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Czasopismo Polskiego Stowarzyszenia
Ekonomistów Środowiska i Zasobów Naturalnych

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PROBLEMY TEORETYCZNE I METODYCZNE

Dariusz PIEŃKOWSKI • Eugeniusz KOŚMICKI

THE PRODUCTION FUNCTION IN THE CIRCULAR ECONOMY

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FUNKCJA PRODUKCJI GOSPODARKI ZAMKNIĘTEGO OBIEGU

STRESZCZENIE: W systemach naturalnych odpady czy emisje włączane są w naturalne obiegi materii i energii poprzez ich wykorzystanie na różnych poziomach troficznych. Tymczasem, powstające odpady czy emisje w procesach gospodarczych częstokroć nie tylko przekraczają pojemność ekosystemów naturalnych w zakresie ich przetwarzania, ale również stanowią rozwiązania technologiczne, które bez ingerencji człowieka trudne są do utylizacji w długim okresie czasu. W niniejszej pracy wskazuje się na pojawiające się w tle rozważań ekonomicznych koncepcje gospodarki obiegu zamkniętego, która jest formą przebudowy technologicznej i społeczno-gospodarczej w zakresie podejścia do odpadów i emisji. W pracy oferuje się nie tylko szerokie podejście do gospodarki obiegu zamkniętego, ale również zmianę w zakresie funkcji produkcji zgodnie z tymi zasadami wskazując na nową formę kapitału antropogenicznego – kapitał wtórny. Ten rodzaj kapitału nie jest celem produkcji, ale nie jest również ujmowany w kategoriach kosztów stając się zasobem surowcowym. Dopóki nie może być włączony bezpiecznie w naturalne obiegi materii i energii powinien być nieustannie wykorzystywany w obiegu gospodarczym, jako kapitał antropogeniczny wtórny. Dopiero jego transformacja zgodna z obiegiem materii i energii w przyrodzie może się wiązać z przekształceniem tego kapitału w zasoby kapitału naturalnego.

SŁOWA KLUCZOWE: gospodarka zamkniętego obiegu, odpady, emisja

Introduction

In natural systems waste, excrement or other kinds of physiological products of some organisms are at the same time a valuable capital resource for other organisms (for example, as a building material for their nests or hiding places, or as a food base). A good example here is the earth-boring dung beetle (*Geotrupes stercorarius*) feeding on excrement[1]. Similarly, problematic municipal wastewater is a valuable source of energy for heating homes and sidewalks in cities, while PET (polyethylene terephthalate) caps are used as a raw material in the textile industry (for the production of knitwear) or the pharmaceutical industry.

However, the traditional approach to production processes did not consider waste and emissions generated in the economic process, and focused strongly on the volume of production. Waste and emissions have been accounted for as production costs if they could be traded, or as social costs that were shifted to the environment and the sector of non-economic social activities.

This paper presents the concepts of the circular economy emerging on the background of economic considerations. In the light of this discourse attempts are made to change the approach to the problems of waste and emissions, which are a valuable source of anthropogenic capital. The cost of all forms of the safe disposal of waste and recycling that do not take into account the possibility of their reuse or safe inclusion in the natural cycles of matter are shifted onto the natural environment or society. The best examples of problems associated with this type of activity are numerous public protests and studies that indicate the burden caused by this strategy to both the environment and local communities[2].

The key issue in this approach involves the huge resources of matter and energy which can be effectively utilised in business, reducing the burden on the environment and at the same time generating additional resources for production processes. This, however, requires not only rethinking the nature

1 B. Glass (eds), *Survey of Biological Progress*, New York 2013, pp. 168.

2 M. Biesiada, *Ocena ryzyka zdrowotnego mieszkańców Wiślinki związanego z oddziaływaniem hałdy fosfogipsu*, Sosnowiec 2006; L. Budek, M. Wardas, A. Kasprzyk, *Rozprzestrzenianie się metali ciężkich w środowisku wód powierzchniowych wokół wysypiska odpadów komunalnych w Baryczy*, „Inżynieria Środowiska" 2000 Vol. 5, No. 2, pp. 397–413.

of waste[3] as a by-product of human activity, but also economic analysis considering its generation in categories other than costs. This does not imply that creating waste is the purpose of manufacturing processes, but waste is an inevitable element, which should be treated as capital resources.

Nevertheless, the issue of a zero waste economy seems to be a political and business practice taken into account to only a small extent in theoretical deliberations by economists. This paper points out the theoretical assumptions of these transformations and at the same time proposes a change in the approach to the production function, which in mainstream economic discourse ignores these precious natural resources and assumes linear models of management.

The origin and definition of the circular economy

The concept of the zero waste economy initially appeared in practice and politics. In business this term was first used by Paul Palmer in 1973 as the name of his company, which recovered resources from chemicals used in industry and science[4]. In a wider sense this concept appears, however, only in the 1990s, mainly in the context of waste management indicating the need for a holistic change in the approach to the problem of the storage or disposal of waste.

Today the concept of zero waste economy is strongly identified with the term circular economy, which has been addressed in much more numerous publications. A. Murray et al.[5] and F. Qiao et al.[6] when referring to the circular economy point to the writings by K. Boulding[7] and assume that this term was coined in opposition to the one-way, linear concept of the 'cowboy economy', inadequate for modelling the closed earth ecosystem which has become a single spaceship. In the linear economy resources are extracted, turned into products, and waste and emissions are removed. Both input and output in

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3 J. Birkeland, *Ecological waste: rethinking the nature of waste*, „BEDP Environment Design Guide" 2007 Vol. 1, No. 6, pp. 1–9.

4 A. Uz Zaman, *A Comprehensive Review of the Development of Zero Waste Management: Lessons Learned and Guidelines*, „Journal of Cleaner Production" 2015 No. 91, p. 13.

5 A. Murray, K. Skene, K. Haynes, *The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context*, „Journal of Business Ethics" 2015 No. 3.

6 F. Qiao, N. Qiao, *Circular Economy: An Ethical and Sustainable Economic Development Model*, „Prakseologia" 2013 No. 154, p. 254.

7 K.E. Boulding, *The Economics of the Coming Spaceship Earth*, in: H. Jarrett (ed.), *Environment Quality in a Growing Economy: Essays from the Sixth RFF Forum*, Baltimore 1966, pp. 3–14.

such an economic model are problematic in the context of limited resources and space to accommodate waste.

The economic discourse also emphasizes the strong involvement of Chinese researchers who popularized the principle of closed loop production, not only in scientific discussions, but also in business practice and legislation, in the development of the concept of the circular economy. The above-mentioned A. Murray et al. also points to the papers of environmental economists or deliberations in the field of industrial ecology which present similar approaches to the problem of waste[8].

However, as recently as in 2007 P. Glavič and R. Lukman analyzed the key concepts related to the issues of sustainable development and indicated that actually the definition of zero waste production has not been presented in any documents released by organizations dealing with the protection of the environment, such as the United Nations Environment Programme, the European Environment Agency, and the US Environmental Protection Agency[9]. In fact, even today, in spite of the development of programmes already based on the concept of zero waste economy in the European Union[10], most sources refer to the definition used by the *Zero Waste International Alliance*[11] established in 2002. According to the definition proposed in 2009 by ZWIA, "Zero Waste is a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. Zero Waste means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them. Implementing Zero Waste will eliminate all discharges to land, water or air that are a threat to planetary, human, animal or plant health"[12].

This definition is very broad and indicates the holistic nature of changes in ethical, economic and environmental aspects. F. Qiao et al. even compares

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8 A. Murray, K. Skene, K. Haynes, op. cit., p. 4.

9 P. Glavič, R. Lukman, *Review of Sustainability Terms and Their Definitions*, „Journal of Cleaner Production" 2007 No. 15(18), p. 1880.

10 European Commission, Towards a circular economy: A zero waste programme for Europe, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (Brussels: European Commission, 2014).

11 J. Zwier et al., *The Ideal of a Zero-Waste Humanity: Philosophical Reflections on the Demand for a Bio-Based Economy*, „Journal of Agricultural and Environmental Ethics" 2015 No. 2(28), p. 13.

12 ZW International Alliance, „ZW Definition", *ZW Definition*, 2009, www.zwia.org [05/02/2016].

it to the Copernican change[13], J. Birkeland indicates the shift of the paradigm in product design[14], while S. Lehmann has a similar approach to cultural transformations in urban development[15]. On the other hand, A. Gillespie stresses that the emphasis is on avoiding not just the management of waste, since preventing the generation of waste is much more beneficial[16]. Consequently, it is vital to take actions in all areas of human activity, from the production process to change of lifestyle and consumer behaviour.

The zero waste concept is today linked with many other terms and concepts in waste management, such as clean production[17] or cleaner economy[18], low emission economy[19] or low carbon economy[20], bioeconomy[21] or bio-based economy[22], circular economy[23], as well as sustainable development[24]. Clean production or a bio-based economy are narrower concepts. The first one refers only to the aspects of zero waste economy from the perspective of production process (although in a very broad sense), while zero waste economy covers a wide range of activities, even in the area of consumption or the general transformation of communities. P. Glavič and R. Lukman define cleaner production (cleaner economy) as "a systematically organised approach to production activities, which has positive effects on the environment. These activities encompass resource use minimisation, improved eco-efficiency and source reduction, in order to improve the environmental protection and to reduce risks to living organisms" [25].

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13 F. Qiao, N. Qiao, op. cit., p. 253.

14 J. Birkeland, op. cit., p. 1.

15 S. Lehmann, *Resource recovery and materials flow in the city: Zero waste and sustainable consumption as paradigms in urban development*, „Sustainable Development Law & Policy" 2010 No. 11, p. 28.

16 A. Gillespie, *Waste Policy: International Regulation, Comparative and Contextual Perspectives*, Waikato 2015, p. 34.

17 F. Qiao, N. Qiao, op. cit., p. 261.

18 P. Glavič, R. Lukman, *Review of Sustainability Terms and Their Definitions*, „Journal of Cleaner Production" 2007 No. 15(18), p. 1879.

19 O. Davidson et al., *The development and climate nexus: the case of sub-Saharan Africa*, „Climate Policy" 2003 No. 3, pp. 97–113.

20 K. Shimada et al., *Developing a long-term local society design methodology towards a low-carbon economy: An application to Shiga Prefecture in Japan*, „Energy Policy" 2007 No. 9(35), pp. 4688–4703.

21 K. McCormick, N. Kautto, *The Bioeconomy in Europe: An Overview*, „Sustainability" 2013 No. 5/ 6, pp. 2589–2608.

22 S. Nebe, *Bio-Based Economy in Europe: State of Play and Future Potential, Summary of the position papers received in response of the European Commission's Public on-line consultation, Studies and Reports*, Brussels 2011.

23 A. Murray, K. Skene, K. Haynes, op. cit.

24 F. Qiao, N. Qiao, op. cit., p. 261.

25 P. Glavič, R. Lukman, op. cit., p. 1879.

On the other hand, the concept of bio-economy (*bio-based economy,* BBE) is related to the philosophy of G. Bataille[26], who in response to the criticism of the mainstream economy developed his own 'general economy' and indicated that in the latter, "resources, production, circulation, growth and value are thought of not just in relation to the societal or private economy, but also in relation to the economy of nature and the universe"[27]. The key process here is the circulation of energy that is restricted by human communities, which rely on the concepts of mainstream economics, appropriating nature and leading to a significant depletion of global resources. Restricted economy treats energy as a purely economic commodity and ignores its relevance to biological processes. The European Commission defines the concept of bio-economy as "the production of renewable biological resources and the conversion of these resources and waste streams into value added products such as food, feed, bio-based products and bioenergy"[28]. The concept of clean production, low emission (low carbon) economy, and zero waste economy also encompass broader actions with respect to products that do not have to be biodegradable. The concepts of low emission and low carbon economy (containing the previous concept) have been coined mainly with reference to climate policy and the need to reduce greenhouse gas emissions. They have a very broad meaning for the regulation of production and consumption, but from the perspective of the concept of zero waste economy they must be considered as complementary and more focused on emissions rather than on waste. Each of these concepts can be used as a sustainable development strategy, which involves intergenerational respect for resources and a holistic approach to the relationship between the economy, community and nature.

The concept of circular economy is presented in the European Union and other documents as a zero waste strategy. The key document addressing this problem is *Towards a circular economy: a zero waste programme for Europe*[29]. This concept has been defined rather vaguely, as "closing the loop of product lifecycles through greater recycling and reuse, and bring benefits for both the environment and the economy"[30]. A report by the United Nations Environmental Programme defines the circular economy in a very similar way as an economy that balances economic development with environmental and

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26 J. Zwier et al., op. cit.

27 A. Sorensen, *On a Universal Scale: Economy in Bataille's General Economy*, „Philosophy & Social Criticism" 2012 No. 2(38), p. 172.

28 European Commission, *Innovating for Sustainable Growth: A Bioeconomy for Europe, Research & Innovation,* Brussels 2012, p. 9.

29 European Commission, Towards a circular economy: A zero waste programme for Europe.

30 U. Pisano et al., *The role of stakeholder participation in European sustainable development policies and strategies*, ESDN Quarterly Report, Vienna 2015, p. 20.

resources protection, and puts emphasis on the most efficient use and recycling of resources. The term also features low energy consumption, low emission of pollutants and high efficiency[31]. On one hand, it is a broader approach than the zero waste concept, as it also covers emissions, but on the other hand, the emphasis is on the reduction of resource use and their management, unlike in the more restrictive approach of zero waste presented in EU documents.

Nevertheless, in many documents and discussions the concept of the zero waste economy is identified with the restricted circulation economy. For example, according to the Ellen MacArthur Foundation, a circular economy is one that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles[32]. In China, 'the world's largest factory', the circular economy was already put into practice in 1998[33] and is defined in legislation as a term for reducing, reusing and recycling activities conducted in the process of production, consumption and circulation[34]. It is difficult, therefore, to speak of a universally accepted definition, and additionally most analyses are carried out in the form of practical, political, or theoretical discourse.

Calculation of the production function in the circular economy

In this paper, the production function is calculated based on the broad definition of the circular economy, similar to the one presented in the United Nations Programme. In this sense, it is assumed that in the economic process all cycles of matter must be closed in line with the generally accepted principles of the zero waste economy, but also taking into account emissions. Therefore, matter and energy in a broad sense, generated during economic activities, should be included in the cycle, not only to avoid the storage and disposal of waste, but also to prevent emissions in the perspective of climate change and energy management mentioned in the concept of the bioeconomy.

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31 UNEP, *Circular Economy. An Alternative Model for Economic Development*, Paris 2006, p. 1.

32 Ellen MacArthur Foundation, *Towards A Circular Economy: Business Rationale For An Accelerated Transition*, 2015, p. 2.

33 Z. Dajian, *Plan B: Rescuing a planet under stress and a civilization in trouble*, „Chinese Journal of Population, Resources and Environment „ 2003 No. 6(4), p. 4.

34 F. Preston, *A global redesign? shaping the circular economy*, „Energy, Environment and Resource Governance „ 2012 No. 2, p. 3.

Winpenny pointed to the special role of some natural capital in sustaining biological and socio-economic processes[35]. Consequently, it is necessary to distinguish the natural capital and fundamental natural capital, which is difficult to assess in economic terms due to its significant role in the functioning of all living organisms.

In view of the above classification and postulates put forward by ecological economists, D. Pieńkowski proposed a definition of the production function, in which the goal of every economic process is also to improve the quality of fundamental natural capital[36]. In reference to these considerations, a traditional production function has the form of equation (1).

$$f(K, L) = Q \tag{1}$$

where: K – capital, L – labour, Q – volume of production.

Following the concept of J. T. Winpenny the production function can be extended to include the role of natural capital, as in equation (2).

$$f(k, P, Ś, L) = Q \tag{2}$$

where: $K = k + P + Ś$, k – man-made capital, P – natural capital, Ś – fundamental natural capital.

Finally, if we consider the postulate proposed by D. Pieńkowski, the production function can be described by equation (3).

$$f(k, P, L) = Q + Ś \tag{3}$$

As we can see in the latter case, the goal of every economic process is, in addition to production utilising man-made capital, labour and natural capital (natural resources), the improvement of the quality of fundamental natural capital such as air, water or the landscape. This approach requires that the improvement of the environment is taken into account whenever economic activities are designed and undertaken in line with the previously mentioned postulate by the European Commission "to bring benefits for both the environment and the economy". However, in view of the objectives of the circular economy, there is no direct reference to the secondary man-made capital, which is the key element necessary to change the approach to the process of production.

According to the objectives of the circular economy, two key assumptions have to be adopted here. Firstly, we have to add to the current discussion an

35 J.T. Winpenny, *Wartość środowiska. Metody wyceny ekonomicznej,* Warszawa 1995, p. 20.

36 D. Pieńkowski, *Kapitał naturalny w teoretycznych analizach czynników produkcji*, „Ekonomia i Środowisko" 2002 No. 1(21), p. 15.

element obvious to all economists, but from the perspective of the production function treated as waste or emissions, more or less shifted onto nature. Due to the limited analyses in terms of the market value of these production effects, they were ignored in the formula for the production function, which should be expressed as follows (4).

$$f(K, L) = Q + W = Q_w \quad (4)$$

where: W – matter and energy generated in the process of production but not being the main goal of this process, Q – the volume of primary production representing market value.

Secondly, we have to consider postulated changes in the paradigm in terms of the approach to matter and energy generated in the process of production and not being the main goal of this process. In this sense, any waste or emissions form the secondary man-made capital and should be retained in the circulation of man-made capital as long as its inclusion in the circulation of matter and energy in the natural system does not create a risk to the balance of natural ecosystems. Following this assumption, the production function is expressed in formula (5).

$$f(k_a, k_w, P, L) = Q_w + Ś \quad (5)$$

where: $k = k_a + k_w$, k_a – primary man-made capital, k_w – secondary man-made capital.

As we can see, the volume of production (Q) is expressed as the sum of the classically expected volume of production from equation 1, i.e. the goal of production (Q) and the amount of generated matter and energy (W). The inclusion of secondary man-made capital (kw) in the economy does not eliminate the need for undertaking measures or considering the effects of business operations on the quality of the fundamental natural capital (Ś). Of note is that the secondary man-made capital is a factor of production. It may be consumed and/or may be part of the fundamental natural capital if this does not deteriorate the quality of the environment. In the latter case, the secondary man-made capital can be assumed as an element of bio-economy.

Although in environmental economics the internalization of external costs (including those related to the generation of waste and emissions) is widely discussed, both with respect to political (the Pigou tax) and market solutions (the Coase theorem)[37], from the perspective of the concept of the circular economy such measures are temporary and must lead to a change in the approach to secondary man-made capital, particularly in situations

37 A. Graczyk, *Ekologiczne koszty zewnętrzne,* Białystok 2005.

where business operations are very burdensome for the environment and people, or all the possible consequences of undertaking these operations are associated with a high level of risk and uncertainty.

But the key problem is rethinking the process of management and shifting the core considerations from the category of cost to the category of valuable man-made resources. In this aspect also the technological development will not be perceived in opposition to biological processes, especially when it is associated with the inclusion of man-made capital in the natural capital without upsetting the balance of the global ecosystem.

Summary

A specific feature of waste and emission management is the anthropogenic origin of this capital and its secondary character with respect to the major goal of business. However, in the process of closing the loop of man-made matter and energy modelled on the cycling of natural capital in the environment the deliberate and full utilisation and management of this capital has to be designed at the stage of production planning. The existing practices put a stronger emphasis on the safe and effective disposal of waste rather than its reuse. In this sense, production should be launched only if each of the products of the process (including secondary products) can be reused by the producer or sold or handed over to another producer who has a suitable technology for the reuse of this secondary product. Disposal of waste implies the expectation that nature, over a long time, can more or less safely return these resources into the cycle of matter and energy. However, because of the scale of matter and energy transformation in economic activity and the specific nature of these transformations, modern society is forced to adopt an integrated approach to the management of business operations by closing cycles of man-made matter and energy, or by including them in the natural processes, without upsetting the balance of local and global ecosystems.

Waste and emissions are resources that can be largely utilised in business operations if the consequences of their generation, and at the same time the possibility of their reuse, are planned in advance and included in the cycling of matter and energy between the economic and natural environment. The old approach to the economic process, focused only on the efficient use of resources, including restricted consumption and production, requires a broader look at business processes from the perspective of the inclusion of emissions and waste in business operations as value added elements in business.

Authors' contributions to this article:

prof. Dariusz Pieńkowski, PhD – 50%
prof. Eugeniusz Kośmicki, PhD – 50%

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ENVIRONMENTAL POLICY AND MANAGEMENT

POLITYKA EKOLOGICZNA I ZARZĄDZANIE ŚRODOWISKIEM

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OBSTACLES AND POSITIVE TRENDS IN THE DEVELOPMENT OF SUSTAINABLE CONSUMPTION IN POLAND

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BARIERY I POZYTYWNE TENDENCJE W ROZWOJU ZRÓWNOWAŻONEJ KONSUMPCJI W POLSCE

STRESZCZENIE: W artykule zaprezentowano zarówno bariery, jak i możliwości implementacji koncepcji zrównoważonej konsumpcji w Polsce. Na wstępie zdefiniowano koncepcję zrównoważonej konsumpcji. Zrównoważona konsumpcja została przedstawiona jako ważny cel spośród 17 Celów Zrównoważonego Rozwoju na lata 2016–2030. Następnie przeanalizowano bariery oraz zaprezentowano pozytywne tendencje w rozwoju zrównoważonej konsumpcji w Polsce. Umożliwiło to opracowanie zestawienia, które może pomóc w opracowaniu strategii zrównoważonej konsumpcji w Polsce. W artykule wykorzystano metodę analizy krytycznej literatury.

SŁOWA KLUCZOWE: zrównoważona konsumpcja, możliwości i zagrożenia implementacji zrównoważonej konsumpcji w Polsce

Introduction

Sustainable consumption is one of the main goals of sustainable development. It is also strongly associated with creating better quality of life as an overarching objective of the new development paradigm[1]. Sustainable consumption and production are often treated as the core of the sustainable development goal and a cross-cutting issue to be embedded within other goals[2]. Some researchers noted that the sustainable consumption and production goal is the priority in terms of links with the implementation of other sustainable development goals[3]. That is why it is so important, in the opinion of the author of this article, to deal with sustainable consumption and to link it with relevant sectoral policies, such as tourism, transport, agriculture, energy, and construction[4]. At the beginning, however, a specific analysis should be carried out to see how this concept is implemented in Poland. The aim of this article is to identify barriers and present positive trends in the development of sustainable consumption in Poland.

Sustainable consumption – main definitions

The official definition of sustainable consumption was proposed quite a long time ago, in 1994, during the Oslo Symposium on Sustainable Consumption. According to this definition sustainable consumption is "the use of goods and services that respond to basic needs and bring a better quality of life, while minimising the use of natural resources, toxic materials and emissions of waste and pollutants over the life cycle, so as not to jeopardise the needs of future generations"[5].

