJ W RAMACH RAPORTOWANIA ESG W WYBRANYCH KONCERNACH BRANŻY MOTORYZACYJNEJ

STRESZCZENIE: Brak jednolitych wytycznych dotyczących sposobu obliczania mierników ESG prowadzi do braku transparentności oraz problemów z porównywaniem ich na przestrzeni czasu oraz pomiędzy różnymi podmiotami. Można zauważyć, że pomocne we wdrażaniu raportowania ESG będą systemy zarządzania środowiskowego, a w szczególności wymagania EMAS. Celem artykułu jest analiza możliwości wykorzystania raportowania środowiskowego wymaganego w ramach rozporządzenia 2018/2026 w zakresie raportowania ESG oraz wskazanie możliwości wykorzystania dotychczasowych rozwiązań w celu zapewnienia porównywalności wyników pomiędzy poszczególnymi obszarami dotyczącymi wpływu na środowisko oraz organizacjami. W niniejszej publikacji przedstawiono najnowsze wytyczne w zakresie sprawozdawczości dotyczącej zrównoważonego rozwoju, poddano ocenie możliwość wykorzystania dotychczasowej sprawozdawczości stosowanej w ramach EMAS do raportowania wskaźników środowiskowych oraz zaprezentowano obecne podejście wybranych koncernów motoryzacyjnych do raportowania ESG. Artykuł przyczynia się do wykorzystania istniejących systemów raportowania, aby nie nakładać nadmiernego obciążenia administracyjnego na przedsiębiorstwa i maksymalnie wykorzystać efekt synergii.

SŁOWA KLUCZOWE: ESG, CSR, EMAS, efekty środowiskowe, sprawozdawczość dotycząca zrównoważonego rozwoju

Anna KUCZUK, Janusz POSPOLITA, Jacek PIECZONKA

EMERGETYCZNA ANALIZA HODOWLI RYB STAWOWYCH – STUDIUM PRZYPADKU DLA WIELKOOBSZAROWEGO GOSPODARSTWA RYBACKIEGO W POLSCE

STRESZCZENIE: Bezpośrednim celem artykułu jest analiza emergetyczna produkcji ryb w przykładowym gospodarstwie rybackim. Dodatkowo porównano ją z innymi przykładowymi produkcjami rolniczymi w zakresie obciążenia środowiska. Na podstawie obliczonej emergii dopływów do systemu obliczono wybrane wskaźniki emergetyczne (ELR, EYR, REN), pokazując skalę wykorzystania zasobów odnawialnych i nieodnawialnych. Wyniki pokazują, że analizowana produkcja rybacka nie obciąża środowiska i korzysta w znacznej mierze z jego zasobów odnawialnych, w odróżnieniu od wielu innych produkcji rolniczych mających intensywny charakter. Wartość ELR porównano z jego wartościami innych przykładowych produkcji rolniczych. Dla przykładu hodowli ryb wskaźnik ten jest najczęściej niższy od 1. Przyjmuje się, że taka działalność nie obciąża środowiska. Produkcja zwierzęca wymaga zaangażowania dodatkowej powierzchni na wytworzenie pasz, dlatego pokazano także różnice w areałach faktycznie koniecznych do wytworzenia jednostki żywieniowej (GJ) przykładowych produktów roślinnych i zwierzęcych. Analiza emergetyczna oraz jej wyniki mogą dostarczyć cennych informacji dla decydentów w zakresie kierunku prowadzenia danej produkcji.

SŁOWA KLUCZOWE: rachunek emergetyczny, środowisko, akwakultura śródlądowa, wskaźniki emergetyczne

Agnieszka WARTECKA-WARZYŃSKA

WPŁYW LĄDOWYCH FARM WIATROWYCH NA WALORY TURYSTYCZNE ŚRODOWISKA W OPINII MIESZKAŃCÓW POLSKI. ANALIZA WYNIKÓW WTÓRNYCH BADAŃ EMPIRYCZNYCH

STRESZCZENIE: W Polsce po kilkuletnim zastoju lądowa energia wiatrowa zaczyna stanowić ważny przedmiot zainteresowań władz państwowych, samorządowych i społeczeństwa. Pojawia się zatem optymistyczna perspektywa inwestycji w turbiny wiatrowe. Celem artykułu jest przedstawienie społecznych warunków będących wyrazem świadomości społecznej, aprobujących budowę farm wiatrowych oraz rozpoznanie opinii społecznej dotyczącej wpływu tych farm na lokalny krajobraz, szczególnie na jego walory turystyczne. W charakterystyce badanego tematu wykorzystano metodę analizy literatury przedmiotu, metodę analizy statystycznej oraz metodę analizy dokumentów wtórnych. Wyniki ogólnopolskich badań empirycznych zawarte w wykorzystanych raportach wskazują wysoki poziom świadomości społecznej mieszkańców Polski, akceptujących inwestycje w lądowe farmy wiatrowe. Nie umniejszają jego wartości turystyczno-rekreacyjnej i nie ograniczają rozwoju ruchu turystycznego.