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1 T. Borys, *Wybrane problemy metodologii pomiaru nowego paradygmatu rozwoju – polskie doświadczenia*, "Optimum. Studia Ekonomiczne" 2014 No. 3(69), pp. 9–11.

2 L. Akenji, M. Bengtsson, *Making Sustainable Consumption and Production the Core of the Sustainable Development Goals*, Kanagawa 2014, p. 4.

3 D. Le Blanc, *Towards integration at last? The Sustainable Development Goals as a network of targets,* Rio +20 working papers, December 2014, pp. 3–16, www.sustainabledevelopment.un.org [23/02/2015].

4 T. Borys, op. cit., p. 11.

5 www.iisd.ca [21/10/2015].

In practice, strong and weak sustainable consumption are identified[6]. Weak sustainable consumption is achieved through the eco-efficiency of appliances and technological improvements. As noted by S. Lorek, this approach has dominated political and scientific thinking, in particular after the Earth Summit in Johannesburg in 2002, and is expressed in the concept of sustainable consumption and production (SCP). SCP is focused on products, services and consumer responsibility for buying 'green', sustainable products. On the other hand, strong sustainable consumption approaches additionally indicate the need for significant changes in the levels and patterns of consumption. They emphasize the need for an overall reduction in resource consumption. Quality of life, wellbeing and non-economic human activity are important elements of strong sustainable consumption[7].

According to the author of this article, the overarching goal of sustainable consumption is the lasting improvement of quality of life (which corresponds with the concept of strong sustainable consumption) in the aspects of 'to have', 'to be' and 'to love'. Sustainable consumption is a conscious consumption based on consumers' responsibility and high awareness of their needs, which is reflected in making informed and responsible consumer decisions. Sustainable consumption is the use of alternative energy-saving appliances made of renewable materials, which is the 'technological' way to solve problems. Sustainable consumption means 'consuming less' but also 'consuming differently'. Consuming less means, for example, limiting travel by car, while consuming differently means that people follow the principles of ecodriving.

The United Nations Summit on Sustainable Development held in New York on 25–27 September 2015 established the 17 Sustainable Development Goals for 2016–2030[8]. One of them is Goal 12, to ensure sustainable consumption and production patterns[9]. Goal 12 will be implemented through 11 targets, such as the efficient use of natural resources, reduction of food losses, prevention of waste generation, corporate social responsibility (CSR), green public procurement (GPP), support for developing countries to strengthen their technological capacity, sustainable tourism, phasing out inefficient fossil-fuel subsidies, and shaping social awareness for sustainable lifestyles. As one can see, the above targets do not contain provisions stating explicitly the

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6 S. Lorek, D. Fuchs, *Strong sustainable consumption governance – precondition for a degrowth path?*, „Journal of Cleaner Production" 2013 No. 38, p. 36.

7 Ibidem, pp. 37–38.

8 These goals were criticized by Angus Deaton, a winner of the 2015 Nobel Prize in Economic Science. "I am not a great fan, there is no way to measure them. A lot of it is just people trying to make themselves feel better", Deaton said. [*Nobel Prize winner Angus Deaton shares 3 big ideas*, "Financial Times", www.ft.com [13/10/2015].

9 www.sustainabledevelopment.un.org [13/10/2015].

reduction of excessive consumption. This fact is not surprising, because freedom of consumption is one of the two basic aspects of human economic freedom, and people can decide how they spend their income. It can be assumed that the UN provisions indirectly express the essence of sustainable consumption without limiting the free choices of individuals – the aim of the eighth target is only to ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature.

Barriers to the implementation of sustainable consumption in Poland

In Poland there are a number of serious barriers to the implementation of sustainable consumption. The most important ones are listed below:

1. First barrier: **lack of precise definitions**

An important problem, and not only in Poland, is the lack of precise definitions for sustainable and unsustainable consumption.

Problems with the operationalization of sustainable consumption result from difficulties with the precise definition of the categories of quality of life, because the sustainable quality of life encompasses, for example, the quality of 'having', the quality of 'being' and the quality of 'loving'[10]. These difficulties also arise from linking environmental wellbeing with human and economic wellbeing (improved quality of life). This is confirmed in the recent scores for the Sustainable Society Index (SSI) for 2014[11]. The SSI offers a picture of the level of sustainability of countries worldwide[12]. It measures the level of sustainability in three dimensions: human wellbeing, environmental wellbeing and economic wellbeing. A disturbing finding from the analysis of the SSI is the strong negative correlation between environmental and human wellbeing: increased human wellbeing usually means lower environmental wellbeing. The same can be seen for economic wellbeing – higher income is related to higher economic wellbeing but lower environmental wellbeing. This negative correlation, according to the authors of the SSI report, should be of major concern. Therefore, starting from 2014, reports do not present an overall SSI score for a sustainable society, and the level of sustainability in individual

10 B. Kryk, *Zrównoważona jakość życia a zrównoważona konsumpcja i zachowania ekologiczne polskich konsumentów*, „Handel Wewnętrzny" 2013 No. 6, pp. 5–18.

11 www.ssfindex.com [21/10/2015].

12 B. Kryk, *Jakość życia w kontekście zrównoważonego rozwoju*, "Handel Wewnętrzny" 2012, July-August, Vol. 1, pp. 145–155.

countries is shown in particular dimensions of wellbeing. Currently, the SSI team is developing a new tool that can be used to identify countries at the highest level of sustainability[13].

In light of the above-mentioned findings one can wonder whether the definition of sustainable development is still valid, and whether we can still talk about the harmonised implementation of the three goals of sustainable development. It should be noted that the countries with the best scores of consumption (i.e. those where consumption in global hectares per person is below 0.7) are also in distant positions when it comes to other dimensions of wellbeing – human and economic. These countries are: Bangladesh, Haiti, Iraq, North Korea, India, Pakistan, Yemen, Congo, Mozambique, and Tajikistan[14].

2. Second barrier: **unsustainable practices in transport**

In Poland in 2014 there were 519.9 passenger cars per 1,000 people[15]. Before 2000 this figure was about two-fold lower. The average age of a car in Poland at the end of the reporting year was 15.5 years. In this respect Poland is very different from the EU average, which was 8.2. This situation is due to the presence of old cars, which after 2004 could be brought to Poland without any problems. Between May 2004 and the end of 2011 Poles imported almost 7 million pre-owned cars, and more than half of them were at that time older than 10 years. The technical condition of cars sold is often unsatisfactory: 74% of them had been involved in a road accident, and in 66% of cases the condition of the car declared in the advertisement did not correspond with the actual condition. Almost 80% of cars offered for sale are imported, of which the most by far are from Germany[16]. The current situation would perhaps be different if appropriate administrative and legal measures restricting the private importation of cars were introduced at the right moment. Today it can be assumed that further improvement in the economic status of Poles will result in the withdrawal of obsolete, inefficient cars from use.

The Transport Development Strategy predicts a number of adverse changes in the transport sector in Poland by 2020, including: further increase in the use of private cars, a significant increase in air transport, a decline in the use of urban public transport, a progressive decline in foot traffic in cities, only slightly offset by increased bicycle traffic. Some optimistic data relate

13 A. Manuel, G.van de Kerk, R. Kleinjans, *Sustainable Society Index 2014*, Hague 2014, pp. 23–24, www.ssfindex.com [21/10/2015].

14 Ibidem, p. 53.

15 Sustainable development indices. www.stat.gov.pl [20/10/2015].

16 www.pieniadze.gazeta.pl [5/02/2015].

only to the potential growth in passenger transport by rail, provided, however, the quality of services is improved and a high-standard rail system is put into operation[17].

3. Third barrier: **the lack of a stable governmental vision for institutional support in the implementation of sustainable consumption**

In Poland, a major problem is the lack of a stable governmental vision as to institutional support in the implementation of sustainable consumption. This is reflected, for example, in the very general nature of the only document addressing this issue, namely *The strategy for changing production and consumption patterns to favour the implementation of the principles of sustainable development,* adopted in 2003[18], as well as the lack of further updates. In addition, the Working Group for sustainable consumption and production established at the Ministry of the Economy is focused mainly on the problems of corporate social responsibility (CSR)[19].

4. Fourth barrier: **insufficient understanding of the core of sustainable consumption by society**[20]

The subjective perception of consumption by respondents varies widely and is strongly correlated with factors such as place of residence (consumers from the largest cities perceive their consumption as fairly sustainable), education (better educated respondents perceive their own consumption as sustainable) and financial status (respondents with higher incomes see their own consumption as more sustainable).

However, the survey revealed that the subjective opinions of respondents are not consistent with their behaviour; in some areas it is villagers who more often believe that their consumption is unsustainable but show more sustainable behaviour; a similar situation concerns people with higher and secondary education who, given their declared high level of sustainable consumption, in fact, do not show more sustainable behaviour; therefore, the

17 Strategia Rozwoju Transportu do 2020 roku (z perspektywą do 2030 roku)/Transport Development Strategy by 2020 (with a prospect until 2030), Ministry of Transport, Construction and Maritime Economy, Warsaw 22 January 2013, www.mir.gov.pl [20/10/2015].

18 Strategia zmian wzorców produkcji i konsumpcji na sprzyjające realizacji zasad trwałego, zrównoważonego rozwoju/ A government document adopted by the Council of Ministers on 14 October 2003, www.mg.gov.pl [21/08/2015].

19 www.mg.gov.pl [21/10/2015].

20 B. Jaros, A questionnaire-based survey on consumption conducted in August and September 2014 on a representative sample of 500 adult residents of the Silesian province aged 19 years and older (part of the doctoral thesis, unpublished work). Due to the regional nature of the survey, there is limited ability to extrapolate the results to the entire population of Poland.

author of this article believes that such a distribution of answers may stem from a lack of knowledge about sustainable consumption.

The surveyed respondents showed ambivalent attitudes towards the principles of sustainable consumption. For example, respondents on one hand declare that they save energy, and on the other hand they usually leave electronic appliances in standby mode; on one hand they separate waste motivated by the desire to protect the environment, but on the other hand do not pay much attention to the separate collection of pharmaceuticals.

Sustainable consumption is not fully understood, which is proven by the fact that most respondents indicate financial costs as the main obstacle to implement sustainable consumption ('it is too expensive'); in turn, for those with the highest income the major obstacle to sustainable consumption is the lack of time ('it requires a lot of time').

5. Fifth barrier: **the occurrence of a negative rebound effect**

The rebound effect is the range of the energy savings produced by investments in energy-efficient appliances, which will be taken over by consumers in the form of increased consumption as the greater number of hours for which these appliances will work. The rebound effect is calculated by subtracting the actual savings made by the use of energy-saving appliances from the potential savings that could be gained through the use of the same good. In this way the savings from energy efficient appliances are offset by the demographic and social factors and human behaviour[21].

The existence of the rebound effect is confirmed by statistics on the use of electricity in Poland. In 2004–2010 the consumption of energy per year per capita grew steadily from 597.3 kWh to 773.0 kWh, and in the following years (2011–2013) began to decrease slightly to reach 758.8 kWh[22].

Another example of the rebound effect is the decreasing household size – the smaller the household, the higher the consumption of natural resources per capita; the higher number of households also means that larger areas designated for development, new residential buildings are constructed and more construction materials are used. The increase in the number of households increases the demand for household appliances such as refrigerators, freezers, cookers, washing machines and television sets. More furniture and cars are being sold as well. In addition, all these appliances generate indirect energy consumption for households related to the demand for energy during the production and distribution of these goods. In Poland

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21 H. Throne-Holst, P. Strandbakken, *From theory to practice – Towards an efficiency of consumption*, in: E. Hertwich, T. Briceno, P. Hofstetter, A. Inaba (eds.), *Sustainable Consumption: The Contribution of Research*, Trondheim 2005, pp. 39–47.

22 www.stat.gov.pl, op. cit.

between 2000 and 2013 the number of households formed by single people increased significantly from 10.6 to 21.7 per cent.[23]

6. Sixth barrier: **behaviours in the consumer society**

Clear signs of consumerism can be observed among Polish consumers, and this behaviour is becoming more and more popular[24]. Consumerism is an ideology that encourages the acquisition of goods and services in ever-increasing amounts, without considering the environmental, social and personal costs[25]. Consumerism is manifested in overconsumption, which is the use of short-lasting and cheap products on the principle that it is better to have more than less, but to the detriment of the quality of the purchased goods. According to O. Leszczak: "the problem is not that people become stuff collectors and attach too much importance to physical objects and material goods, but that they do not attach any importance to them"[26].

The majority of surveyed consumers like shopping and do it frequently[27]. This is also reflected in the high propensity of respondents to visit retail outlets. Only a small fraction of respondents claim to be happy when their basic needs are satisfied. The most important reasons driving purchasing decisions are: striving to meet needs at a sufficient level, the desire to be like others, and the desire to stand out. Consumers consider a luxury car, fashionable brand clothing and holidays at an exotic destination as the best signs of high status. For almost half of consumers fashion is a fundamental driver of their purchasing decisions. Almost half of the respondents buy products to stock up, which undoubtedly promotes the wastage of resources.

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23 Ibidem.

24 E. Kieżel, *Konsumpcjonizm i dekonsumpcja w zachowaniach polskich konsumentów,* in: E. Kieżel, S. Smyczek (eds.), *Zachowania konsumentów. Procesy unowocześniania konsumpcji*, Warszawa 2014, p. 95.

25 Ibidem, p. 80.

26 O. Leszczak, *Paradoksy konsumpcjonizmu. Typologia i lingwosemiotyka*, in: R. Stefański (ed.), *Życie w konsumpcji – konsumpcja w życiu – konsumpcja życia: współczesny człowiek w społeczeństwie konsumpcyjnym*, "The Peculiarity of Man" 2012 No. 15, p. 33.

27 E. Kieżel, op. cit., pp. 83–90; results of this survey cannot also be extrapolated to the entire population of consumers in Poland, since the survey was carried out on a group of 258 respondents from the Silesian province.

Positive trends in the implementation of sustainable consumption in Poland

Barriers to the implementation of sustainable consumption in Poland are significantly offset by positive trends, for example:

1. **Growing interest in the issues of sustainable consumption**

The new paradigms of development and consumption are rapidly developing areas of research in Poland and worldwide; a new scientific discipline – sustainable development economics – is emerging, as well as various forms of environmental education (including those promoting sustainable consumption). The issues of sustainable consumption and production have been highlighted as a separate goal in the UN Sustainable Development Goals. In Poland the Working Group for Sustainable Consumption and Production has been established at the Ministry of the Economy. In 2015 the Nobel Prize in Economic Sciences was awarded to Angus Deaton for his analysis of consumption, poverty and welfare. The justification for this decision reads that understanding how consumers distribute their spending among different goods is necessary for explaining and forecasting actual consumption patterns.

2. **Development of theoretical foundations for sustainable consumption**

To some extent the theoretical foundations of sustainable consumption are well-established, and agreement has been reached on the nature and scope of instruments supporting sustainable consumption, consumption areas and products that have the most negative impact on the environment, and indicators of sustainable consumption and production.

3. **Promotion of environmentally-friendly behaviours**

There are social campaigns promoting environmentally-friendly consumer behaviours, such as those organised by the Ministry of the Environment „Wyłączamy prąd. Włączamy oszczędzanie" (Turn off electricity. Turn on saving), „Nie zaśmiecaj swojego sumienia" (Clear trash. Keep your conscience clean.), "Zielone miasta – w stronę przyszłości" (Green cities – heading towards the future), or an informational campaign on raising public awareness of biodiversity and actions in support of ecosystems[28].

[28] www.mos.gov.pl [26/10/2015].

4. Development of the *sharing economy*

The popularity of the *sharing economy* in Poland is growing steadily. This term is broad and encompasses a number of slightly different ideas, such as[29]:

Collaborative economy is an economic system of decentralized networks and marketplaces that unlocks the value of underused assets by matching needs and haves in ways that bypass traditional middlemen (examples from Poland: Banki Czasu (Time Banking) is a pattern of reciprocal service exchange, e.g. a one-hour guitar lesson is exchanged for a one-hour English lesson, and a unit of time is used as a currency);

Sharing economy is an economic system based on sharing underused assets or services, for free or for a fee, directly from individuals (examples from Poland: Airbnb – rental/letting of beds in private homes, BlaBlaCar is a service matching drivers who offer vacant seats with people seeking transport);

Collaborative consumption is the reinvention of traditional market behaviours – renting, lending, swapping, sharing, bartering, gifting – through modern technologies – the Internet, mobile apps (examples from Poland: Allegro, eBay – websites operating online auctions, Zipcar – car rental by the hour so users only pay for the actual use of the car (for now the service is unavailable in Poland, but it may be launched soon);

On-demand services – platforms that directly match customer needs with providers to immediately deliver goods and services (for example Uber – ordering car transport services by matching passengers with drivers that use the Uber mobile application, DeskBeers – in the UK the platform provides beer from small artisan breweries, Alfred – in the United States, helps find people who will do your household chores).

5. Instruments supporting sustainable consumption

Positive environmental effects have been observed as a result of the use of instruments supporting sustainable consumption. The most important of these are eco-labelling, charging customers for disposable shopping bags, changes in the municipal waste management system, and the popularisation of energy-saving fluorescent lamps.

6. Developing monitoring of sustainable consumption

The scope of monitoring in the area of sustainable development and consumption has been extended; in 2011 the Central Statistical Office (GUS)

[29] R. Botsman, *Defining The Sharing Economy: What is Collaborative Consumption – And What Isn't?*, www.fastcoexist.com [20/10/2015].

published a report on sustainable development indicators for Poland (*Wskaźniki zrównoważonego rozwoju Polski)*[30]; GUS also launched a special module in BDL (Bank Danych Lokalnych/Local Data Bank), „Wskaźniki zrównoważonego rozwoju"/Sustainable development indicators, which presents statistics on sustainable consumption and production".

Summary

It is difficult to clearly determine the trends prevailing in Poland. It should be kept in mind that Poland still has to catch up with richer countries of Western Europe in terms of economic growth, so we can expect that consumption in Poland will grow as the standard of living increases. In such a situation instruments supporting sustainable consumption should be used so that consumers can make the most sustainable choices. There are quite a few options for action in this field. For example, new energy-efficient technologies can be promoted, awareness of the effects of overconsumption can be raised, people can be educated to appreciate the aspect of quality of goods and services and understand the importance of components of quality of life other than 'to have'. Consumers can also be educated in the area of sustainable consumption and economic knowledge, or smart *nudging* solutions can be used[31].

In June 2016 a conference organised by SCORAI (Sustainable Consumption Research and Action Initiative)[32] focused on the issue of *Transitions Beyond a Consumer Society*. This topic indicates the most urgent problem to solve in the area of sustainable consumption – how to develop a strategy for transition from a consumer society to a sustainable society, whose economy and culture are not primarily based on mass consumption.

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30 *Wskaźniki zrównoważonego rozwoju Polski*, Katowice 2011.

31 When *nudging* one arranges the choice situation in a way that makes a desirable outcome the easiest or the most attractive option. Nudging is currently one of the most promising tools for sustainable behaviour, see R. Thaler, C. Sunstain, *Impuls. Jak podejmować właściwe decyzje dotyczące zdrowia, dobrobytu i szczęścia*, Poznań 2008; O. Mont, M. Lehner, E. Heiskanen, *Nudging. A tool for sustainable behavior?* Swedish Environmental Protection Agency Report 6643, December 2014, www.swedishepa.se [26/10/2015].

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CONDITIONS FOR FULFILLING THE OBLIGATION OF THE RECOVERY AND RECYCLING OF COMPOSITE PACKAGING WASTE

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UWARUNKOWANIA REALIZACJI OBOWIĄZKU ODZYSKU I RECYKLINGU ODPADÓW OPAKOWAŃ WIELOMATERIAŁOWYCH

STRESZCZENIE: Odzysk i recykling odpadów opakowaniowych wielomateriałowych jest wielkim wyzwaniem dla systemu gospodarki odpadami komunalnymi. Opakowania wielomateriałowe stanowią tylko 1,62% całkowitej masy wszystkich opakowań. Kategoria ta obejmuje kilkadziesiąt różnych rodzajów opakowań. Ponadto, nie ma także typowych dla nich sposobów recyklingu. Powyższe czynniki powodują problemy w zapewnieniu efektywności ekonomicznej recyklingu, jak również trudności w zakresie organizacji i technologii tego procesu.

SŁOWA KLUCZOWE: gospodarka odpadami, odpady opakowaniowe, odzysk

Introduction

The recovery and recycling of composite packaging waste is a particular challenge for municipal waste management systems. Composite packaging accounts for only 1.62% of the total weight of packaging introduced to the market. The category of composite packaging includes several dozen various packaging types which are completely unrelated to each other, and they cannot be identified or recorded. Additionally, there are no common methods of recycling dedicated for them. The aforementioned factors cause problems in ensuring the economic efficiency of recycling, as well as difficulties in the area of the organisation and technology of this process. This paper includes results of research conducted under the project *Analysis of conditions for processing hazardous packaging waste and composite packaging waste in Poland.*

Characteristics of the stream of composite packaging waste

As defined in Polish legislation, the term composite packaging refers to "any packaging made of at least two different materials which cannot be separated by hand or by simple mechanical methods". The term 'material' refers here to solid substances with specific properties. Despite the precise definition of composite packaging, this category does not include packages made of different plastics which are classified in one group. This classification has been laid down in Commission Decision 97/129/EC establishing the identification system for packaging materials. The said decision in Annex VII relating to composites does not provide any identification system for packaging made of different types of plastic (plastic/plastic, plastic/plastic/plastic). However, plastics used for the production of packaging differ greatly in terms of physico-chemical characteristics, and therefore cannot be treated as a single material. The recycling of packaging combining different plastics requires the use of advanced technologies which are more complicated than the recycling of composite packaging in which paper is the predominant material.

Available statistics on the weight of composite packaging introduced to the Polish market show significant inconsistencies. For example, OŚ-OP2 reports for 2014 indicate that 80.1 K Mg of packages were introduced to the market, while reports by the chambers of commerce implementing agreements on recycling estimated this weight at 90 K Mg. The structure of the stream of composite packaging by type is presented in Figure 1.

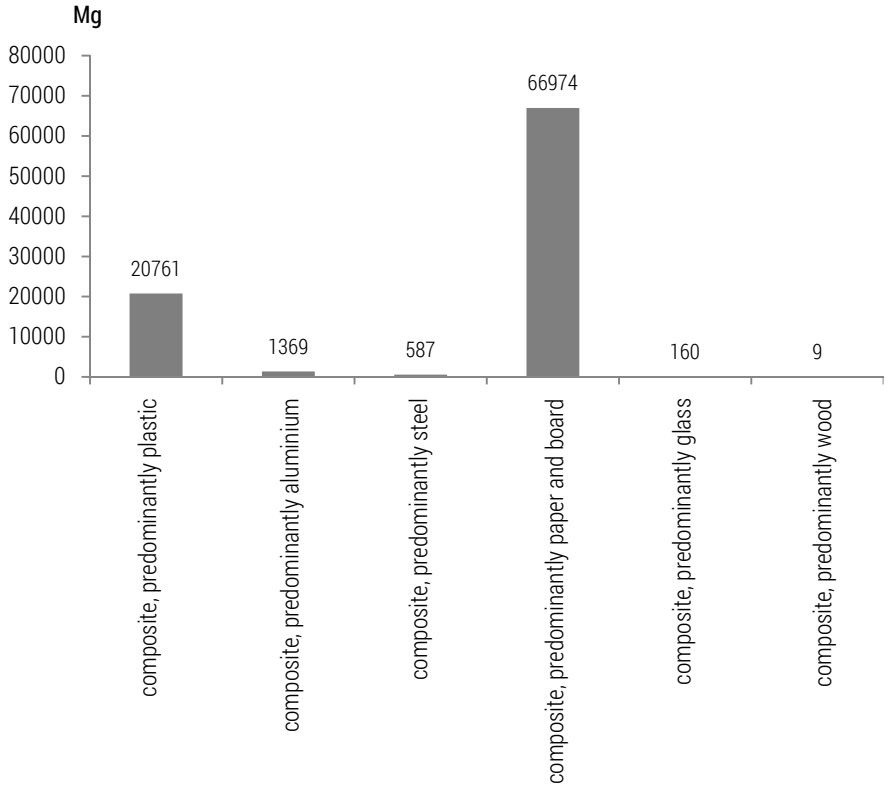


Figure 1. Weight and types of composite packages introduced in the market in 2014 according to the reports of chambers of commerce implementing agreements on recovery and recycling

Source: author's own analysis based on: Zbiorcze zestawienie informacji dotyczących funkcjonowania porozumień pomiędzy izbami gospodarczymi a marszałkami województw/Summary report on the implementation of agreements between chambers of commerce and marshals of provinces, www.mos.gov.pl [20/03/2016].

Composite packaging made predominantly of paper and board (67 K Mg) and plastic (21 K Mg) have the highest shares in the packaging waste stream. The share of other packages in the waste stream is marginal. In the category of packaging made predominantly of paper and board the highest share is reported for liquid food cartons. In the past 10 years a steady 2% yoy increase in the weight of cartons introduced to the market was observed, and in 2014 it reached the level of 66 K Mg. In European countries, and gradually also in Poland, food manufacturers are departing from the use of this type of

packaging. This is particularly important for the undertaken research problem because cartons are the only type of packaging potentially suitable for recycling, and at the same time, in accordance with existing regulations, they can be used to fulfil the obligations related to other composite packaging. Thus, the reduction in the weight of food cartons introduced to the market will cause problems in the fulfilment of obligations concerning the recovery and recycling of other composite packages.

Problems with the estimation of the actual stream of composite packages introduced to the market is even more serious if we consider the analysis of OPAK–1, OPAK–2 and OPAK–3 reports. According to statistics presented in these reports for 2013 (currently available data), 65 K Mg of composite packages were manufactured in Poland, 229 K Mg of packages were imported, while 112 K Mg of packages with products and empty packages were exported. The balance of these figures shows that over 181 K Mg of packages remained in Poland. As specified in the OŚ-OP–2 report, only 19 K Mg of these packages were introduced on the market in 2013 and 80 K Mg in 2014. Differences between data in OŚ-OP2 and OPAK reports, as one can guess, result to a significant extent from the erroneous classification of packages by businesses introducing them to the market. These misclassifications are either due to unawareness or a deliberate action motivated by lowering the costs related to the recovery and recycling obligations.

Obligation of recovery and recycling of composite packaging waste

The new law on packaging and packaging waste restores legal solutions existing before 1 April 2005 relating to composite packaging. It restores the category of composite packaging and specifies for it the same obligation of recovery and recycling as for single-material packaging, despite the fact that the reasons for which this category was liquidated are still valid.

By law, companies marketing packed products are obliged to reach a specific level of recovery and recycling of packaging waste of the same type as packaging in which their products were marketed. Recovery and recycling obligations were specified by establishing minimum targets of recovery and recycling. For composite packages the required recycling level is determined according to the predominant packaging material, and ultimately it will be the same as the level established for the same type of material in single-material packaging.

Businesses introducing single material packages on the market can either arrange for the recovery and recycling of packaging waste themselves, or

through a recovery organization. Businesses introducing composite packaging can also arrange recovery and recycling themselves, or through the chamber of commerce which has entered into a relevant agreement with the marshal of the province (Figure 2). This solution is an example of over-complicated law and an obstacle in running a business. For example, a company producing both single material packages and composite packages must conclude two separate agreements for the fulfilment of its obligations, one for the recovery and recycling of single material packaging waste with a recovery organization, and another for the recovery of composite packaging waste with a chamber of commerce.

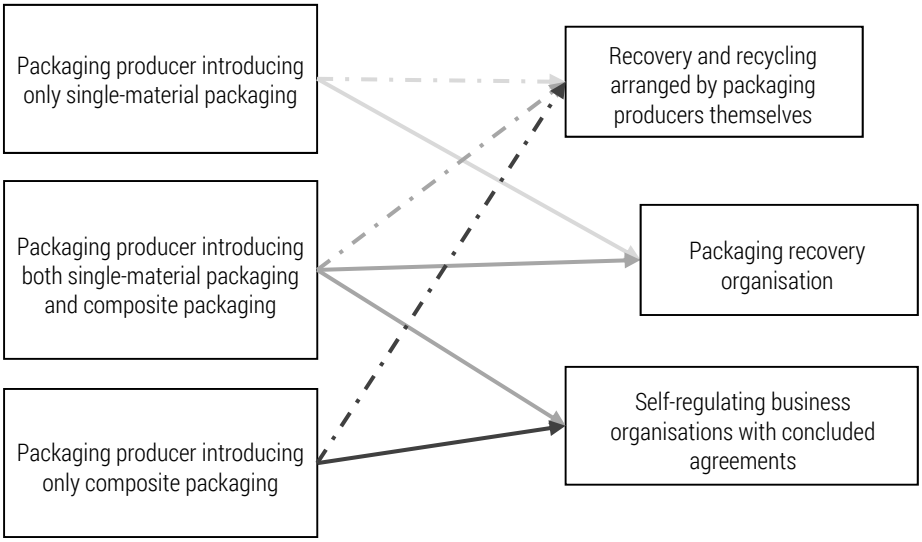


Figure 2. Methods of fulfilling the obligation of packaging waste recovery by packaging producers

At this point it should be emphasized that chambers of commerce acting as an intermediary organisation in the fulfilment of the obligation provide real security to the interests of businesses. Self-regulating business organizations, by principle, act solely in the interests of their members. Such a claim cannot be made with respect to recovery organizations established by private domestic or foreign investors, whose primary goal is to maximize the profit of company owners (with the exception of recovery organizations formed by business operators and acting on their behalf). Consequently, it would be reasonable to extend the powers of chambers of commerce in terms of the possibility to fulfil the obligation of the recovery and recycling of single-material packaging waste.

The *Law on packaging and packaging waste* introduced a new solution differentiating the statutory levels of recycling, depending on the way in which the obligation is fulfilled. Business operators who arrange the recovery of waste themselves are required to recover and recycle only packaging waste produced by them or packaging waste collected from other operators who introduced the same type and volume of packaging waste as those generated through the marketing of packed products. The target recovery rate in this case is 100%. Thus, the possibility of fulfilling this obligation by producers themselves is purely theoretical. Packaging producers are forced by legislators to cooperate with recovery organizations and provide them with sensitive information for their competitiveness in the market. The claim according to which the recovery organizations ensure proper implementation of the obligation remains valid only because for the last 16 years no effective system has been developed enabling the control of recyclers and the packaging recovery notes issued by them. A reliable system for the control of recyclers and PRNs issued by them, together with a system for PRNs trading (for example, a trading platform) would undermine the reason for the operation of agents helping to fulfil the said obligation.

Legislation establishes a transition period in reaching recovery targets when the obligation of the recovery and recycling of composite packaging waste is fulfilled through chambers of commerce. This solution results – as will be shown later in the article – from the insufficiently developed processing capacity, which prevents the fulfilment of the obligation imposed on packaging producers. Recovery and recycling targets for composite and single material packaging waste will be brought to the same level not earlier than in 2020.

Currently in Poland 10 agreements have been concluded between the marshals of provinces and self-regulating business organizations for the establishment and maintenance of systems of collection, transport, recovery or disposal of composite packaging waste. These agreements are listed in Table 1.

Table 1. Agreements concluded between self-regulating business organisations under Article 25 of the Law on packaging and packaging waste for the fulfilment of the obligation of the recovery and recycling of composite packaging waste

No.	Marshal of province	Self-regulating business organization	Date of conclusion
1	Łódzkie	Polska Izba Odzysku i Recyklingu Opakowań	09/07/2014
2	Mazowieckie	Krajowa Izba Gospodarcza Przemysłu Spożywczego i Opakowań	11/02/2014
3	Mazowieckie	Krajowa Izba Gospodarcza	27/03/2014
4	Mazowieckie	Polska Izba Gospodarcza „Ekorozwój"	07/04/2014
5	Mazowieckie	Izba Przemysłowo Handlowa Inwestorów w Polsce	07/07/2014
6	Mazowieckie	Związek Pracodawców „Izba Recyklingu i Odzysku Odpadów"	18/05/2015
7	Śląskie	Polska Izba Ekologii	22/07/2014
8	Śląskie	Izba Gospodarcza Metali Nieżelaznych i Recyklingu	22/07/2014
9	Zachodniopomorskie	Północna Izba Gospodarcza w Szczecinie	27/08/2014
10	Małopolskie	Ogólnopolska Izba Gospodarcza Ochrony Środowiska	15/09/2015

Source: author's own analysis based on information from marshals' offices.

Processing capacity for composite packaging waste

The fulfilment of the recovery and recycling obligation depends on the processing capacity and efficient waste collection system, which determines the supply of material for recycling. Currently in Poland the recycling capacity of composite packaging waste is created by:

1. Four systems for processing liquid food cartons, with an annual capacity of 16 K Mg: Mondi Świecie SA, Fabryka Papieru i Tektury "Beskidy" SA Wadowice, and TOP S.A. Tychy. Because packaging producers have signed agreements for recycling liquid food cartons with foreign service providers, the actual available processing capacity for waste collected in Poland is about 11.5 K Mg. When investment is completed at Fabryka Papieru i Tektury BESKIDY SA, the processing capacity of this plant will increase by 10 K Mg, but it is difficult to specify how much of this capacity will be allocated to the recycling of cartons coming from Polish and foreign markets. Assuming that the future capacity will be used only for recycling

packaging waste collected from Poland, the actual recycling capacity of cartons in 2017 will be at the level of 21.5 K Mg.

2. One plant processing packaging waste made of plastic composites, composites containing predominantly plastics and liquid food cartons – PMP Recykl in Ćmielów. The current capacity of this plant is up to 3 K Mg, but it processes both municipal waste and waste collected from the production of packaging. The actual capacity of the system operated by PMP Recykl in processing municipal waste is estimated at 1.5 K Mg. The company is planning investments to increase its processing capacity by 2 K Mg.

Poland has a sufficient processing infrastructure with respect to the fulfilment of the obligation to recover composite packaging waste, which includes:

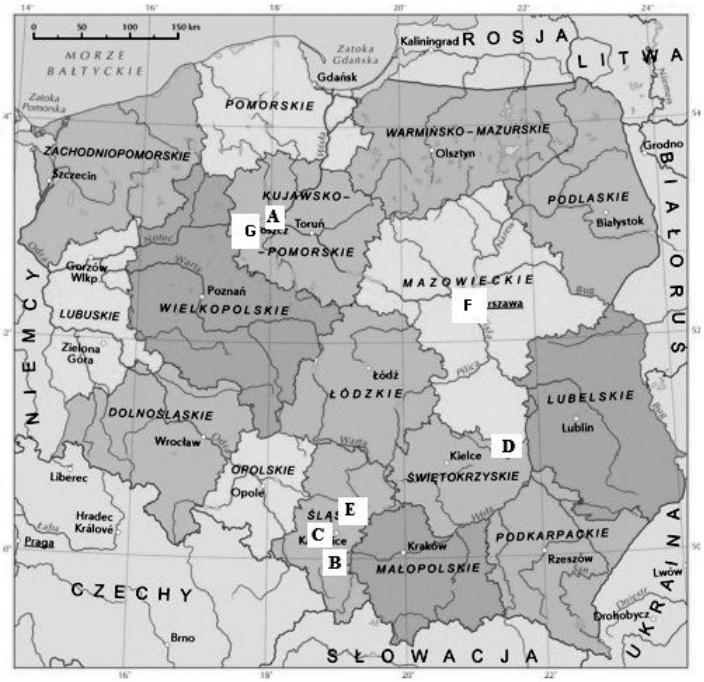


Figure 3. The location of plants for the recovery and recycling of composite packaging waste (except cement plants)

Legend:
A – Mondi Świecie SA
B – Fabryka Papieru i Tektury "Beskidy" SA Wadowice
C – TOP S.A. Tychy
D – PMP Recykl Ćmielów
E – Veolia – SARPI Dąbrowa Górnicza
F – Incineration plant for municipal waste in Warsaw
G – Incineration plant for municipal waste in Bydgoszcz

- incineration plants for hazardous waste (SARPI Dąbrowa Górnicza, capacity for code 15 01 05 – 14 K Mg per annum),
- operating, as well as soon-to-be-open incineration plants for municipal waste,
- refuse derived fuel (RDF) systems; co-incineration at cement plants is widely used for the processing of polyethylene and aluminium, which are by-products of shredding liquid food cartons; the processing capacity of cement plants operating refuse derived fuel systems in Poland is estimated at 1.5 million Mg, of which 900 K Mg is utilised[1]; leaving about 600 K Mg capacity available.

The location of plants for the recovery and recycling of composite packaging waste (except cement plants) is presented in Figure 3.

In terms of an effective system of separate collection the identified problems include: insufficiently developed systems for the separate collection of composite waste in municipalities, the lack of understanding of the concept of composite packaging, and the ability to distinguish composite packaging from single material ones among Poles. Despite the provisions of Article 3 clause 2 section 3 of the Act on maintaining cleanliness and order in municipalities[2], as many as 382 municipalities do not carry out the separate collection of composite waste[3].

In most other municipalities composite packaging waste is collected only in theory. Regulations specify that composite waste should be separated but citizens do not comply with this obligation and are also unaware that this type of waste exists. This problem will be a key driver in the fulfilment of the obligation in the coming years. It should also be emphasized that local authorities feel totally without obligation as regards non-compliance with the law on waste and the responsibilities associated with it.

Feasibility of fulfilling recycling obligations

To assess the feasibility of fulfilling recycling obligations the target volume of waste that has been established for subsequent years has to be compared against the available processing capacity. The analysis should be

1 G. Wielgosiński, *Co można nazwać paliwem alternatywnym?,* www.mos.gov.pl [20/03/2016].

2 Ustawa z dnia 13 września 1996 r. o utrzymaniu czystości i porządku w gminach/Law of 13 September 1996 on maintaining cleanliness and order in municipalities, Dz.U. 1996 No. 132 item 622 as amended.

3 T. Styś, P. Zieliński, *Rynek gospodarowania odpadami opakowaniowymi w Polsce. Wybrane regulacje i ich implementacja*, Warszawa, September 2015.

focused on the feasibility of fulfilling the obligation with respect to composite packaging waste made predominantly of plastic, as well as paper and board.

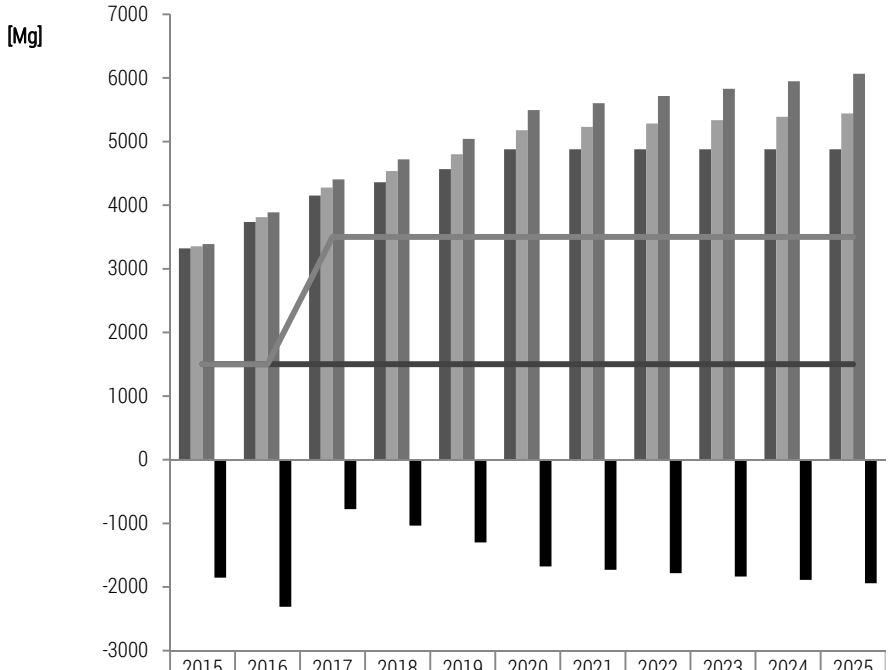
As previously mentioned, Poland has one plant for the processing of municipal composite packaging waste made predominantly of plastic, and it has a capacity of about 1.5 K Mg, which can be increased through investments up to 3.5 K Mg. The recycling capacity for composite packaging waste made predominantly of plastic is therefore very limited. The feasibility analysis for the fulfilment of recycling obligations was carried out considering the existing processing capacity for three scenarios describing the growth in the weight of packaging introduced to the market:

1. constant scenario (WCTW) – the weight of packaging introduced to the market remains at the same level as in year 2014,
2. 1% growth scenario (W1TW) – the weight of packaging introduced to the market increases at a rate of 1% per year until 2025,
3. 2% growth scenario (W2TW) – the weight of packaging introduced to the market increases at a rate of 2% per year until 2025.

According to the W1TW scenario, the weight of packaging placed on the market will grow from the current level of 21 K Mg to 22 K Mg in 2020 and 23.2 K Mg in 2025. If we assume the W2TW scenario, the waste stream will reach 23.4 K Mg in 2020 and 25.8 K Mg in 2025. The weight of packaging waste that needs to be recycled in subsequent years by 2025 in accordance with the current levels for packaging producers arranging recovery through self-regulating business organisations is presented in Figure 4.

The presented analysis clearly indicates the impossibility to fulfil the obligation of recycling composite packaging waste containing predominantly plastic. The obligation can only be fulfilled through the inclusion of liquid food cartons in calculating the balance. The deficit in recycling capacity in 2016 has been estimated at 2.3 K Mg. In subsequent years the level of this deficit will depend on the completion of the investment at PMP Recykl. If this investment is completed, the deficit will drop to 1.7 K Mg in 2020 and 2 K Mg in 2025. Otherwise, the deficit in recycling potential will grow to about 4 K Mg in 2020 and 4.5 K Mg in 2025.

To ensure packaging producers the possibility of meeting their obligations the recycling capacity has to be increased to 3.8 K Mg in 2016, to 5.5 K Mg in 2020, and to 6 K Mg in 2025. It has been estimated that to reach statutory targets after 2020 two processing plants with capacity up to 5 K Mg would have to be built. This capacity will be used for municipal waste as well as packaging waste supplied by packaging producers. Considering the location of the existing plants, it would be best to establish the new ones in north and south-west Poland.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
WCTW	3322	3737	4152	4360	4567	4879	4879	4879	4879	4879	4879
W1TW	3355	3812	4278	4537	4800	5179	5231	5283	5336	5389	5443
W2TW	3388	3888	4406	4719	5043	5494	5604	5716	5831	5947	6066
DP - W1TW	-1855	-2312	-778	-1037	-1300	-1679	-1731	-1783	-1836	-1889	-1943
APR	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
PPR	1500	1500	3500	3500	3500	3500	3500	3500	3500	3500	3500

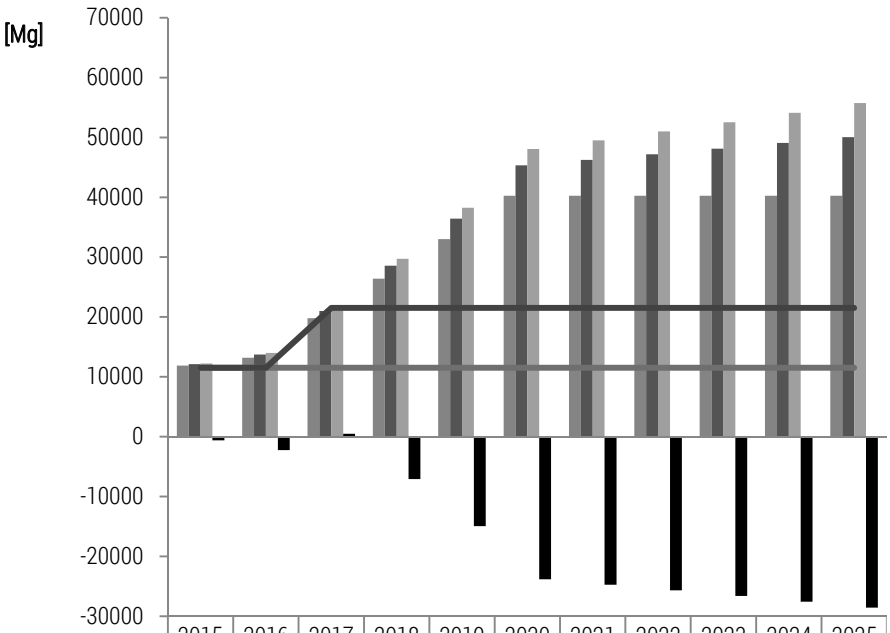
Figure 4. The weight of composite packaging waste made predominantly of plastic that has to be recycled before 2025 in line with the existing recycling targets specified in the Regulation of the Minister of the Environment (Dz.U. 2014 item 618)

Legend:
APR – current recycling capacity
PPR – future recycling capacity (including the increased processing capacity of PMP Recykl in Ćmielów by 5 K Mg)
DP-W1TW – deficit/surplus of recycling capacity for the W1TW scenario

Source: W. Piontek, S. Jarzębowski, op. cit.