SŁOWA KLUCZOWE: energia wiatrowa, świadomość społeczna, krajobraz turystyczny

Marta SZABAN, Magdalena STEFAŃSKA

BARIERY WPŁYWAJĄCE NA ZACHOWANIA ZAKUPOWE ZIELONYCH PRODUKTÓW PIELĘGNACJI OSOBISTEJ – INTEGRACJA PERSPEKTYWY TEORII OPORU WOBEC INNOWACJI I MODELU ETAPÓW ZMIAN

STRESZCZENIE: Celem badania było zidentyfikowanie i wyjaśnienie postrzeganych przez konsumentów barier w konsumpcji zielonych produktów na każdym etapie zmiany behawioralnej. Ramy teoretyczne badania oparto na konwergencji teorii oporu wobec innowacji (ang. *Innovation Resistance Theory*) oraz modelu etapów zmian behawioralnych (ang. *Stages of Change Model*). Przeprowadzono 20 indywidualnych pogłębionych wywiadów z konsumentami będącymi na różnych etapach transformacji w kierunku zielonej konsumpcji w badanej kategorii produktów. W rezultacie badania bariera wiedzy została wyodrębniona jako osobny konstrukt w modelu teorii oporu wobec innowacji, gdyż uznano ją za istotny czynnik psychologiczny kształtujący proces adaptacji na każdym etapie zmiany. Czynniki takie jak bariera tradycji, wartości, użytkowania i ryzyka wykazały silniejszą moc hamującą na niższych etapach zmiany. Wraz z kolejnymi etapami wybrane bariery słabną, a inne, tj. bariera wiedzy i wizerunku ewoluują, przybierając inny przebieg i oddziaływanie. Dodatkowo, badanie ujawniło szereg czynników stymulujących zieloną konsumpcję badanej kategorii produktów. Spostrzeżenia te są istotne dla dziedziny zielonego marketingu i mogą pomóc w kształtowaniu ukierunkowanych interwencji dla skuteczniejszego stymulowania zrównoważonej konsumpcji.

SŁOWA KLUCZOWE: teoria oporu wobec innowacji, model etapów zmian, bariery ekologicznej konsumpcji, ekologiczne produkty higieny osobistej

Jan SIKORA, Kazimierz ZIMNIEWICZ

ODNAWIALNE ŹRÓDŁA ENERGII SPOSOBEM PRZECIWDZIAŁANIA OCIEPLENIU KLIMATU W POLSCE

STRESZCZENIE: Prowadzona w Polsce dyskusja na temat odnawialnych źródeł energii, szczególnie energii wiatrowej i słonecznej ujawnia zróżnicowane stanowiska wśród przedstawicieli nauki, biznesu i władzy rządowej oraz samorządowej. Ogólnie uważa się, że odnawialne źródła energii są ważnym czynnikiem ograniczenia ocieplenia klimatu. Ale też podkreśla się, że wytwarzanie tej energii pochłania duże koszty związane m. in. z pozyskiwaniem metali rzadkich stosowanych w produkcji np. turbin wiatrowych, baterii słonecznych oraz koszty z opracowaniem sposobów utylizacji zużytych części elektrowni wiatrowych, paneli słonecznych. Celem publikacji jest przedstawienie opinii jako wyrazu postaw społecznych przedstawicieli nauki, praktyki gospodarczej, władzy rządowej i samorządowej na powyższe problemy. Przykładem wyrażanych opinii jest dyskusja w przestrzeni publicznej, którą tworzą artykuły i wywiady zamieszczane w czasopismach i publikacjach zwartych. W artykule przyjęto tezę wskazującą na różnicę poglądów reprezentantów nauki, praktyki gospodarczej i władzy na temat znaczenia odnawialnych źródeł energii w ograniczaniu ocieplenia klimatu. Weryfikacja tezy łączyła się z przeprowadzeniem badań, w których zastosowano metodę analizy literatury przedmiotu, raportów z badań empirycznych publikowanych w postaci artykułów w czasopismach krajowych i zagranicznych oraz na stronach internetowych. W wyniku przeprowadzonych badań stwierdzono, że występują przeciwstawne opinie w zakresie oceny przyczyn ocieplenia klimatu, że energia wiatrowa z jednej strony jest czysta i ogranicza proces ocieplenia klimatu, a z drugiej nie zapewnia bezpieczeństwa energetycznego kraju, powoduje szkody w krajobrazie i zdrowotne u ludzi. Rozwój tej energii hamują przeszkody prawno-organizacyjne, techniczno-technologiczne i ekonomiczne. Potrzebę rozwoju energii wiatrowej popiera jednak 85% polskiego społeczeństwa, niezależnie od argumentów za i przeciw reprezentantów nauki, gospodarki i polityki.

SŁOWA KLUCZOWE: klimat, energia wiatrowa, bariery rozwoju, globalne ocieplenie klimatu

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