Packaging made predominantly of paper and board is particularly important for at least three reasons: the stream of packaging entering the market, the increase in the statutory target of recycling from 18% to 61% in just 5 years, and the fact that this category of packaging is recovered by packaging producers marketing products in other types of composite

packaging to comply with statutory obligations. The target level of recycling (61%) should be considered the upper limit of system performance. Analyses and consultations with experts carried out to date suggest that it is impossible to achieve a level of recycling for liquid food cartons higher than 61% of the total packaging stream.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
WCPT	11880	13200	19800	26400	33000	40260	40260	40260	40260	40260	40260
W2PT	12118	13733	21012	28576	36435	45339	46246	47171	48114	49077	50058
W3PT	12236	14004	21636	29713	38256	48073	49515	51000	52530	54106	55729
DP-W2PT	-618	-2233	488	-7076	-14935	-23839	-24746	-25671	-26614	-27577	-28558
APR	11500	11500	11500	11500	11500	11500	11500	11500	11500	11500	11500
PPR	11500	11500	21500	21500	21500	21500	21500	21500	21500	21500	21500

Figure 5. The weight of waste liquid food cartons that have to be recycled before 2025 in line with the existing recycling targets specified in the Regulation of the Minister of the Environment (Dz.U. 2014 item 618)Legend:

APR – current recycling capacity
PPR – future recycling capacity (including investment being implemented at Beskidy SA)
DP-W2PT – deficit/surplus of recycling capacity for scenario W2PT

Source: W. Piontek, S. Jarzębowski, op. cit.

Three scenarios of changes in the stream size have been considered to estimate the weight of liquid food cartons in subsequent years:

1. constant scenario (WCPT) – the weight of packaging introduced to the market remains at the same level as in 2014,
2. 2% growth scenario (W2PT) – the weight of packaging introduced to the market increases at a rate of 2% per year until 2025,
3. 3% growth scenario (W3PT) – the weight of packaging introduced to the market increases at a rate of 3% per year until 2025.

Under the adopted assumptions the weight of waste cartons for liquid food will account for 66 to 79 K Mg in 2020 and 66 to 92 K Mg in 2025. The W2PT scenario is the most probable one. The weight of packaging waste containing predominantly paper and board that needs to be recycled in subsequent years by 2025 in accordance with the current statutory targets for fulfilling the obligation through self-regulating business organisations is presented in Figure 5.

To meet statutory targets at least 13–14 K Mg of liquid food cartons will have to be recycled in 2016, but the available processing capacity is 11.5 K Mg. The statutory target for the recycling of food cartons will increase to 40–48 K Mg in 2020 and 40–56 K Mg in 2025. Even if we consider the increased processing capacity after the completed investments, by 2025 Poland will face a permanent deficit in recycling capacity for composite packaging waste containing predominantly paper and board. The deficit in processing capacity will reach about 24 K Mg in 2020 and about 29 K Mg in 2025. New processing plants should be located in west and east Poland.

Currently, Poland also lacks recycling plants designed for separating polyethylene and aluminium from shredded liquid food cartons. This type of waste is recovered in the refuse derived fuel (RDF) systems at cement plants. Even though the incineration of polyethylene and aluminium is an exothermic process, it still leads to the loss of valuable non-renewable resources.

Conclusions

The analysis focused on the factors determining the fulfilment of recovery and recycling obligations with respect to composite packaging waste has led to three major conclusions:

1) recovery and recycling obligations have to be defined in more detail to enable their correct fulfilment; the establishment of a new category of *multilayer plastic packaging* should be considered in order to cover composite packages made of different types of plastic; the same obligations

should pertain to this new category of packaging and composite packaging,

2) the fulfilment of recycling obligations in subsequent years depends on the growth in processing capacity and effective separate waste collection,
3) lowering of the minimum recycling targets should be considered until the construction of new processing plants is completed; the existing targets disable the fulfilment of statutory obligations by packaging producers and thus force them to pay the product fee.

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DEVELOPMENT OF WATER AND WASTEWATER MANAGEMENT IN THE EASTERN PROVINCES OF POLAND

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ROZWÓJ INFRASTRUKTURY GOSPODARKI WODNO-ŚCIEKOWEJ W WOJEWÓDZTWACH WSCHODNIEJ POLSKI

STRESZCZENIE: Celem tego artykułu jest zwrócenie uwagi na rozwój gospodarki wodno-ściekowej w Polsce Wschodniej i porównanie do sytuacji w pozostałej części kraju. Dowiedziono znaczący rozwój we wszystkich elementach infrastruktury wodno-ściekowej. Jednakże największy wzrost został zaobserwowany w obszarze infrastruktury odpowiedzialnej za transport, magazynowanie i utylizację ścieków. Zrealizowane inwestycje zminimalizowały istniejącą różnicę infrastrukturalną pomiędzy województwami Polski Wschodniej a pozostałą częścią kraju. W tym zakresie kluczową rolę odegrały fundusze z Unii Europejskiej. Bez nich nie byłaby możliwa tak złożona I szybka modernizacja, a także rozbudowa poszczególnych elementów infrastruktury związanej z gospodarką wodno-ściekową. W artykule podkreślono również konieczność prowadzenia dalszych inwestycji, które powinny być skierowane na obszary wiejskie.

SŁOWA KLUCZOWE: sieć wodno-kanalizacyjna, ścieki, obszary wiejskie, fundusze Unii Europejskiej

Introduction

The concept of development is related to some sort of purposeful and irreversible continuous changes occurring within the structure of complex objects, i.e. systems. Those changes may refer to the quantitative aspect, therefore augmentation or dwindling of certain object features, as well as to their quantitative aspect, i.e. emergence of new object features[1]. With reference to these regions this concept is commonly perceived as a broadly understood socio-economic development. It is important to note that spatial differentiation of region development with reference to individual areas has often subjective character and results from the geographical area diversification[2,3].One of the basic elements determining appropriate regions development in area of social and as well as economic realm is an adequate level of technical infrastructure. Transmission networks and nodal infrastructure related to the water and wastewater management are part of this mentioned infrastructure. This management plays a meaningful role in the regions development. It is the base of long-range changes through the elevation of population life standard and investment attractiveness whilst simultaneously protecting the natural environment.

Enlargement of the European Union highlighted the problem of differences in the interregional development in the whole Commonwealth as well as in the individual countries. The intensification of economic integration in the Europe turned out to be most beneficial in case of better developed countries and regions. In less developed areas a number of disadvantageous phenomena such as a lack of stimulus for continuous development, low social activity and entrepreneurship or strengthening population low life standard have been observed. It should be noted that in the longer time perspective the persistence of excessive differences between regions is unprofitable for socio-economic development of individual countries and whole European Union[4].

Provinces in Poland in terms of development are often divided into four groups. The highest level of development occurs in Mazovian Province and amounts to 70% of the European mean, for the EU-25. The second group con-

1 S. Kurek, *Przestrzenne zróżnicowanie poziomu rozwoju regionalnego w Unii Europejskiej w świetle wybranych mierników*, „Prace Komisji Geografii Przemysłu" 2010 nr 16, s. 87.

2 Z. Szymla, *Podstawy badań rozwoju regionalnego*, „Zeszyty Naukowe Wyższej Szkoły Ekonomicznej w Bochni" 2005 nr 3, s. 102.

3 A. Dubel, L. Preisner, *Ryzyko powodzi i suszy: osiągnięcia i wyzwania*, „Gospodarka Wodna" 2015 nr 8, s. 246.

4 Program Operacyjny Rozwój Polski Wschodniej 2007-2013, www.porpw.parp.gov.pl [15-02-2016]

sists of provinces with development level amounting at around 45% of the European mean, i.e. Silesian, Greater Poland, Lower Silesian and Pomeranian. To the third group one may account six provinces with development level equal to the 40% of European mean. To the last group which is characterized by the lowest level of development (about 33% of the European mean) one may count among: Warmian-Masurian, Podlaskie, Lublin, Świętokrzyskie and Podkarpackie provinces[5]. Listed group of provinces, under the common name Eastern Poland (EP) belongs to the regions of the lowest development level amongst all European Union regions.

The aim of this paper was to conduct the analysis and assessment of water and sewage management development in the Eastern Poland, with reference to the situation in remaining country regions. The area of study selection was dictated by the willingness to verify the consequences of increased efforts and founds dedicated to the elimination of broadly understood underdevelopment of this part of Poland. In this paper attention has been paid to the water and wastewater management, because it is perceived as a determinate factor of an appropriate region development.

Materials and methods

The source of data used in this study was the Local Data Bank of Central Statistical Office in Poland and Yearbooks of the Environmental Protection. Information regarding founds dedicated to the realization of selected investments in area of water and sewage infrastructure was obtained from the Polish Ministry of Regional Development website[6]. In this research common statistical parameters and selected measures and indicators have been applied. The analysis of processes intensity has been done by means of measures calculated based on: the population (people served by waterworks and sewage system) and with reference to the area (waterworks and sewage system saturation). The chain index of dynamics has been determined, which principle is to pertain the current level of investigated phenomenon to the level from the preceding period.

In order to visualize the obtained results a cartographic method of diagram map has been applied. It enabled simultaneous presentation of water volume consumption and waterworks saturation. A significant advantage of this method is the possibility of spatial quantitative analysis which makes it easier to discern existing dependencies.

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5 K. Fiedorowicz, J. Duda, *Polska Wschodnia-warunki wyjścia z niedorozwoju*, „Nierówności Społeczne a Wzrost Gospodarczy" 2007 nr 11, s. 612.

6 Ministry of Regional Development, www.mapadotacji.gov.pl [10-02-2016]

Results and discussion

In the mid-1990s the water and wastewater infrastructure on the area of whole country was significantly underfunded. In this respect significant discrepancies existed amongst individual provinces and within themselves. Particularly visible was disproportion between analyzed infrastructure in cities and rural areas, for the benefit of the first ones[7,8]. It is important to underlie that the total length and number of waterworks connections was several times greater than those of sewage systems.

In the years 1995-2013 the total length of waterworks increased by about several dozen percent. The Eastern Poland provinces at the background prevalent number of regions were characterized by the greatest increase in terms of the waterworks length. It did not translate into an adequate increase of waterworks connections, except Świętokrzyskie and Podlaskie provinces. This indicates much greater dispersed development in the remaining three provinces of the Eastern Poland. A confirmation in that regard may be a significantly lesser population density, which is one of the lowest in Poland.

Development of sewage system in the analyzed period was characterized by a much greater dynamics than it was in the case of waterworks. The mean annual growth rate is a confirmation of this phenomenon, which in reference to the sewage systems amounted from 5.6 to 13.1% (on average 7.6%) and in case of waterworks from 1.5 to 6.1% (on average 3.3%). As a result, in most of the provinces the total length of sewage system increase two or even three times. In the Eastern Poland provinces the length of analyzed network increased to the same extent an exception is Podkarpacie Province where this growth was almost nine fold. What is more this dynamic development of sewage system was accompanied by a simultaneous increase in number of household's connections (table 1).

Juxtaposition of waterworks and sewage system saturation indices (figure 1) points out to the increase of their value and a decrease in disproportion between provinces. Amongst EP provinces the situation underwent significant improvement, however to a different extent. Present waterworks and sewage system saturation in EP provinces is relatively high and does not significantly deviate from remaining provinces. One negative example is Pod-

7 B. Pięcek, *Infrastrukturalne uwarunkowania rozwoju przedsiębiorczości na obszarach wiejskich*, w: M. Kłodziński, A. Rosner (red.), *Ekonomiczne i społeczne uwarunkowania i możliwości wielofunkcyjnego rozwoju wsi w Polsce*, Warszawa 1997, s. 118.

8 I. Kropsz, *Zastosowanie metody analizy skupień oraz wielowymiarowej analizy korespondencji do oceny poziomu infrastruktury obszarów wiejskich*, "Journal of Agrobusiness and Rural Development" 2009 nr 3(13), s. 129.

Table 1. Changes in water and wastewater networks length along with the number of household's connections by provinces in the years 1995-2013

Province	Waterworks			Sewage system			Waterworks connections			Sewage connections		
	1995	2013	1995-2013	1995	2014	1995-2013	1995	2013	1995-2013	1995	2014	1995-2013
	[kkm]		[%]	[kkm]		[%]	[kkm]		[%]	[kkm]		[%]
Lublin	9,8	20,6	109,2	1,5	5,5	260,5	193,4	358,8	85,5	28,1	117,0	316,5
Podkarpacie	7,8	14,2	82,4	1,5	15,1	929,0	163,9	315,4	92,4	30,5	254,7	734,1
Podlasie	6,0	13,1	119,7	0,7	3,2	324,9	106,5	188,0	76,4	15,8	84,5	433,9
Świętokrzyskie	5,8	13,2	126,0	0,9	5,2	456,5	111,6	239,8	114,8	21,4	98,1	358,2
Warmia-Masuria	6,3	15,3	144,0	1,7	6,3	281,2	95,8	165,7	72,9	28,9	88,3	205,1
Lower Silesian	9,6	15,1	57,4	3,4	9,6	180,6	193,7	331,5	71,1	84,5	202,3	139,5
Kuyavian-Pomeranian	13,8	22,7	64,9	1,9	7,4	292,1	169,5	269,6	59,1	44,1	141,3	220,3
Lubuskie	3,7	6,7	80,4	1,0	3,3	225,3	76,4	129,0	68,9	23,6	65,2	176,7
Łódź	12,8	22,4	75,5	2,0	6,0	197,0	229,9	382,1	66,2	37,5	135,2	260,7
Lesser Poland	10,3	18,5	78,9	2,6	12,4	384,5	251,1	437,5	74,3	57,6	251,7	337,3
Mazovia	13,8	42,3	206,2	3,6	13,1	265,9	261,8	715,1	173,2	64,8	312,7	382,8
Opole	5,0	7,1	42,0	0,8	4,0	385,0	113,7	161,7	42,2	21,5	90,2	320,5
Pomerania	8,4	15,0	79,3	2,5	9,6	281,9	151,4	268,3	77,2	56,6	182,9	223,1
Silesia	15,4	20,5	33,3	4,4	13,5	206,2	402,0	591,9	47,3	98,2	321,7	227,4
Wielkopolska	20,9	30,4	45,0	2,7	11,5	326,5	340,8	538,5	58,0	69,6	294,1	322,6
West Pomeranian	6,1	10,6	73,3	2,3	7,3	219,8	117,4	180,3	53,6	49,9	124,1	148,6

Source: own elaboration based on Local Data Bank CSO data.

laskie province in which the sewage system length saturation remained at a relatively low level (15.7 km per 100 km^2).

Despite significant development of water and wastewater infrastructure in the analyzed period of time, a simultaneous decrease in terms of consumed water which leads to smaller volume of wastewater is being observed in the whole country. This situation results from the changes in the industry which occurred at the break of the 1980-90 of 20th century. The socio-economic transformation forced dismantling of many manufacturing facilities and extorted their liquidation[9]. At the same time these were the factories which could be characterized by a significant consumption of water. In case of households the factor which led to a decrease in consumed water was an introduction of measuring devices and increase in water prices. Additionally in the analyzed period the waster squandering has been minimized thanks to modern apparatus and the modernization of waterworks and sanitary devices[10].

The greatest decline in terms of consumed water and resulting wastewater were observed in most industrialized regions. Easter Poland provinces, except Świetokrzyskie are characterized by a relatively low number of water intensive branches of economy. Therefore the observed decline in consumed water in those regions was relatively low.

Intensive development of water and wastewater infrastructure led to a meaningful increase in number of population served by these facilities (table 2). A significant growth was observed in case of population having access to sewage systems. In the Eastern Poland provinces the increase in population using both elements of mentioned infrastructure belonged to the highest. It is important to note that this index gained much more in rural areas than in cities. A relatively high share of population served by sewage system occurs in rural areas of Subcarpathian province. It results from very high rural population in this region[11].

Despite significant growths the population served by water and wastewater infrastructure in the Eastern Poland regions remains at the lowest level in the whole country.

Because not always from an economic and technical point of view an investment in sewage system is possible, it is essential to equip those areas

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9 H. Hotloś, *Badania zmian poboru wody w wybranych miastach Polski*, „Ochrona Środowiska" 2010 nr 32(3), s. 39.

10 W. Marszelewski, A. Piasecki, *Analiza rozwoju infrastruktury ściekowej w Polsce w aspekcie ekologicznym i ekonomicznym*, „Zeszyty Naukowe SGGW Polityka Europejska, Finanse i Marketing" 2014 nr 11(60), s. 128.

11 A. Czudec, *Ekspertyza dotycząca województwa Podkarpackiego*, w: *Ekspertyzy do Strategii Rozwoju Społeczno-Gospodarczego Polski Wschodniej do roku 2020*, t. 2, Warszawa 2007, s. 845.

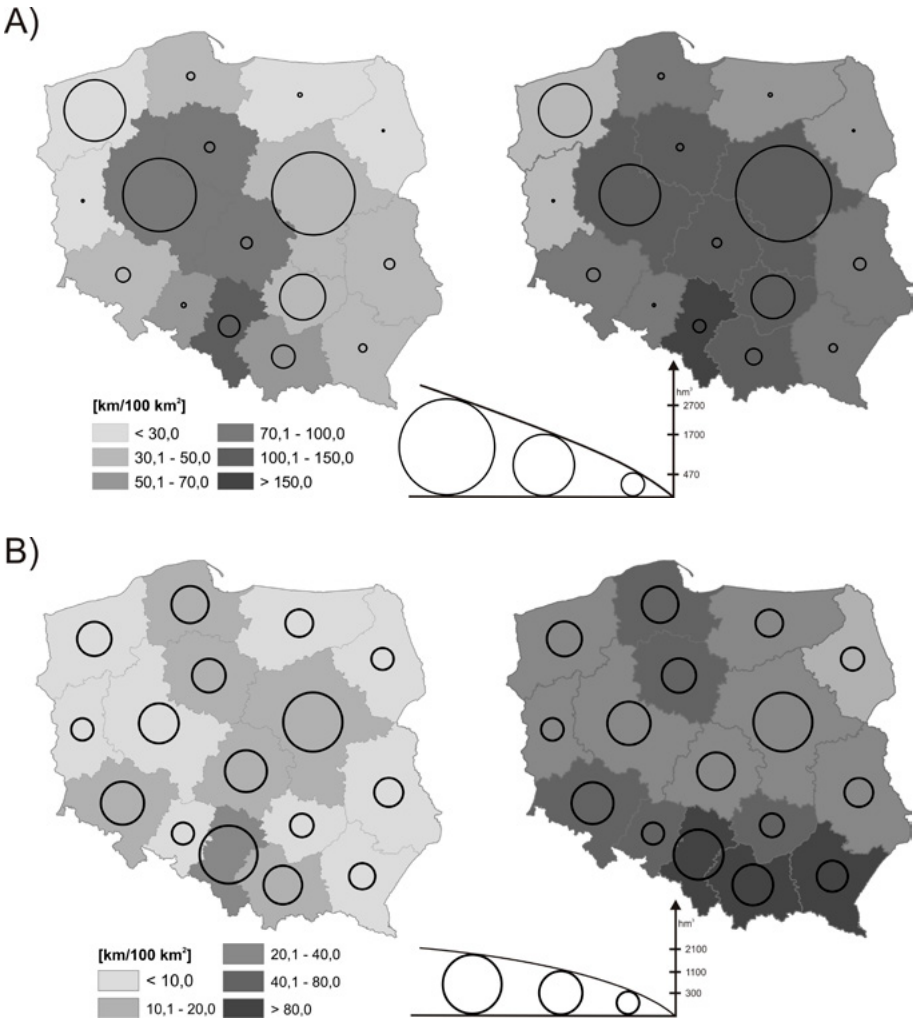

Figure 1. Waterworks (A) and sewage system (B) saturation, consumed water (A) and discharged wastewater

Source: own elaboration based on Local Data Bank CSO data.

with installations enabling storage and then reprocessing of impurities. Till the end of the 20th century the most common solution were holding tanks so called cesspools (figure 2). Currently the greatest number of holding tanks is located in Mazovia and Łódź Provinces however this value is systematically decreasing.

Table 2. Population served by waterworks and sewage system, by provinces

Province	Waterworks						Sewage system					
	overall		city		village		overall		city		village	
	[%]						[%]					
Lublin Province	77,1	81,9	92,7	94,0	63,5	71,5	43,0	49,7	83,5	86,7	7,6	17,7
Podkarpacie Province	72,4	76,7	90,5	92,4	60,0	65,7	44,5	62,6	81,7	86,9	19,3	45,5
Podlasie Province	84,8	88,2	95,2	96,1	69,9	76,2	55,3	62,1	85,9	90,4	11,3	19
Świętokrzyskie Province	79,6	84,8	93,6	95,1	67,7	76,5	41,1	52,5	80,9	85	7,6	26,1
Warmia-Masuria Province	86,4	89,4	96,9	97,5	70,6	77,7	62,1	68,3	90,8	93,1	18,7	32,3
Lower Silesian Province	90,3	92,1	96,4	96,9	75,1	81,2	55,0	60,9	80,8	85,1	7,3	19
Kuyavian-Pomeranian Province	89,2	91,2	95,7	96,2	78,4	83,7	55,5	64,7	81,6	87,8	8	23,2
Lubuskie Province	86,9	89,9	94,9	96,0	72,5	79,4	45,7	56,0	80,6	85,9	10,5	27,6
Łódź Province	88,0	89,9	93,9	94,5	77,1	82,0	65,5	71,5	78,8	82,9	15,4	32,3
Lesser Poland Province	70,5	76,4	90,3	94,1	50,6	59,6	58,9	65,5	84	88,4	13,4	26,2
Mazovia Province	77,6	84,5	88,5	91,8	57,9	71,5	54,7	64,6	82,7	88	16,6	35,8
Opole Province	94,1	94,6	97,3	97,5	90,6	91,5	72,1	77,5	89,2	90,8	33,1	48,3
Pomerania Province	91,2	93,1	97,1	98,1	78,7	83,9	64,8	70,8	83,6	87,2	18,1	33,5
Silesia Province	92,6	93,6	96,7	97,2	77,1	81,4	50,1	63,3	85,1	88,1	11,5	36,2
Wielkopolska Province	91,2	93,1	95,9	96,8	84,8	88,5	59,2	66,1	84,5	88,6	17,6	32,3
West Pomeranian Province	92,7	93,7	96,6	96,9	83,7	86,7	71,3	77,9	91,8	94	27,9	48

Source: own elaboration based on Local Data Bank CSO data

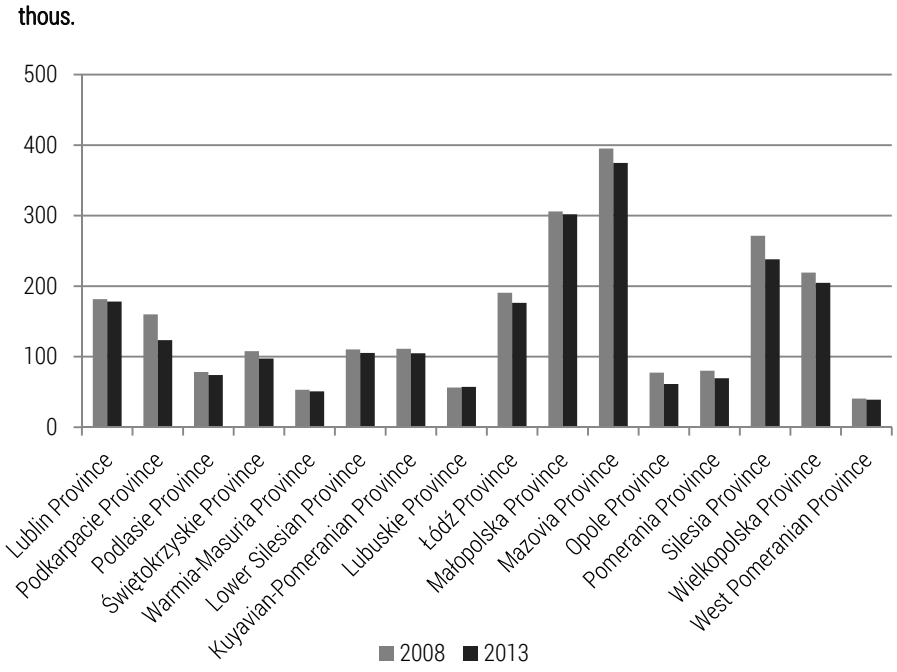

Figure 2. Number of wastewater holding tanks in the year 2008 and 2013

Source: own elaboration based on Local Data Bank CSO data.

Mainly ecological concerns caused that in recent years on non-sewered areas household treatment plants became a preferable solution (figure 3). The growth in terms of the number of individual wastewater treatment plants in the Eastern Poland was highest in Lublin province. Equally significant increase was observed in Podlaskie. It is important to highlight that both of these provinces were characterized by the lowest index of sewage system saturation. A contrary phenomenon occurred in the Podkarpacie province were the intensive development of sewage systems fulfilled population needs. However a relatively low number of individual wastewater treatment in Warmian-Masurian is a disturbing fact. In this case an ecological aspect is of vital importance, considering the large number of lakes prone to eutrophication.

For several years wastewater generated in municipal areas underwent only mechanical treatment, occasionally biological or chemical one. Poland accession to the European Union forced adjustment of national law and infrastructure to the commonwealth standards[12]. In consequence the increase in

[12] L. Kłos, *Stan infrastruktury wodno-kanalizacyjnej na obszarach wiejskich w Polsce a wymogi ramowej dyrektywy wodnej*, „Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania" 2011 nr 24, s. 75.

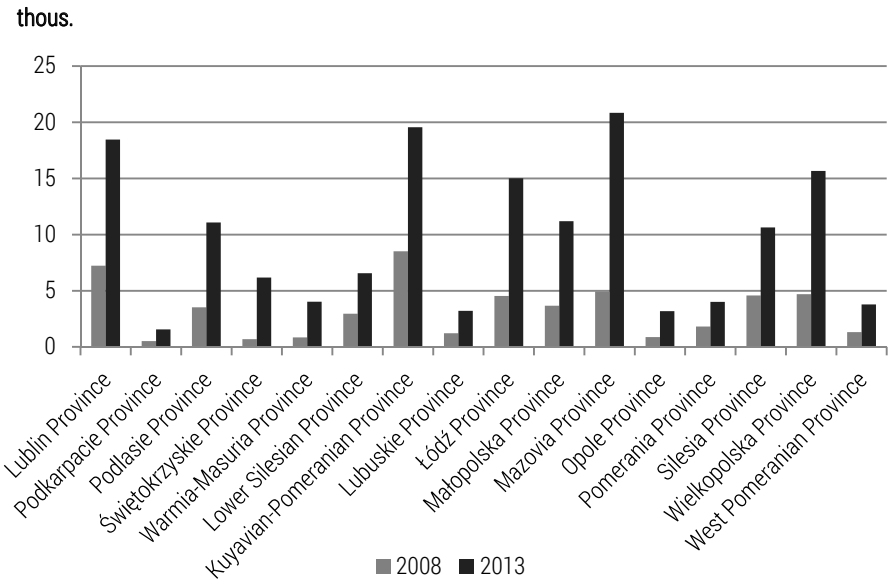

Figure 3. Number of individual treatment plants in the year 2008 and 2013
Source: own elaboration based on Local Data Bank CSO data.

number of biological wastewater treatment plant and those with increased bio gene removal (table 3). From an ecological point of view particularly important are wastewater treatment plants with increased bio gene removal. In comparison to other provinces the number of such plants in the Eastern Poland is relatively big. The greatest progress has been observed in Warmian-Masurian province. This fact should be perceived as a very positive one considering the previous remarks about other elements of water and wastewater infrastructure.

A swift orderliness of water and wastewater management in the area of largest cities was one of the priority targets created by the EU for Poland. The main problem was the amount of founds which should be spend to fulfill those requirements. The cost of creating water and wastewater infrastructure in cities are very high and result mainly from their complexity, the size of the whole waterworks and sewage system and local conditions. What is more a significant amount of funds had to be reserved for wastewater treatment plants and water intakes.

Table 3. Number of wastewater treatment plants by kind in the years 1995-2013

Provine	Wastewater treatment plants								
	mechanical			biological			with increased bio gene removal		
	1995	2004	2013	1995	2004	2013	1995	2004	2013
Lublin Province	4	13	9	75	187	246	4	22	31
Podkarpacie Province	6	5	0	49	153	190	2	31	37
Podlasie Province	0	0	1	28	67	83	1	33	30
Świętokrzyskie Province	5	2	0	28	59	80	0	30	35
Warmia-Masuria Province	17	6	0	44	115	166	3	60	66
Lower Silesian Province	14	1	5	92	141	159	2	57	66
Kuyavian-Pomeranian Province	13	2	0	54	88	109	1	31	31
Lubuskie Province	10	5	0	26	59	83	2	25	27
Łódź Province	4	0	2	42	80	159	6	36	39
Lesser Poland Province	9	3	0	83	189	180	2	35	63
Mazovia Province	6	4	2	75	195	236	5	46	71
Opole Province	13	1	2	22	45	44	0	18	25
Pomerania Province	6	10	3	51	172	142	5	42	42
Silesia Province	22	11	1	89	136	114	6	76	89
Wielkopolska Province	13	6	0	104	199	246	15	89	100
West Pomeranian Province	32	37	14	115	195	168	15	58	68

Source: own elaboration based on Local Data Bank CSO data.

From the beginning of the socio-economic transformation in Poland, one of the most important sources of founding were the EU aid programs. It started with Phare and then ISPA and SAPARD programs. In following years, the character of the EU help underwent gradual changes. At the beginning they aimed at boosting the system and economic transformation, but with the times they focused on integration. From 1 May 2004 Poland became a beneficiary of European structural funds and Cohesion Fund[13]. The biggest cities

[13] A. Piasecki, *Ramowa Dyrektywa Wodna a rozwój infrastruktury wodno-kanalizacyjnej w województwie kujawsko-pomorskim*, „Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie. Polityki Europejskie, Finanse i Marketing" 2013 nr 9(58), s. 356.

of the Eastern Poland used those funds very extensively when it comes to the development and modernization of water and wastewater infrastructure (table 4). Without them the realization of many investments would not be possible or strongly restricted.

Tabela 4. Largest water and wastewater management projects in Eastern Poland co-financed from the European Union

City	Project title	Value in [mln PLN]	Co-financing from the EU [mln PLN]
Olsztyn	Water and wastewater management in Olsztyn	296,9	92,8
Elbląg	Drinking water supply in Elbląg	95,8	58,3
Kielce	Complex protection of underground water in Kielce agglomeration	196,8	105,0
Końskie	Orderliness of water and wastewater management on the area of Końskie city and commune	164,0	81,3
Białystok	Development and modernization of water and wastewater system on the area of Białystok and Wasilków commune	102,0	59,3
	Improvement of water quality in Białystok	76,4	41,6
Suwałki	Modernization of wastewater treatment plant and development of water and wastewater infrastructure in Suwałki – stage II	44,0	25,4
	Improvement of water quality in Suwałki	46,5	22,7
Mielec	Orderliness of wastewater collection and treatment system in Mielec	101,8	69,2
Rzeszów	Improvement of drinking water in Rzeszów agglomeration	129,3	63,1
Sanok	Improvement of water and wastewater management in Sanok agglomeration	121,8	61,2
Lublin	Development and modernization of water supply and wastewater discharge system in Lublin	311,6	147,4
Chełmn	Modernization of wastewater treatment plant along with development of water and wastewater system in Chełm	104,6	46,1

Source: own elaboration based on portal www.mapadotacji.gov.pl [20-02-2016].

The dynamics and development of water and wastewater management in the Eastern Poland provinces should be acknowledge as positive and very significant. The local conditions caused the in each regions the realization of investment followed its specific path. In result, the development of individual elements of water and wastewater infrastructure among provinces is at a different level. In juxtaposition to other regions the scale and range of invest-

ments in the EP was greater. Thanks to that, but with a few exceptions, the level of development and accessibility to the water and wastewater infrastructure is comparable. Specifically it relates to the urban areas. However on the rural areas there are observable lacks in the accessibility to the analyzed infrastructure. Therefore further investments are needed, since as the experiences from other countries show, a significant stimulus which attracts capital to the rural areas is a well-developed infrastructure.

Conclusions

An endeavor to eliminate discrepancies related to the level of development is one of the basic tasks of countries and local governments. In this aspect an essential issue is an adequate development of technical infrastructure. Water and wastewater infrastructure along the mains, gas grid and roads networks is the main element assuring economic development of region which simultaneously improves life standard. Transformations which occurred in this area in the Eastern Poland provinces since the beginning of 90th are very significant. They enabled elimination of infrastructural gap which existed between EP and other regions.

The basic tangible benefit resulting from the conducted investments is a curtailment in number of contaminants escaping into the natural environment. The main contribution to the above mentioned fact one should ascribe to the wastewater treatment plants with an increased bio gene removal. Also a significant increase has been observed in terms of the infrastructure availability. Development of waterworks and improvement in water quality unarguably lead to an increase in population life standard – mainly rural population. Notable is also a greater population ecological awareness which led to decreasing number of septic tank replaced by household treatment plants. Closing the mentioned infrastructural gap directly translated into increase in economical attractiveness of the EP provinces. It relates also to the tourism potential which relies mainly on pure and minimally remolded natural environment.

Such a rapid and significant progress in area of water and wastewater management in the EP provinces and remaining regions would not be possible without financial and legal stimulus from the European Union. The biggest cities of the EP were particularly large beneficiaries of the EU funds. In most cases, obtained funds allowed modernization and orderliness of water and wastewater management.

In the upcoming years one should expect further infrastructural investment in area of water supply and wastewater discharge. Further investments

are needed in water and sewage infrastructure on rural areas. Mechanical wastewater treatment in Lublin Province should be replaced or modernized. On rural areas where building wastewater infrastructure in not economical viable, household wastewater treatment plants must supersede septic tanks.

The contribution of the authors in the article

MSc. Adam Piasecki – concept and objectives, literature review, research (40%)
MSc. Eng. Jakub Jurasz – concept and objectives, literature review, research (40%)
MSc. Michał Mięsikowski – objectives, literature review, research (20%)

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THE BAYESIAN NETWORK AS A TOOL SUPPORTING FLOOD RISK MANAGEMENT – AN EXAMPLE OF CULTURAL HERITAGE PROTECTION

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SIEĆ BAYESOWSKA JAKO NARZĘDZIE WSPIERAJĄCE PROCES ZARZĄDZANIA RYZYKIEM POWODZIOWYM NA PRZYKŁADZIE OCHRONY DZIEDZICTWA KULTUROWEGO

STRESZCZENIE: Artykuł poświęcony jest wsparciu procesu zarządzania ryzykiem powodziowym. Głównym jego celem jest przedstawienie Bayesowskiej sieci, jako narzędzia wspierającego proces oceny ryzyka powodziowego. Funkcjonowanie sieci Bayesowskiej jest zaprezentowane na przykładzie oceny ryzyka powodziowego dla dziedzictwa kulturowego. W pierwszej części opracowania przedstawione są podstawowe zagadnienia takiej jak: powódź, ryzyko powodziowe, zarządzanie ryzykiem powodziowym oraz finansowanie katastrof naturalnych. Druga część poświęcona jest w całości prezentacji sieci Bayesowskiej dla oceny ryzyka powodziowego dla dziedzictwa kulturowego ze szczegółowym opisem poszczególnych jej węzłów.

SŁOWA KLUCZOWE: ryzyko powodziowe, zarządzanie ryzykiem powodziowym, sieć Bayesowska, dziedzictwo kulturowe.

Introduction

Between the 1990s and 2016 Poland was hit by three floods on the scale of natural disasters. These events took place in 1997, 2001 and 2010. Lower Silesia, with its capital, the historic city of Wrocław, was one of many Polish regions which suffered most during these floods.

Despite the rapid and prompt measures undertaken by local authorities, emergency response services and all other units, the floods caused very serious damage to the environment, economic activity, public and private infrastructure, cultural heritage, and, most importantly, to human health and life. In the old part of Wrocław in 1997 the flood affected historic architecture (churches, bridges and others), public facilities (schools, offices, hotels and offices) and residential buildings. One of the most tragic examples of the flood in 1997 is the Kozanów district in Wrocław, where residential buildings, because of their unfortunate location and insufficient flood protection, were submerged up to several floors above ground level.

Currently, river floods are considered one of the main dangers in Central Europe[1]. Effective protection against further flooding requires planning and preparedness, which should take into account all the factors that in any way could affect the occurrence of possible flood risks and adverse consequences of flood events. These factors include, for example, climate, land relief, population density, development rate of areas at risk of flooding and its consequences, flood protection structures, both natural and man-made, or the lack of them, and many others[2].

Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, known as the Floods Directive[3], came into force on 26 November 2007. Its overarching goal was to establish a framework for the assessment and management of flood risks, aiming at the reduction of adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community (EU).

According to the Floods Directive, to reduce the risk of flood events Member States should establish flood risk management plans for particular areas. This is supposed to be a three-phase process. Member States had to complete the preliminary flood risk assessment by December 2011, the flood hazard maps and flood risk maps by December 2013, and flood risk man-

1 Z. Kundzewicz, U. Ulbrich, T. Brucher, M. Szwed, *Summer floods in central Europe. Climate change track?*, "Natural Hazards" 2005 No. 36(1), pp. 165–189.

2 H. Stovel, *Risk preparendness: A management manual for world cultural heritage*, Rome 1998.

3 (DZ.U. EU L 288/27 of 6/11/2007).

agement plans by December 2015. The aim of this paper is to present the causal Bayesian network modified and adapted for the description of the structure and management of flood risk assessment with respect to architectural heritage.

The modified Bayesian network is intended to complement and support the flood risk management plans mentioned in the Floods Directive.

General considerations

The flood in 1997 had a very negative effect on the architectural heritage in Wrocław and other historic cities in Poland. Floods in 2001 and 2010 also caused a lot of damage to cultural heritage. Therefore, relevant measures have to be undertaken to prevent or reduce the adverse impact of future floods on architectural heritage. Of course, the activities described in this paper also apply to the protection of the rest of urban infrastructure, the environment, human life and health, and other spheres and areas covered by the preventive measures.

The United Nations Disaster Relief Organization published general recommendations for natural disasters and a vulnerability analysis[4]. In 2007, the European Parliament adopted the Floods Directive to establish a framework for the assessment and management of flood risks[5]. It should be emphasized here that of all the documents which address the management and assessment of the risk of natural disasters only the Floods Directive of the European Parliament contains information on the protection of cultural heritage[6]. The UNESCO–UNDRO report published in 1979 recommends that the risks should be expressed in terms of value loss, which may be a very difficult task, especially in the context of the assessment of risk for architectural heritage. Therefore, the assessment of risk for cultural heritage assets is currently based on a combination of quantitative and qualitative criteria where the probability of adverse events and the expected consequences are estimated in the risk assessment matrix.

To create the overall structure of the flood hazard some authors propose to additionally incorporate probabilistic models that are created based on the available hydrological data. The basic hydrometric parameters used in the process of flood risk management include the river flow and the water

4 UNESCO-UNDRO. *Natural disasters and vulnerability analysis,* Geneva 1979.

5 The Council, *Directive 2007/60/EC on the assessment and management of flood risks,* Brussels 2007.

6 M. Drdacky et al., *Protecting the cultural heritage from natural disasters. Study of the Europen Parliament IP/B/CULT/IC/2006_163, PE 369.029,* Brussels 2007.

level at a specific point of the river. Definitions of these parameters were presented, for example, by Byczkowski[7]. A detailed description and application of probabilistic models to assess flood risks for selected areas of Lower Silesia can be found in other works of the author of this paper[8].

In general, risk analysis tends to consider all possible events in combination with their adverse consequences. Such events are often caused by extreme hazards, including floods. Relevant risk scenarios and risk probabilities need to be estimated, often based on expert reports[9]. The risk for different engineering systems in hazardous situations can also be analyzed using techniques such as event trees, fault trees, cause-and-effect methods, and causal Bayesian network[10]. Previous studies indicated that the causal Bayesian network supplemented with utility and decision nodes is an especially effective tool for the assessment and management of risk[11]. This paper presents an attempt to implement the Bayesian network into the process of assessment and management of flood risk in the context of architectural heritage.

Management of flood risk – selected problems and aspects

This chapter presents basic definitions and concepts related to flood risk.

Flooding is a natural disaster phenomenon which causes material and non-material damage[12]. Flooding also means the temporary covering by water of land not normally covered by water. This definition includes floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems[13]. When the effects of flooding create a hazard to the life or

7 A. Byczkowski, *Hydrologia,* Vol. 1, Warszawa 1996.

8 Ł. Kuźmiński, *Zastosowanie teorii wartości ekstremalnych w prognozowaniu ostrzegawczym dla ciągu niezależnych zmiennych o rozkładzie normalnym*, in: S. Forlicz (ed.), *Zastosowanie metod ilościowych w ekonomii i zarządzaniu,* „Zeszyty Naukowe Wyższej Szkoły Bankowej we Wrocławiu" 2013 No. 2(34); Ł. Kuźmiński, *Funkcje nadmiaru i hazardu jako narzędzia w analizie ryzyka zagrożenia powodziowego na Dolnym Śląsku*, „Zeszyty naukowe Wyższej Szkoły Bankowej we Wrocławiu" 2014 No. 7(45); Ł. Kuźmiński, *Rozkłady graniczne ekstremów w prognozach ostrzegawczych stanów wód*, „Zarządzanie i Finanse" 2013 No. 3 p. 2, pp. 147–161.

9 M. Stewart, R. Melchers, *Probabilistic risk assessment of engineering systems,* Berlin 1997; R. Melchers, *Structural reliability analysis and prediction,* Chichester 2001.

10 M. Stewart, R. Melchers, op. cit.

11 M. Holicky, *Risk assessment in advanced engineering design*, "Acta Polytechnica" 2003 No. 43(3), pp. 10–16; M. Holicky, *Probabilistic risk optimization of road tunnels*, "Structural Safety" 2009 No. 31(3), pp. 260–266.

12 UNDRO, *Mitigating Natural Disasters Phenomena, Effects and Options,* New York 1991.

13 The Council, *Directive 2007/60/EC on the assessment and management of flood risks,* Brussels 2007.

health of a large number of people, property on a large scale or the environment in large areas, and assistance and protection can be effectively undertaken only with the use of extraordinary measures, in co-operation with various bodies and institutions, and specialized services and units working under a single management, then the flood is classified as a natural disaster[14].

Currently, the European continent is struggling with various natural disasters, which are largely river floods. The United Nations launched an effective platform for discussing the problems of disasters named the *International Strategy for Disaster Reduction*, and the publication *Living with Risk* contributed to a better understanding of these phenomena[15]. The United Nations General Assembly designated the 1990s as the ***International Decade for Natural Disaster*** Reduction. Several years after the end of this period we can see that this initiative increased scientific and practical efforts to reduce the consequences of natural disasters, including floods. Increased interest from economists in methods for the assessment and analysis of the impact of natural disasters, including floods, on welfare and recovery plans has been observed.

Risk is often defined for actuarial purposes as the possibility or probability of loss, and as such it can be adopted for the analysis of floods and other natural disasters[16]. In an alternative definition, which is also suitable for the analysis of flood risk, the risk means the probability of the failure of the system or its element p_f, which can be treated as the probability of flooding[17]

$$RY = p_f \tag{1}$$

Today, risk is very often defined as the mathematical ratio of probability and consequences of flooding (system failure), which is denoted with *S.* For this definition the risk can be calculated from the following equation

$$RY = p_f * S. \tag{2}$$

The use of this definition makes it possible to quantify the economic consequences of flood and to express the risk of its occurrence.

Risk is determined by factors such as vulnerability, i.e. the properties of an object exposed to risk which are relatively objective, and the hazard, i.e. a combination of conditions that makes the occurrence of a peril, flood in this case, more likely. Vulnerability is defined as "the extent to which an indi-

14 (Dz. U. of 2002 No. 62, item 558, No. 74, item 676).

15 ISDR, *Living with Risk. A global Review of Disaster Reduction Initiatives,* Geneva 2002.

16 H. Kunreuther, R. Roth, *Paying the Price,* Washington 1998.

17 B. Yen, *Stochastic methods and reliability analysis in water resources*, "Advanced Water Resources" 1988 Vol. 11.

vidual/object is susceptible to harm due to exposure, in conjunction with its ability (or inability) to cope, recover or basically adapt"[18].

Financing related to natural disasters such as floods involves many different instruments relevant to the needs at every stage of the operation. One of the areas of financing is the liquidation of damage after the flood event. The second area is the financing of the system preventing potential risks of flood, which includes expenditures in the period preceding a possible flood, whose purpose is to prepare for the coming flood, or protection against its consequences or the complete avoidance of such consequences. The third area is the financing of flood mitigation measures and protection of people and their property during flood actions. Each of the presented areas requires a huge budget throughout the country. That is why appropriate (optimised) flood risk management is an important issue.

Flood risk management is a process which includes the estimation and analysis of flood risk, and implementation of sustainable methods to reduce the probability or consequences of floods.

There are three main objectives of flood risk management:

1) preventing further increase of flood risks;
2) minimisation of the existing flood risks;
3) improvement of the flood risk management system.

The main objectives of flood risk management are implemented through the following measures taken before, during and after a flood event:

- prevention and protection to reduce or eliminate the likelihood of flooding and/or its consequences by taking both structural and non-structural measures;
- preparedness, including flood forecasts and early warning systems to increase the awareness of people and relevant authorities; preparation and updating of emergency response plans, and increase of resources necessary for effective emergency response;
- emergency response, including the implementation of emergency response plans, provision of aid to flood victims, prevention of the spread of existing hazards, and reduction in losses and damage;
- recovery, i.e. removal of the effects of natural disasters: returning property affected by flooding to normal, restoration of telecommunication, energy and fuel supply, and transport networks, mitigating the social and economic impacts on the affected population, property and natural environment; and review and improvement of risk management strategies based on lessons learned.

18 P. Jedynak, *Ubezpieczenia gospodarcze,* Kraków 2001.

The Bayesian cause-and-effect network presented in the next subsection has been designed as an effective tool to support actions implementing the main objectives of the flood risk management plan.

The Bayesian cause-and-effect network in the assessment of flood risk

The Bayesian network (a graphical structure for reasoning) modified for the purpose of the assessment and management of flood risk with a focus on cultural heritage is presented in Figure 1. The network consists of the following elements:

- event nodes for flow, effects of flood, structural damage, geotechnical conditions and structural properties;
- decision nodes for permanent and provisional measures;
- utility nodes for the cost of used measures, social and economic consequences, total cost and value loss of cultural heritage.

The direct arrows connecting all nodes indicate the cause-and-effect relationship between a parent and a child. It should be noted that this network is very simplified. In practice, each node can represent a separate subsystem, which may include additional utility nodes.

The event flow node denotes the extreme flows for the respective types of flooding (river floods, torrential floods, floods in cities, floods from the sea in coastal areas) estimated using statistical methods based on available data. Probabilistic models for forecasting extreme flows can be a key element in the assessment and management of flood risk.

The event node for the effect of flood denotes various events that can occur during floods, including hydrostatic effects (lateral pressure and capillary growth), hydrodynamic effects (relating to the flow velocity or surge), erosion and wash-outs, buoyancy, and non-physical events (chemical and biological); more details on this can be found in Kelman and Spence[19]. The effects of flooding depend on two decision nodes – permanent and provisional preventive measures.

The permanent measures include, for example, levees, actions associated with the management of the river (changes of direction, maintenance and/or restoration of floodplains and modification of the depth, width and shape of river channels) that can modify the impact of flooding. Protective barriers, relocation of movable property, immediate removal of floating debris from the supports of bridges, and the evacuation of people and movable elements

[19] I. Kelman, R. Spence, *An overview of flood actions on buildings*, "Engineering Geology" 2004 Vol. 73, No. 3–4, pp. 297–309.

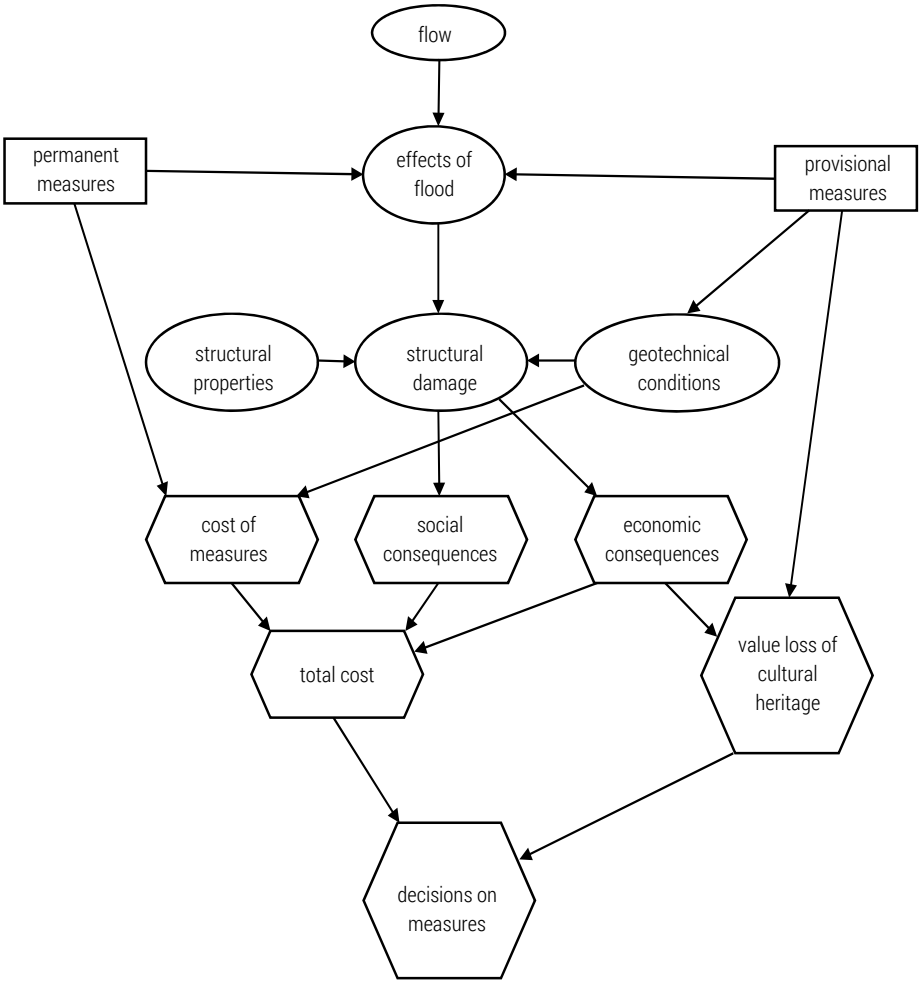

Figure 1. Bayesian cause-and-effect network

of cultural heritage from the affected areas may also be considered as provisional measures. The cost of measures is presented in the utility node, which denotes the expected expenditures on permanent and provisional protective measures.

The effects of flooding, even on a small scale, can directly lead to loss in the value of cultural heritage. For example, increased humidity can damage equipment, fittings, collections, libraries, and archival records[20]. However, appropriate provisional measures may prevent or reduce these losses.

[20] H. Stovel, *Risk preparendness: A management manual for world cultural heritage*, Roma 1998.

Floods can cause structural failure such as damage, local malfunction, or partial or total collapse of structures; these effects of flooding are presented in the Bayesian network as a random node of structural damage. The likelihood of structural damage and its size depends on the geotechnical conditions (soil, level and flow of groundwater) and structural properties (structural integrity, susceptibility of structural materials to increased moisture). The reliability of analyses for architectural heritage can be ensured by the preparation of an annex to the international standard for the assessment of existing structures (ISO 13822 2008). This annex will be mainly based on the fundamental recommendations presented in documents of the International Council on Monuments and Sites[21].

Structural damage can have social and economic consequences and cause losses in architectural heritage. The utility node for social consequences denotes the expected social consequences dependent on the expected number of fatalities per year due to structural failure caused by flooding, and acceptable expenses for averting one fatality, which can be estimated using the social value of life time[22].

The value loss of cultural heritage denotes the ratio of the value of the analysed architectural heritage lost during the flood to the total value of this architectural heritage. This ratio is usually estimated based on expert reports. Nevertheless, the estimation of the value of cultural heritage is a difficult task.

It should also be noted that the value loss of cultural heritage leads to significant social and economic consequences. However, it may be appropriate to consider the value of cultural heritage and the economic and social consequences alone, especially when the value of cultural heritage is assessed only in qualitative terms.

Decisions on permanent and provisional measures should be focused on the optimization of the total cost and minimization of loss in the value of cultural heritage. When the value of cultural heritage is assessed only in qualitative terms, a separate assessment should be done for the value loss of cultural heritage and the total cost.

The cooperation of different professionals from the construction industry and experts on heritage assets, such as engineers, architects, surveyors, archaeologists, historians and the responsible local and international authorities can be highly beneficial in this regard.

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21 ICOMOS. *Recommendations for the analysis, conservation and structural restoration of architectural heritage,* Paris 2003.

22 M. Holicky, *Probabilistic risk optimization of road tunnels*, "Structural Safety" 2009 No. 31(3), pp. 260–266.

Conclusions

Floods are part of the natural world in which we live and will certainly occur in the future. The strategy for flood protection should cover the entire river basins and consist of two parts: national and regional. Some of the main measures should be the same for the whole country, but each region should have an appropriate regional strategy of flood protection, tailored for local characteristics in terms of local flood risk.

The paradigm needs to be changed through the transition from defensive measures to risk management and emergency response actions. The efficient cooperation of all the bodies involved in the process of flood risk management at all levels is also important.

The presented Bayesian cause-and-effect network is a potential tool for improving the system of flood risk management at national and local levels.

The valuable architectural heritage in the city of Wrocław, for which this modified Bayesian network was created, is only one example illustrating its capabilities. This tool can also be used for the development of flood risk management plans related to any aspect of social and economic life.

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ANALYSIS OF WEATHER RISK IN AGRICULTURE AS AN IMPORTANT PART OF ADAPTATION TO CLIMATE CHANGE

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ANALIZA RYZYKA POGODOWEGO W BRANŻY ROLNEJ JAKO ISTOTNY ELEMENT DZIAŁAŃ ADAPTACYJNYCH DO ZMIAN KLIMATU

STRESZCZENIE: Z każdym rokiem zmiany klimatyczne nabierają na sile. Jednym z nadrzędnych celów Unii Europejskiej jest ograniczenie emisji gazów cieplarnianych. Jednak należy pamiętać, że nawet jeżeli emisja dwutlenku węgla zostanie obniżona do deklarowanego poziomu to i tak niektóre zmiany klimatu są nieuniknione. Dlatego już teraz powinny być podejmowane działania, które pozwolą przystosować się zarówno gospodarce społeczeństwu, jak i środowisku do nowej rzeczywistości.

Celem artykułu jest przedstawienie kroków analizy ryzyka pogodowego, jakie powinno podjąć przedsiębiorstwo rolne aby skutecznie zarządzać ryzykiem pogodowym, co stanowi nieodłączny element działań adaptacyjnych do zmian klimatu. Aby podkreślić istotność omawianego tematu, biorąc pod uwagę koncepcję zrównoważonego rozwoju, na wstępie omówiono społeczny, ekonomiczny i środowiskowy wymiar zmian klimatu. Następnie przedstawiono metody identyfikacji ryzyka pogodowego, elementy efektywnego zarządzania ryzykiem pogodowym w rolnictwie, proponowane zabezpieczenia finansowe i fizyczne, tak aby na końcu zaprezentować schemat analizy ryzyka pogodowego w przedsiębiorstwie rolnym.

SŁOWA KLUCZOWE: ryzyko pogodowe, zmiany klimatu, branża rolna, analiza ryzyka

Introduction

Weather conditions have a significant impact on business, when analyses are done at both a macro and micro scale. Advancing climate change has caused weather anomalies to became a reality. The variability and unpredictability of weather has become a part of everyday life.

Due to the increasing number and scale of extreme weather conditions, the governments of many countries are being forced to implement adaptive measures against climate change. These include the financial and physical support of citizens in the event of a disaster, as well as activities connected with the preparation of infrastructure in the event of extreme weather phenomena. The economy of a country affected by a natural disaster is exposed to a huge loss. This comes not only from the physical destruction caused, but also by a supply shock, or the redirection of national investments from production activities to disaster effect mitigation.

In addition to energy and construction industries, agriculture is listed as one of the most vulnerable to the negative impact of weather conditions, as the majority of its activities are performed outside.

The aim of this article is to present the steps of weather risk analysis that an agricultural enterprise should take in order to manage weather risk effectively. This is an integral part of adaptation measures to climate change. To emphasise the importance of this subject, the social, economic and environmental dimensions of climate change are discussed in the introduction, taking into account the concept of sustainable development. Then, we present weather risk identification methods, the elements of effective weather risk management in agriculture, and the proposed financial and physical protection from these risks. This allows us to present the overall scheme of weather risk analysis in agricultural enterprise.

Social, economic and environmental dimensions of climate change

When making analyses concerning the effects of climate change, one generally emphasises their economic dimension, however, omitting the social and environmental effects, which are no less harmful. The European Union estimates that the lack of action to reduce the negative impact of weather on investments and business will cost the European economy around 100 billion

euros per year until 2020; by 2050, this amount could rise to 250 billion EUR per year[1].

The most dangerous consequence of climate change are weather anomalies. Since 1980, 90% of natural disasters have been directly or indirectly caused by weather and climate[2]. Economic losses due to extreme weather events (mainly floods and droughts) in the period 1974–2006 in Albania amounted to 69 billion USD, in Bosnia and Herzegovina 23 billion USD, in Bulgaria 15 billion USD, in Croatia 34 billion USD, in Romania 293 billion USD, in Serbia 82 billion USD, in Slovenia 7 billion USD, and in Turkey 561 billion USD[3]. In Poland, from June to August 2009 the reported losses were estimated at 64 thousand PLN. In the years 1997–2008 the government allocated 600 million PLN for assistance measures for victims; in 2008 alone, this figure was more than 52 million PLN[4].

Another consequence of climate change is a change in weather characteristics, which is non-catastrophic weather risk that requires changes in production methods. It can even result in the complete cessation of production, which in the new weather conditions proves to be unprofitable.

Among the sectors that will lose the most thanks to progressing climate changes are agriculture, energy and tourism. In agriculture, projected climate changes will affect crops, livestock management and the location of production. The increasing number and scale of extreme phenomena will significantly increase the risk of unsuccessful harvests[5]. Climate changes will cause significant changes in the quality and availability of water resources, affecting many sectors, including food production.

In the energy sector, climate change will have a direct impact on both energy supply and demand. The forecasts concerning the impact of climate change on precipitation and melting glaciers show that in Northern Europe, an increase in hydropower production of at least 5% is possible, and in Southern Europe there could be a decline of at least 25%. It is also expected

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1 *An EU Strategy on adaptation to climate change,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2013) 216 final, Brussels 16.04.2013, p. 20.

2 *Impacts of Europe's changing climate. An indicator-based assessment*., EEA Report 2004 No. 2, p. 16.

3 *Economic loss of other perils is also included for calculating annual average economic loss*, from EM-DAT, National Geophysical Data Centre website, GDP – World Bank statistics, Brussels 2007.

4 Z. Jęska, *Sektor ubezpieczeń wobec rosnących strat powodowanych przez gwałtowne zjawiska pogodowe,* Warszawa 2009, www.koalicjaklimatyczna.org [15/02/2014].

5 www.klimada.mos.gov.pl [02/02/2015].

that decreased precipitation and heat waves will negatively affect the cooling process, and thus the performance of power plants[6].

The tourism sector is likely to suffer from decreasing snow cover in the mountains, and an increase in air temperature in the traditional areas of recreation on the shores of warm seas.

Changing weather conditions have a significant impact on society, especially on human health. With the increase in frequency of extreme weather phenomena, there might be an increase in deaths and diseases related to weather conditions, such as excessive mortality due to heat, the occurrence of invasive carriers of infectious diseases, and an earlier start and increased seasonal production of allergenic pollen, especially in the high and mid-latitudes of northern hemisphere.

The social costs of climate change should include those which cannot be converted into money, including, among other things, an increase in child mortality in developing countries, conflicts caused by migration, competition for raw material sources and work, deterioration of educational opportunities, and gender equality[7].

Climate change is affecting, and will impact on, the range and distribution of species, their reproductive cycles, growing seasons and interactions with the environment. Many species of animals and plants may become extinct as a result of climate change limiting the diversity of habitats and mobility. The most vulnerable species are living in the Antarctic zone, for instance polar bears, as well as alpine and marine species, such as coral reefs, jellyfish and microplankton[8].

Among the effects of climate change on the environment, the impact on coastal and marine ecosystems should be mentioned. The coastal erosion phenomenon will increase, and existing protective measures may be insufficient to prevent the flooding of coastal areas in many regions[9].

Weather risk identification methods

While analysing weather risk identification methods, the first thing one should do is divide the risk into catastrophic risk and non-catastrophic risk. Catastrophic weather risk is the danger associated with the occurrence of extreme weather phenomena such as hurricanes, floods, torrential rains, hail, snow storms, or extremely high temperatures. Whereas the concept of

6 Ibidem.

7 Stern Review: The economics of climate change, Part I, London 2006, p. 20.

8 J.D. Sachs, *Common wealth: economics for a crowded planet*, New York 2008, p. 88.

9 www.klimada.mos.gov.pl [20/03/2015].

non-catastrophic risk is used to describe the financial consequences for businesses caused by events as heat, cold, rain, snow, or wind[10].

Depending on the sort of weather risk one faces, appropriate methods of identification and measurement must be adjusted to it, and in addition to this one should consider the protection of activities, using the instruments dedicated to a particular type of weather risk.

Identifying weather risk for a company involves creating a list of potential weather phenomena that may affect its revenues or costs. Risk is measured by determining the amount of expected losses caused by given weather events in monetary units. In general, adverse weather conditions can be divided into those in which their parameters and effects are known, and those with unknown parameters and/or effects.

Effective management of weather risk in enterprise is a very complicated process. In the case of catastrophic weather risk, the very identification of weather anomalies that the enterprise is exposed to is the problem, and predicting the potential losses caused by them (mainly because of their unpredictability and violent character). When analysing non-catastrophic risk, the same weather events that generate losses for one entity may be beneficial to another. Another method of risk identification involves historical data analysis. Historical financial time series can be tested to identify the causes of any changes occurring in them. More specifically, one should answer the question of whether these changes were caused only by the influence of weather events. Other important factors, such as, market share (or the number of customers), the price of complementary and substitutive goods, and the market price of goods or services should be removed from the initial data. The biggest problem during this process is the availability and quality of financial historical data[11].

Agricultural industry and the weather risk

A very dangerous consequence of advancing climate changes for agricultural sector enterprises are extreme weather phenomena. Drought or flood can destroy hectares of cultivated fields, and lead to bankruptcy of many agricultural entrepreneurs. The amount of rainfall often has a decisive impact on the quantity of harvested crops. Insufficient rainfall (not just the lowest leading to drought) delays plant growth, and can even lead to their total destruction. Too much rain reduces plant growth, and during the harvest

10 R.B. Connors, *Weather derivatives allow construction to hedge weather risk*, "Cost Engineering" 2003 No. 45(3), pp. 21–24.

11 Ibidem.

hinders work on the fields. Higher than expected temperatures can also significantly affect agricultural productivity, agricultural income and food security. Overly high temperatures during crop trimming can adversely affect the physiological processes of plants, such as the development of leaves and grains, and reduced viability of pollen and grains during flowering[12].

Climate change threatens agricultural biodiversity. The IPCC predicts that 20–30% of plant and animal species will be threatened with extinction if the air temperature on Earth rises by 1.5–2.5°C[13]. The new climatic conditions will also contribute to increase in the amount of weeds, insects, and diseases of plants and animals. New species of pests and infectious diseases may also appear[14].

The risk of climate change in the agricultural sector may influence the number of negative events that occur, such as the depletion of supplies (damage to or loss of crops), price fluctuations, the risk of bankruptcy of agricultural enterprises, and a reduction in their productivity and profitability.

Non-catastrophic weather risk influences the supply and demand of the agricultural sector. In 2003, 64% of wheat crops in Ukraine were destroyed by low temperatures, while in England, 40–50% of the production of rapeseed oil was destroyed as a result of excessive rainfall during harvest. The weather can affect not only the quantity but also the quality of agricultural production. An example is the cultivation of barley used for beer production. A key factor influencing the quality of the barley might be rain occurring during harvest – rain leads to change in the colour and reduction of grains. A brewery that does not have barley of sufficient quality, must purchase it at market prices, which is associated with additional costs. On the demand side, the impact of weather is associated also with quality. In order to deal with new weather conditions, agricultural producers use agricultural chemicals. These are pesticides, artificial fertilizers and agricultural protection measures, which reduce the quality of sold agricultural products[15].

Another important issue, is taking into consideration the weather conditions when designing local budgets, which allows one to specify in what way the government recognises the problem of weather risk. As indicated by the OECD (*Organization for Economic Co-operation and Development*) the

12 D.S. Battisti, R.L. Naylor, *Historical warnings of future food security with unprecedented seasonal heat*, "Science" 2009, pp. 240–244.

13 IPCC (Intergovernmental Panel on Climate Change), Mitigation. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, Climate change 2007: contribution of Working Group III to the 4th Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, Cambridge University Press 2007 (www.ipcc.ch [10/04/2015]).

14 J.M. Hall-Spencer, R. Rodolfo-Metalpa, *Volcanic carbon dioxide vents show ecosystem effects of ocean acidification*, "Nature" 2008 No. 454(7200), pp. 96–99.

15 www.guaranteedweather.com [22/01/2015].

government has a duty to support farmers in risk management that should focus on catastrophic weather risk. According to the OECD, the likelihood of extreme weather events is rare, but if it occurs, it causes huge damages, simultaneously, in the homesteads of many farmers. The primary task for the government is, through training and information campaigns, to raise the awareness of climate change and the impact of weather on agricultural activities in entrepreneurs in the agricultural sector, and to provide adequate instrumentation to help manage this risk. The OECD emphasizes the importance of well-designed contingency plans in the event of a disaster, which determine the scope of responsibilities for both governments and entrepreneurs[16].

Weather risk management in the agricultural enterprises

The process of weather risk management in the agricultural enterprise should include the following steps[17]:

1. Risk analysis – identifying the impact of weather risk on agricultural production, determining the probability of an event and determining both the consequences of an incident and quantitative determination of the impact of adverse weather conditions on the revenue of a given agricultural enterprise.
2. Formulating conditions – identifying possible alternatives as well as outlays and costs of particular solutions.
3. Risk assessment – declaring readiness, determining the ability of the entity to risk, determining the actual level of risk, qualification of solutions to control risk.
4. Risk control – tool selection, prioritisation and applying the optimal combination (including choosing the right kind of physical and/or financial protection).
5. Control, monitoring and evaluation of activities – assessing the impact of the effects of taken measures, when the decision is wrong – new arrangement of risk management process and the use of tools that would ensure the success of management.

Identifying the impact of weather risk for a particular production comprises three stages: identifying areas of production exposed to the negative

16 J. Anton, *A Comparative Study of Risk Management In Agriculture under Climate Change,* in: OECD Food. Agriculture and Fisheries Papiers, No. 58, OECD Publishing 2012, p. 42.

17 T. Kaczmarek, *Ryzyko i zarządzanie ryzykiem. Ujęcie interdyscyplinarne*, Warszawa 2006, p. 34.

impact of weather, identifying the period in which the weather can affect a particular agricultural production and determining which weather factor (temperature, precipitation, or wind) can lead to lower quality and quantity of agricultural production.

In quantifying the impact of adverse weather conditions on an agricultural enterprise, there are two possible approaches. The first involves determining the extent to which the entity is exposed to financial losses due to the negative impact of a given atmospheric factor. In the second, the limit is set; this is the maximum financial protection needed to cover any potential losses caused by the weather event. These approaches, depending on the weather factor that negatively affects the business, can be used interchangeably or in combination.

To calculate the financial effects of a given weather event[18] for a certain agricultural production, one can determine a financial equivalent, which determines the degree of vulnerability of the agricultural enterprise for a given weather event. For this purpose, one may, for example, take into account production costs or consider the anticipated revenue from the sale of a harvest, which is especially authoritative for producers with fixed price contracts or for those who use price risk management instruments[19].

If the price is not known, one needs to estimate (using the regression line, historical data relating to a given weather factor and agricultural production, e.g. sales revenues, the amount of produced agricultural product), how a given weather event affects the size of agricultural production and how in the final effect it may affect the achieved revenue. In other words, one needs to estimate how much the revenue will change if a given atmospheric factor works, for example, how much the revenues of a given homestead will change if the temperature during the growing season of plants drops by 10°C. In order to determine the maximum value (limit), which the agricultural producer may lose, one can take into account the costs incurred by the company in the event of total crop failure (the incurred costs of agricultural production and the value of lost revenues), or one should analyse historical data of an agricultural enterprise and find the worst result achieved by the company (the lowest production or the lowest revenues).

When the company receives an answer to the question of the extent to which its production is exposed to the negative impact of a particular weather factor in a given period, one should secure it physically and/or financially.

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18 Weather events can be both catastrophic and non-catastrophic in nature.

19 T. Kaczmarek, op. cit., p. 35.

Financial solutions

When analysing financial protection against the negative impact of weather on the agricultural sector, one should use the division of risk into catastrophic and non-catastrophic risk. In case of catastrophic risk, a dedicated tool is provided by traditional insurance policies.

Comparative analysis of already existing agricultural insurance schemes shows large differences between particular countries. Governments in many countries support the creation of systems to insure crops and livestock, treating it as a form of subsidies and support for the development of agriculture. Insurance of basic crops often operates as mandatory insurance, or in connection with loans provided to homesteads, both ordinary and partly refundable by individual governments. Moreover, in many countries, every year so-called "disaster funds" are decreed and managed by the governments.

In the USA there is no insurance for specific risks, but crop insurance covers most of the risks, from the primary or catastrophic coverage, which guarantees 50% of the average yield of the homestead, up to 80 or 100%[20]. In the USA, both revenue and income insurances operate. The majority, 73%, of contributions comes from revenue insurance products, which include: revenue insurance by indexed area, the price of livestock insurance, gross margin insurance of inventory and income insurance of the entire homestead. Three standard insurance revenue products are *Crop Revenue Coverage* (CRC), *Revenue Assurance* (RA), and *Income Protection* (IP).

In the USA approximately 45% of cultivated field production is insured (in the EU 23%). The average contribution rate is close to 9%, which is much higher than in Europe (4%), mainly because of the fact that insurance offers broader coverage: revenue or yield insurance versus mainly insurance of one risk. Total support of insurance by the US government is 72% of all contributions (in the EU around 500 million EUR = support 32%)[21].

While comparing insurance schemes, it may be noted that in the European crop insurance it is necessary to establish which risk resulted in a loss, while US multi-peril crop insurance (MPCI) includes the loss of crops due to plagues and diseases, and damages are calculated simply as the difference between the guaranteed and actual yield.

In the Czech Republic, Bulgaria, Hungary, Portugal, Slovenia, and Sweden, combined risks insurances are accessible (as in Poland). The main products available for Belgium, Germany, the Netherlands and the UK are insurances against hail or one-product insurances. The demand for other products is

20 E. Wojciechowska-Lipka, K. Rojewski, L. Rybak, *Ubezpieczenie upraw w USA, Prawo, Reasekuracja, Ubezpieczenia*, Warszawa 2002.

21 Ibidem.

irrelevant. There is no public support for insurance. In some northern countries, there is less demand for crop insurances, or they have only begun to develop their systems (Latvia and Lithuania). In Finland, private crop insurance is less developed, but there is a public „Crop Compensation Program" designed to compensate for crop losses after natural disasters[22].

In France, the government finances the purchase of 50% of crop insurance. French insurance companies insure crops only from hail (corn and sunflower also against hurricane risk). In the event of a natural disaster, a condition to receive help is to have a complex property, and crop insurance and the minimum loss of the harvest of a given crop must be in the region of 27%, or 14% for the whole farm[23]. In Greece, crop insurance is also mandatory and costs 3% of the turnover of the farm. This insurance protects the crops against the effects of almost all natural risks and the upper limit of compensation is up to 70% of the damage. In the UK and Italy, the crops are insured from hail only (subsidised from the national budget in the amount of 50% of contributions); other risks concerning crops are seen as uninsurable. In these countries, assistance to victims of natural disasters occurs in the form of low-interest loans and subsidies, emergency assistance and recovery of losses of crops, tax rebates and deferrals of tax payments, and taking over the liabilities on account of social insurance. Aid is given to homesteads affected by natural disasters when the damage exceeds 35% of the harvest in a given area[24].

The issue of crop insurance and its high price in Poland is regulated by law. Moreover, in insurance companies offers there are insurances designed specifically for farmers that additionally and voluntarily allow to protect one's business. In Poland, every farmer is obliged to purchase the following compulsory insurances[25]:

1. liability insurance of farmers on account of the ownership of a farm, known as *ubezpieczenie OC rolników* (Eng. third party liability insurance for farmers),
2. insurance of buildings constituting the farm against fire and other random events, called *ubezpieczenie budynków rolniczych* (Eng. the insurance of agricultural buildings).

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22 M. *Łozowski, Z. Obstawski, Podstawy budowy Wspólnego Systemu Ubezpieczeń Rolnych w Unii Europejskiej*, "Zeszyty Naukowe SGGW, Polityki Europejskie, Finanse i Marketing" 2009 No. 2(51), p. 190.

23 J. Baranowski, *Surowy sprawdzian polskich ubezpieczeń rolnych*, "Fair Magazine" October 1997, pp. 51–52.

24 M. *Łozowski, Z. Obstawski,* op. cit., pp. 192–193.

25 I. Ługiewicz, M. Szymański, *Minimalizacja ryzyka w gospodarstwach rolnych. Ubezpieczenia w zarządzaniu ryzykiem*, Toruń 2010, p. 183.

In addition to compulsory insurance, insurance companies offer voluntary insurance. These include insurances of movable property, livestock, agricultural machinery and equipment, agricultural products, supplies, means for crop and animal production and crop production in progress in the event of a weather event[26]. Insurance companies define weather events differently, and they determine different sums of insurance, insurance coverage, amounts of compensations, and policy conditions. This is a very big obstacle for the enterprise wishing to protect its business against catastrophic weather risk.

Instruments dedicated to non-catastrophic weather risk are weather derivatives. Weather derivatives are bilateral future contracts that are settled on the basis of weather conditions[27]. A classic derivative weather instrument can be described by the type of contract. This may be a forward/futures, option or swap contract.

Contracts for weather derivatives can be concluded on the stock market or OTC market. Currently the stock market in the world is created mainly by the stock exchange *Chicago Mercantile Exchange*, which quotes the option and futures contracts for 35 locations in the world (excluding Poland) mostly based on the index of temperature.

The OTC market is the market of „tailor-made" contracts for specific businesses. Therefore, the mechanism and parameters of settling a given contract may take any form[28].

So far in Poland, no weather derivative contracts have been signed. Market development of weather derivatives in Poland may be completed in several ways. The first is the introduction of indexes based on weather conditions to trading on the Warsaw Stock Exchange. This will allow for the use of existing technical and organizational infrastructure in the field of stock market derivatives.

This instrument can be traded also on the OTC market by organising a web-based platform, taking into account weather derivatives in the offer of the interbank OTC market by financial institutions serving large companies from branches particularly exposed to the weather risk or by organising a specialised market of weather derivatives by the companies interested in limiting the weather risk.

In Poland, the only company having the instrument of weather derivatives in its offer is Consus S.A. Consus S.A. has its headquarters in Toruń, while regional offices are located in Łódź, Katowice and Szczecin. The

26 Ibidem, p. 184.

27 www.consus.eu [07/10/2014].

28 J. Preś, *Wybrane metody oceny ofert zabezpieczenia finansowego częściowego lub całkowicie opartego na indeksach pogody*, Szczecin 2009, pp. 1–2.

company specialises in the sale of weather derivatives in Poland and Europe. The company Consus is also, as the only company in Poland, a member of the international Weather Risk Management Association: WRMA. Until now, the company Consus S.A. has not entered into any weather contract in Poland. It is a company known only from the sale of rights to emit carbon dioxide.

Physical solutions

In the agricultural sector, the development of technology and innovation plays an important role among the adaptation measures to climate change. Introducing new crop varieties and production techniques, and conservation techniques of agricultural production can offer the potential to improve efficiency in the face of new weather conditions.

Examples regarding the physical protection of agricultural production against non-catastrophic weather risk are presented below:

- the risk of frost damaging the vegetation of plants – depending on the size of the crops, one may protect it by covering it with straw, leaves, branches of coniferous trees, nonwoven fabric (agro nonwoven fabric), bark, peat, sawdust (applied especially for the cover of tree roots in the orchards);
- the risk of too much sun – shield made of a shading net;
- the risk of excessively high temperatures – special irrigation systems;

When the strength of the prevalent weather conditions accumulates and leads to occurrence of extreme weather values, agricultural enterprises can benefit from the solutions presented below:

- flood risk – levees, appropriate landform allowing for water drainage, attention to proper functioning of drainage ditches, and possession of water drainage devices;
- risk of drought – special irrigation systems of fields;
- the risk of damage caused by strong winds – depending on the type and size of the crops, good solutions may be live hedges, planting coniferous trees alongside crops and shading net.

Depending on the region and the type of weather risk and a particular event, agricultural enterprise should use other solutions, physically protecting their production against the negative influence of weather conditions.

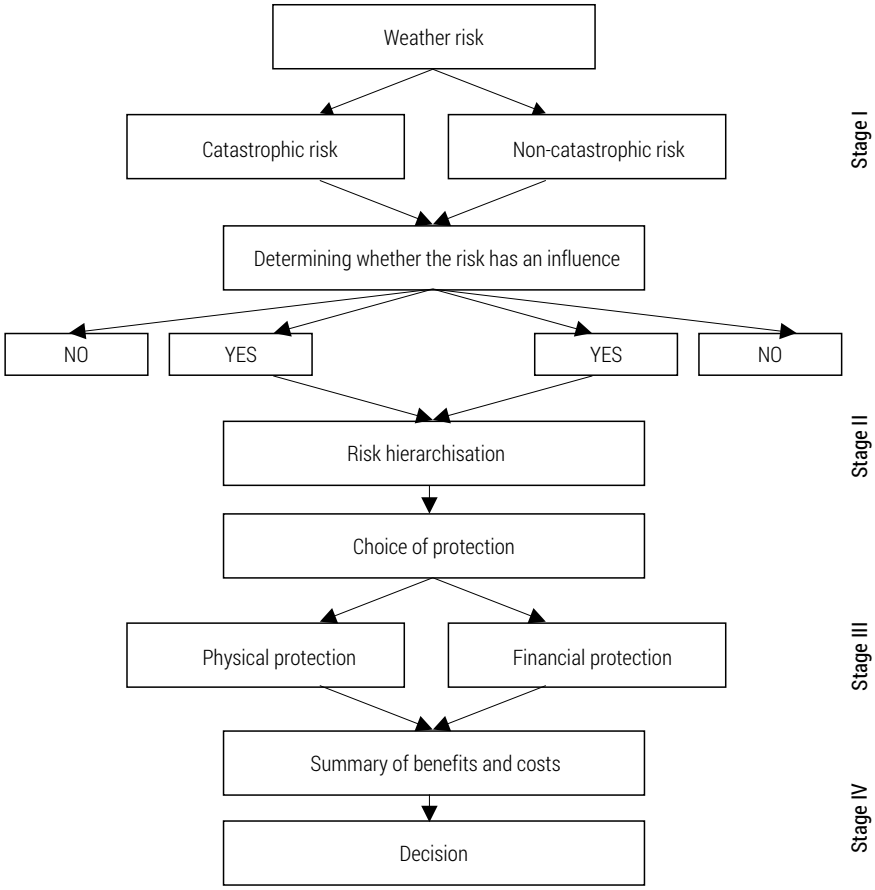

Figure 1. Schematic analysis of weather risk in the agricultural company

Stages of weather risk analysis

Stages of weather risk analysis in the agricultural company are shown in Figure 1. The primary objective of the first stage is to determine whether, and to what extent weather conditions affect the revenue or the amount of agricultural production. This stage is followed by the hierarchisation of weather risk, which allows one to select the appropriate protection tool.

If in the first stage, it turns out that there is a probability of occurrence of extreme weather phenomena, one should calculate the maximum value that a farm business may lose as a result of weather anomalies. To determine whether an agricultural enterprise is exposed to the negative impact of non-catastrophic weather risk, one should examine in what way the average

monthly temperature, average monthly precipitation and average monthly wind speed will be affected and how this will affect its revenue and/or quantity of production.

To determine the hitherto impact of non-catastrophic weather risk on agricultural production, one can use the method of least squares[29]. In this study, for the amount of produced agricultural production or the amount of sales, one uses single-equation linear econometric model in a general form:

$$Y_t = \alpha_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon_t,$$

where:

Y_t – the quantity of produced agricultural production/revenues from sales of agricultural production,
X_1 – temperature [°C],
X_2 – precipitation [mm],
X_3 – wind speed [km/h],
α_0 – free term,
β_1, β_2, β_3 – parameters standing by explanatory variables.

The results obtained from the model will answer the question, how the amount of produced agricultural production or the amount of sales will change if the temperature changes by 1°C, precipitation by 1 mm and wind speed by 1 km/h.

Using econometric models can also forecast the future value of sales of agricultural products with changes in meteorological values. Preliminary research shows that after substituting the forecasted Y value to the regression model of agricultural enterprise seasonality occurs. Therefore, models of seasonal fluctuations will be used for the forecasts. The most commonly used method in this analysis is the indicator method. It involves setting indices of seasonality for the individual phases of the cycle.

After evaluating vulnerability to a given weather risk, one should prioritise the risks on two levels. The first, in which one must indicate the place in the hierarchy of weather risk among other risks that accompany a given agricultural production. The second, that should determine the place of the weather risk in the hierarchy of among other types of weather risks. Taking into account the weather risk by ordering the risk factors from the most to

[29] The method of least squares (full name: the method of least squares of errors) is a standard method of approximation of solutions of overdetermined systems, i.e. sets of equations in which there are more of them than variables. The name „least squares" means that the final solution by this method minimizes the sum of error squares by solving each of equations. It aims to lay the regression line, the trend line for the collected data. It is used both for the estimation of the linear as well as non-linear dependency. Source: A. Welfe, *Ekonometria*, Warszawa 2003, p. 30.

least important, one should consider risk factors that cause higher losses as the most important. Due to the difficulty of determining the likelihood of weather risk, the method of risk hierarchisation, in which the most important risk factor is the one having the most significant probability, is not appropriate. What is worth emphasising, is that the difficulties with determining the probability of a given weather event are often the cause of passivity in taking safety measures.

Stage three is the choice of the right securing tool (physical and/or financial protection), which requires the determination of costs and benefits. In this, there is an identification of available governmental instruments to support management of weather risk in the agricultural company.

Finally, one should compare the costs with the benefits, that is, to answer the question of whether it is profitable to invest the funds for the purchase of the insurance.

The above mentioned stages of weather risk analysis allow the agricultural enterprise to answer the following questions: Will it be profitable to purchase weather insurance in the case of a particular agricultural enterprise? Should the enterprise invest funds for the physical protection of agricultural production and/or the purchase of new technological solutions? Should the enterprise stop or reclassify a given agricultural production for better adapted to new weather conditions?

Conclusions

Essential elements of the effective weather risk management in agriculture are:

- reliable weather forecasts, meteorological measurements at the local level;
- analyses of climate data;
- analyses of the existing relationships between individual crops and meteorological conditions – data on the effects of the conditions on agricultural production (historical meteorological data are essential for conducting analyses – average, minimum, maximum temperature, rain, wind speed, information about the dry and wet periods, knowledge about local conditions – local environmental conditions, agricultural practices, production systems, market prices, the costs of entering the market, used agricultural practices, specific problems of soil);
- analyses of climate threats and assessment of the effects of climate changes – climate change scenarios;

- available modern technologies and innovations, including early warning systems;
- economic and econometric models that allow to forecast the size of agricultural production, depending on the impact of a particular meteorological factor;
- available protection tools (such as weather derivatives and agricultural insurance) and financial tools (for example, loans on preferential terms available to agricultural enterprises affected by a climatic catastrophe);
- activities supporting adaptation to climate change carried out by governmental institutions (including operational scenarios in the event of weather anomalies, contingency plans and raising awareness of agricultural enterprises on the impact of weather conditions on the business and ways to manage weather risk, increasing aversion to risk;
- developed information networks.

The above mentioned elements constitute a generalised picture of risk management in the agricultural company. Effective management of weather risk requires an individual approach to each type of the agricultural enterprise. It depends on the type of soil and crop – different stages of plant growth, harvest, and thus other types of hazards. The presented scheme is a compilation of all the necessary elements of conscious weather risk management in the agricultural company and it may significantly help to carry out activities regarding the adaptation of Polish agricultural enterprises to climate change.

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STUDIES AND MATERIALS

STUDIA I MATERIAŁY

Ewa ROSZKOWSKA • Marzena FILIPOWICZ-CHOMKO

ASSESSMENT OF SOCIAL DEVELOPMENT OF POLISH VOIVODESHIPS BETWEEN 2005 AND 2013 IN THE CONTEXT OF IMPLEMENTING THE CONCEPT OF SUSTAINABLE DEVELOPMENT WITH THE USE OF THE TOPSIS METHOD

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OCENA ROZWOJU SPOŁECZNEGO WOJEWÓDZTW POLSKI W LATACH 2005–2013 W KONTEKSCIE REALIZACJI KONCEPCJI ZRÓWNOWAŻONEGO ROZWOJU Z WYKORZYSTANIEM METODY TOPSIS

STRESZCZENIE: Celem badań była ocena zróżnicowania rozwoju społecznego województw Polski w latach 2005–2013 w kontekście realizacji koncepcji zrównoważonego rozwoju. Oceny zróżnicowania poziomu rozwoju społecznego regionów z podziałem na obszary tematyczne oraz zmian trendów w ujęciu przestrzennym i czasowym dokonano z wykorzystaniem miary syntetycznej TOPSIS ze wspólnym wzorcem rozwoju. W badaniach wykorzystano dane BDL GUS.

SŁOWA KLUCZOWE: zrównoważony rozwój, rozwój społeczny, zrównoważona produkcja i konsumpcja, włączenie społeczne, zmiany demograficzne, zdrowie publiczne, bezpieczeństwo publiczne, TOPSIS

Introduction

Implementing the concept of sustainable development in a region is the result of multiple processes and socio-economic phenomena. The analysis regarding the level of sustainable development of Polish voivodeships[1] and specific issues related to social development of the regions were the subject of many studies and quantitative analyses. They concerned sustainable production and consumption[2], transport[3], energy[4], social inclusion[5], employment[6], demographic changes[7], public health[8], public safety[9], the quality of life[10], and income convergence[11].

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2 A. Borowska, *Społeczeństwo konsumpcyjne – charakterystyka*, „Zeszyty Naukowe Politechniki Białostockiej" 2009 No. 14, pp. 7–18; B. Kryk, *Zrównoważona jakość życia a zrównoważona konsumpcja i zachowania ekologiczne polskich konsumentów*, „Handel Wewnętrzny" 2013, November–December (A), Vol. 2; E. Lorek, A. Lorek, *Rozwój rynku dóbr i usług ekologicznych jako podstawa wdrażania zrównoważonej konsumpcji i produkcji*, „Optimum. Studia Ekonomiczne" 2014 No. 4(70).

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11 J. Batóg, *Analiza krańcowej pionowej konwergencji dochodowej typu β w krajach Unii Europejskiej w latach 1993–2010*, „Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania" 2013 No. 31, pp. 29–48.

The study presents a multi-dimensional assessment of the differentiation of social development of Polish voivodeships in the years 2005–2013. The analysis of the progress of the regions in implementing the concept of sustainable development in the context of social order was based on the rankings of voivodeships within the subject areas indicating the level of social development, the level of territorial cohesion, and the direction and pace of changes in 2013 compared to 2005. Synthetic measures determined by the TOPSIS method with the common pattern of development, through the overall analysis of the partial indicators, made it possible to assess the overall level of development of the regions. In addition, they made it possible to sort and group the studied regions due to the considered subject areas of social development.

Research methodology

In order to compare the changes and evaluate the progress of individual regions towards sustainable development in 2013 in comparison with 2005, the TOPSIS procedure was used with the common pattern and anti-pattern of development[12]. The stages of this procedure are as follows:

1) Selection of indicators based on substantive and statistical premises. Construction of a data matrix:

$$X = [x_{ikt}],$$

where x_{ikt} is the k-th value of indicator of sustainable development (k = 1,2,...,m) for the i-th voivodeship (i = 1,2,...,16) in the t-th year (t = 2005; 2013).

2) Normalization of the values of the indicators in order to achieve their comparability:

– for stimulants:
$$z_{ikt} = \frac{x_{ikt} - \min\limits_{i}\{x_{ikt}\}}{\max\limits_{i}\{x_{ikt}\} - \min\limits_{i}\{x_{ikt}\}},$$

– for distimulants:
$$z_{ikt} = \frac{\max\limits_{i}\{x_{ikt}\} - x_{ikt}}{\max\limits_{i}\{x_{ikt}\} - \min\limits_{i}\{x_{ikt}\}},$$

where: i – is the number of the voivodeships (i = 1,2,..., n = 16), k is the indicator number of sustainable development (simple feature) (k = 1,2,...,m) , and t is the year (t = 2005; 2013).

[12] C.L. Hwang, K. Yoon, *Multiple Attribute Decision Making: Methods and Applications*, New York 1981.

$\max_i \{x_{ikt}\}$ – is the maximum value of the *k*-th indicator of sustainable development in 2005 and 2013;

$\min_i \{x_{ikt}\}$ – is the minimum value of the *k*-th indicator of sustainable development in 2005 and 2013.

3) Calculation of the Euclidean distance between the voivodeships from the pattern (z^+_{kt}) and anti-pattern (z^-_{kt}) according to the formulas:

$$d_{it}^{+} = \sqrt{\sum_{k=1}^{m} \left(z_{ikt} - z_{kt}^{+}\right)^2} \quad d_{it}^{-} = \sqrt{\sum_{k=1}^{m} \left(z_{ikt} - z_{kt}^{-}\right)^2},$$

where: $z^+_{kt} = (1,1,...,1)$, $z^-_{kt} = (0,0,...,0)$ for (i = 1,2,..., n = 16), (t = 2005, 2013).

4) Determining the value of the synthetic measure of the *i*-th voivodeship, and *t*-th year:

$$q_{it} = \frac{d_{it}^{-}}{d_{it}^{-} + d_{it}^{+}},$$

where: (i = 1,2,..., n = 16), (t = 2005, 2013). $0 \le q_{it} \le 1$ occurs at this.

Higher values of the measure q_{it} indicate a higher position in the ranking of the *i*-th voivodeship.

5) Establishing the voivodeships ranking due to the value of the synthetic measure of sustainable development.

Evaluation of the situation of voivodeships due to the value of the synthetic measure of development[13]: $0 < q_{it} \le 0.2$ represents a very unfavourable situation, $0.2 < q_{it} \le 0.4$ an unfavourable situation, $0.4 < q_{it} \le 0.6$ a moderate situation, $0.6 < q_{it} \le 0.8$ a favourable situation, and $0.8 < q_{it} \le 1.0$ a very favourable situation. On the basis of the measure, one determines the **predominance** of the voivodeship for which the value of the synthetic measure is greater than or equal to 0.6 and the **limitation** of the voivodeship for which the value of the synthetic measure is less than 0.4. In order to evaluate the progress of voivodeships in the direction of sustainable development, we adopted a difference of no less than 0.2 in the case of **clear progress** and

13 B. Bal-Domańska, J. Wilk, *Gospodarcze aspekty zrównoważonego rozwoju województw – wielowymiarowa analiza porównawcza,* „Przegląd Statystyczny" 2011 No. LVIII (3/4), pp. 304.

a difference of less than or equal to –0.1 in the case of a **threat** to the voivodeship[14].

The analysis was performed in each subject area in terms of time and space. We carried out an evaluation of the differentiation of voivodeships due to the indicators describing particular areas in the years 2005–2013. In terms of the time approach, we assessed the progress of voivodeships towards sustainable development with regard to the social level in 2013 compared with 2005.

Selection of diagnostic variables to assess the level of social development within the subject areas in the context of sustainable development

According to the available data, we suggested a set of 37 potential diagnostic variables of social development. The features can be divided into five subject areas: sustainable production and consumption, social inclusion, demographic changes, public health, and public safety[15]. Selected individual indicators were the most significant in terms of the conducted research according to the formal and substantive criteria. They complied with the relevant statistical properties, such as universality (universally recognized importance and relevance of the indicator), comparability (presented in the form of intensity indicators), weak correlation of variables with each other (eliminating duplication of information), and adequate diversification (a coefficient of variation higher than 7%)[16]. The choice of variables was also dependent on the availability, completeness, and continuity of the occurrence of statistical data from the regional perspective in 2005 and 2013. The initial set of 37 diagnostic variables was reduced to 25 indicators divided into subject areas. In addition, a set of accepted variables was divided into two subsets: stimulants and distimulants. High values of the stimulant (S) are desirable from the point of view of the synthetic measure. In the case of distimulants (D), high values of the variables are undesirable and cause a decrease in the value of the synthetic measure:

I. **Sustainable production and consumption**
Z1: Electricity consumption [kWh] (D)
Z2: Gas consumption [m^3] (D)

14 Ibidem.

15 Lokal Data Bank, www.stat.gov.pl [24/06/2015].

16 A. Młodak, *Analiza taksonomiczna w statystyce regionalnej*, Warszawa 2006.

Z3: Water consumption [m^3] (D)
Z4: Passenger cars per 1000 population (D)
Z5: Average monthly consumption of meat per capita (D)
Z6: Average monthly consumption of vegetables per capita (S)

II. **Social inclusion**
Z8: Average monthly available income per capita in private households (S)
Z9: Unemployment rate (BAEL – Eng. LFS) [%] (D)
Z10: The employment rate of disabled people [%] (S)
Z11: The share of people out of work aged 18–59 living in households in the total number of household members [%] (D)
Z13: Children covered by pre-school education in percentage of the total number of children at the age 3-5 (in rural areas) [%] (S)
Z17: Life-long learning of persons aged 25-64 [%] (S)

III. **Demographic changes**
Z19: Natural increase per 1000 population (S)
Z22: Demographic dependency ratio: post-working age population per 100 persons of pre-working age [persons] (D)
Z23: Ratio of balance of permanent migration person at working age (international migration) (S)
Z24: Ratio of balance of permanent migration person at working age (intervoivodship migration) (S)
Z25: Average monthly gross retirement pensions from non-agricultural social security system in relation to average monthly gross wages and salary (S)

IV. **Public health**
Z28: Deaths by selected causes of death in percentage of total (diseases of the circulatory system) [%] (D)
Z31: Deaths by selected causes of death in percentage of total (diseases of the respiratory system) [%], (D)
Z32: Suicide rate for 10 thous. population (D)
Z33: Entitled to practise doctors per 10 thous. population (S)
Z34: Persons injured in accidents at work per 1000 employed persons (D)

V. **Public Safety**
Z35: Ascertained crimes in completed preparatory proceedings per 1000 population (D)
Z36: Rate of detectability of the delinquents of ascertained crimes [%] (S)
Z37: Fatal victims of road accidents per 100 thous. registered motor (D)

The values of the synthetic measure for the voivodeships determined by the TOPSIS method in the particular areas in 2005 and 2013 are presented in Table 1.

Assessing the differentiation of the level of social development of Polish voivodeships in the years 2005–2013

Area: sustainable production and consumption

The synthetic indicator *sustainable consumption and production* takes values from the range [0.419; 0.742] for the year 2005 and from the range [0.272; 0.600] for the year 2013. In 2013, for each voivodeship, we observed an unfavourable situation of decline in the value of this measure compared to 2005 (Table 1). The best positions were occupied by Podkarpackie (position 1), Świętokrzyskie (position 3 in 2005, position 2 in 2013), and Lubelskie (position 2 in 2005, position 3 in 2013) in the rankings of voivodeships created for the years 2005 and 2013. Apart from Podkarpackie, the same positions were maintained by the following voivodeships: Warmińsko-Mazurskie (4), Wielkopolskie (15), and Mazowieckie (16). The biggest change of position in the rankings occurred for Lubuskie (change from position 7 in 2005 to 14 in 2013). For other regions, there was a change in position from 1 to 4 in the ranking in 2013 compared with 2005 (Table 2).

In 2005 and 2013, a *favourable situation* in the area of *sustainable consumption and production* was recorded for Podkarpackie; *moderate situations* was found for: Kujawsko-Pomorskie, Łódzkie, Małopolskie, Pomorskie, and Śląskie. For the other regions, we observed deterioration of the situation from *favourable* to *moderate* for Lubelskie, Opolskie, Podlaskie, Świętokrzyskie, and Warmińsko-Mazurskie and from *moderate* to *unfavourable* for Dolnośląskie, Lubuskie, Mazowieckie, Wielkopolskie, and Zachodniopomorskie. For all regions, the change in the value of the synthetic indicator took a value of less than –0.1. This indicates a threat to the development of the region in this area. The biggest threat occurred in Lubuskie (change = –0.254).

Area: social inclusion

The synthetic measure of *social inclusion* takes values from the range [0.163; 0.465] for the year 2005 and from the range [0.436; 0.734] for the year 2013. In 2013, we observed a favourable situation of increase in the value of the measure for each region compared to 2005 (see Table 1).

In the rankings of voivodeships, the best positions were occupied by Lubelskie (position 1) and Podlaskie (position 2) in 2005 and by Mazowieckie

Table 1. The value of TOPSIS for voivodeships by subject areas in 2005 and 2013

Voivodship	Sustainable production and consumption			Social inclusion			Demographic changes			Public health			Public safety		
	2005	2013	change	2005	2013	change	2005	2013	change	2005	2013	change	2005	2013	change
Dolnośląskie	0.576	0.378	-0.198	0.312	0.586	0.275	0.559	0.458	-0.101	0.430	0.450	0.020	0.418	0.598	0.181
Kujawsko-pomorskie	0.581	0.444	-0.137	0.290	0.606	0.315	0.661	0.552	-0.108	0.444	0.473	0.029	0.374	0.772	0.398
Lubelskie	0.737	0.553	-0.184	0.465	0.667	0.202	0.543	0.438	-0.106	0.527	0.600	0.073	0.579	0.845	0.266
Lubuskie	0.594	0.341	-0.254	0.269	0.600	0.331	0.677	0.552	-0.125	0.377	0.364	-0.013	0.466	0.644	0.178
Łódzkie	0.563	0.408	-0.154	0.354	0.628	0.274	0.486	0.399	-0.087	0.543	0.583	0.040	0.282	0.680	0.398
Małopolskie	0.576	0.437	-0.139	0.424	0.673	0.249	0.784	0.690	-0.095	0.590	0.735	0.145	0.423	0.715	0.292
Mazowieckie	0.419	0.272	-0.147	0.445	0.734	0.289	0.576	0.579	0.004	0.610	0.623	0.013	0.267	0.632	0.364
Opolskie	0.619	0.451	-0.167	0.436	0.591	0.155	0.444	0.359	-0.085	0.518	0.566	0.048	0.556	0.747	0.191
Podkarpackie	0.742	0.600	-0.142	0.399	0.547	0.147	0.635	0.561	-0.074	0.491	0.591	0.099	0.682	0.919	0.237
Podlaskie	0.615	0.478	-0.137	0.457	0.604	0.147	0.553	0.465	-0.088	0.531	0.587	0.057	0.554	0.829	0.275
Pomorskie	0.522	0.409	-0.112	0.304	0.733	0.429	0.720	0.669	-0.050	0.519	0.483	-0.036	0.341	0.669	0.329
Śląskie	0.552	0.408	-0.144	0.338	0.655	0.317	0.524	0.434	-0.090	0.463	0.700	0.237	0.368	0.657	0.289
Świętokrzyskie	0.712	0.556	-0.156	0.220	0.586	0.365	0.539	0.437	-0.102	0.543	0.581	0.038	0.515	0.848	0.332
Warmińsko-mazurskie	0.651	0.502	-0.149	0.163	0.436	0.274	0.631	0.527	-0.104	0.196	0.464	0.268	0.429	0.771	0.342
Wielkopolskie	0.464	0.336	-0.128	0.396	0.660	0.265	0.784	0.681	-0.103	0.502	0.499	-0.003	0.530	0.795	0.264
Zachodniopomorskie	0.515	0.367	-0.148	0.192	0.507	0.315	0.661	0.553	-0.108	0.431	0.524	0.093	0.278	0.711	0.433

The values of the synthetic measure were highlighted using different shades of grey, indicating an advantage or a threat to the region in the given area.

Source: The author's own study on the basis of GUS (Central Statistical Office of Poland) data.

Table 2. The positions of the voivodeships by area determined by the TOPSIS method in 2005 and 2013

Voivodship	Sustainable production and consumption			Social inclusion			Demographic changes			Public health			Public safety		
	2005	2013	Change	2005	2013	Change	2005	2013	Change	2005	2013	Change	2005	2013	Change
Dolnośląskie	9	12	−3	10	12	2	10	11	−1	14	15	−1	10	16	−6
Kujawsko-pomorskie	8	7	1	12	8	4	6	7	−1	12	13	−1	11	6	5
Lubelskie	2	3	−1	1	4	−3	12	12	0	6	4	2	2	3	−1
Lubuskie	7	14	−7	13	10	3	4	8	−4	15	16	−1	7	14	−7
Łódzkie	11	10	−1	8	7	1	15	15	0	3	7	−4	14	11	3
Małopolskie	10	8	2	5	3	2	1	1	0	2	1	1	9	9	0
Mazowieckie	16	16	0	3	1	2	9	4	5	1	3	−2	16	15	1
Opolskie	5	6	−1	4	11	−7	16	16	0	8	9	−1	3	8	−5
Podkarpackie	1	1	0	6	14	−8	7	5	2	10	5	5	1	1	0
Podlaskie	6	5	1	2	9	−7	11	10	1	5	6	−1	4	4	0
Pomorskie	13	9	4	11	2	9	3	3	0	7	12	−5	13	12	1
Śląskie	12	11	1	9	6	3	14	14	0	11	2	9	12	13	−1
Świętokrzyskie	3	2	1	14	13	1	13	13	0	4	8	−4	6	2	4
Warmińsko-mazurskie	4	4	0	16	16	0	8	9	−1	16	14	2	8	7	1
Wielkopolskie	15	15	0	7	5	2	2	2	0	9	11	−2	5	5	0
Zachodniopomorskie	14	13	1	15	15	0	5	6	−1	13	10	3	15	10	5

Source: The author's own study on the basis of GUS (Central Statistical Office of Poland) data.

(position 1) and Pomorskie (position 2) in 2013. Two voivodeships maintained the same positions: Zachodniopomorskie (15) and Warmińsko-Mazurskie (16). The biggest changes in the positions in the years 2005 and 2013 were observed for Pomorskie (from position 11 to 2) and Podkarpackie (from position 6 to 14). Other regions were characterized by a change in the position from 1 to 7 in the ranking in 2013 compared with 2005 (Table 2).

In 2005 in the area of *social inclusion* there was no voivodeship for which the situation could be described as *very favourable* or *favourable*. A *moderate* situation was reported for Opolskie. In other voivodeships there were improvements of the situation: from *moderate* to *favourable* for Lubelskie, Małopolskie, Mazowieckie, and Podlaskie; from *unfavourable* to *favourable* for Kujawsko-Pomorskie, Łódzkie, Pomorskie, Śląskie, and Wielkopolskie, from *unfavourable* to *moderate* for Dolnośląskie, Lubuskie, Podkarpackie, and Świętokrzyskie; and from *very unfavourable* to *moderate* for Warmińsko-Mazurskie and Zachodniopomorskie. Pomorskie made significant progress in the development of the social level in the area of *social inclusion*, where the change in the value of the synthetic measure amounted to 0.429.

Area: demographic changes

The synthetic measure for the area of *demographic changes* takes values from the range [0.444; 0.784] for 2005 and from the range [0.359; 0.690] for 2013. Only in Mazowieckie was there a slight increase (0.004) in the value of the synthetic measure in the year 2013 compared to 2005. Other regions experienced an unfavourable situation of a decline in its value (Table 1).

In the rankings of voivodeships, the best positions in 2005 and 2013 were occupied by the voivodeships of Małopolskie (position 1), Wielkopolskie (position 2), and Pomorskie (position 3). The same positions were also maintained by Lubelskie (12), Świętokrzyskie (13), Śląskie (14), Łódzkie (15), and Opolskie (16). Mazowieckie (change of position from 9 to 4) and Lubuskie (change of position from 4 to 8) displayed the biggest changes of positions in the rankings of voivodeships in 2005 compared to 2013. Other regions changed their positions from 1 to 2 in the ranking in 2013 compared with 2005 (Table 2).

In 2005 and 2013 there was no voivodeship for which the situation could be described as *very favourable* in the area of *demographic changes*. Favourable situations occurred for Małopolskie, Pomorskie, and Wielkopolskie; *moderate* situations occurred for Dolnośląskie, Lubelskie, Mazowieckie, Podlaskie, Śląskie, and Świętokrzyskie. For all other regions, the situation deteriorated: from *favourable* to *moderate* for Kujawsko-Pomorskie, Lubuskie, Podkarpackie, Warmińsko-Mazurskie, and Zachodniopomorskie and from *moderate* to *unfavourable* for Łódzkie and Opolskie.

In the case of eight voivodeships – Dolnośląskie, Kujawsko-Pomorskie, Lubelskie, Lubuskie, Świętokrzyskie, Warmińsko-Mazurskie, Wielkopolskie, and Zachodniopomorskie – the change in the value of the synthetic measure took a value below -0.1, indicating a threat to the development of the region in this area. Lubuskie faced the biggest threat (change = -0.125).

Area: public health

The synthetic measure in the case of *public health* takes values in the range of [0.196; 0.610] for 2005 and in the range of [0.364; 0.735] for the year 2013. In 2013 there was a slight decrease in the value of the synthetic measure in this area compared to 2005 for three voivodeships: Lubuskie, Pomorskie, and Wielkopolskie. All other regions had favourable situations of increases of its value (Table 1).

In the rankings of voivodeships, the best positions in 2005 and 2013 were occupied by Mazowieckie (position 1 in 2005 and 3 in 2013) and Małopolskie (position 2 in 2005 and 1 in 2013). None of the voivodeships kept their positions in the ranking. Śląskie showed the biggest change in the rankings of voivodeships (change of position from 11 in 2005 to 2 in 2013). Other regions were characterized by a change in position from 1 to 5 in the ranking (Table 2).

In 2005 and 2013, there was no voivodeship for which the situation could be described as *very favourable* in the area of *public health*. Improvement of the situation from *moderate* to *favourable* was observed for Małopolskie and Śląskie; from *very unfavourable* to *moderate* for Warmińsko-Mazurskie. We observed a *favourable* situation for Mazowieckie, an *unfavourable* one for Lubuskie, and *moderate* situations for the remaining 11 voivodeships. Śląskie (change = 0.237) and Warmińsko-Mazurskie (change = 0.268) indicated significant progress in the development of the social level in the field of *public health*.

Area: public safety

The synthetic measure of *public safety* takes values from the range [0.267; 0.682] for 2005 and from the range [0.598; 0.919] for the year 2013. All voivodeships had a very favourable situation of growth in the value of the indicator in the year 2013 compared to 2005 (Table 1).

In the rankings of voivodeships, the best positions in 2005 and 2013 were occupied by Podkarpackie (position 1 in 2005 and 1 in 2013) and Lubelskie (position 2 in 2005 and 3 in 2013). Except for Podkarpackie, three voivodeships maintained their positions in the ranking: Podlaskie (4), Wielkopolskie (5), and Małopolskie (9). The biggest change in the rankings of

voivodeships was observed in Lubuskie (change of position from 7 in 2005 to 14 in 2013). Other regions were characterized by a change in position from 1 to 6 in the ranking in 2013 compared with 2005.

In 2005 and 2013 in the area of *public safety*, the situation can be regarded as *moderate* only for Dolnośląskie. In the case of other voivodeships, we observed improvements of the situation: from *unfavourable* to *favourable* for Kujawsko-Pomorskie, Łódzkie, Mazowieckie, Pomorskie, Śląskie, and Zachodniopomorskie, from *moderate* to *favourable* for Lubuskie, Małopolskie, Warmińsko-Mazurskie, Wielkopolskie, and Opolskie, from *moderate* to *very favourable* for Lubelskie, Podlaskie, and Świętokrzyskie, and from *favourable* to *very favourable* for Podkarpackie. In the case of 13 voivodeships we may talk about clear progress in the development of the social level in the area of *public safety*, while the largest increase in the value of the measure occurred for Zachodniopomorskie (a change of 0.433). For three voivodeships – Dolnośląskie, Lubuskie, and Opolskie – the change in the measure was less than 0.2.

Summary

In this study, we carried out a multidimensional analysis of the level of social development in regional terms on the basis of an integrated system of indicators divided into five subject areas. This enabled the assessment of the level of diversification of the regions and the trends of changes in social development. However, it should be remembered that the final list of diagnostic variables and the choice of the synthetic measure of development largely determine the results of this study. Due to the lack of one recognized method of measuring the level of sustainable development, the conducted study may be considered, at most, as one of the proposals in the context of literature. The synthetic measures of the level of social development are a function of many explanatory variables taken for research that reflect different aspects of social development within the subject areas under consideration.

The conducted studies indicate differential levels of socio-economic development of voivodeships in particular subject areas that describe the level of development in the years 2005–2013.[17] Significant differences were

[17] The research results also confirm conclusions drawn by the authors of other studies (for example: B. Bal-Domańska, J. Wilk, op. cit.; B. Bal-Domańska, J. Wilk, B. Bartniczak, *Pomiar postępów …*, op. cit.; B. Bal-Domańska, J. Wilk, B. Bartniczak, *Ocena realizacji …*, op. cit.; B. Kryk, *Zrównoważona jakość …*, op. cit.; J. Wilk, T. Bartłomowicz, op. cit.; E. Roszkowska, R. Karwowska, E.I. Misiewicz … op. cit.; D. Perło, E. Roszkowska, op. cit.; R. Karwowska, E. Roszkowska, op. cit.) about differential levels of social devel-

observed between the regions with the highest and lowest values of the synthetic measure. The largest span occurred for the area of *public health* (0.441 in 2005 and 0.375 in 2013), and the smallest occurred for the area of *social inclusion* (0.191 in 2005 and 0.194 in 2013). In 2013, the level of regional cohesion improved slightly in the areas of *public health* and *public safety.* In other areas, it worsened slightly.

The obtained results also showed that among the regions in Poland there is neither a model (ideal) voivodeship that would be the leader in each of the studied areas nor a voivodeship that would represent the anti-pattern of development in each of the analysed areas. Only a few voivodeships in selected areas remained at constant levels in the years 2005 and 2013. The positions of most voivodeships in the rankings change considerably. Relatively small changes in positions of the regions in the ranking occurred in the area of *demographic changes*, while relatively large ones occurred in the area of *social inclusion*. These observations are supported by Pearson coefficients between the measures for the years 2005 and 2013 within the subject areas, which respectively amount to 0.933 for the area of *sustainable production and consumption*, 0.610 for *social inclusion*; 0.957 for *demographic changes*; 0.614 for *public health*, and 0.760 of *public safety*. In the case of three areas – *sustainable production and consumption*, *demographic changes,* and *public health* – the leading voivodeships usually occupied similar positions in 2013 and 2005. A similar trend was observed for the regions closing the ranking.

Also, we observed a fairly fast pace and differentiation regarding the direction of changes of the regions within the areas. For example, compared with 2005, in 2013 Śląskie and Warmińsko-Mazurskie reported **significant progress** in the areas of *social inclusion*, *public health*, and *public safety*, with simultaneous **threats** to Śląskie in the area of *sustainable production and consumption* and Warmińsko-Mazurskie in the areas of *sustainable production and consumption* and *demographic changes*. In the areas of *social inclusion* and *public safety*, **significant progress** was achieved by Kujawsko-Pomorskie, Lubelskie, Łódzkie, Małopolskie, Mazowieckie, Pomorskie, Świętokrzyskie, Wielkopolskie, and Zachodniopomorskie. Kujawsko-Pomorskie, Lubelskie, Świętokrzyskie, Wielkopolskie, and Zachodniopomorskie recorded **threats** in the areas of *sustainable production and consumption* and *demographic changes*, while Łódzkie, Małopolskie, Mazowieckie, and Pomorskie did so in the area of *sustainable production and consumption*. It is also worth noting that in most cases, the voivodeships are characterized by *moderate* situations within the areas under consideration. The exception here is the

opment in the subject areas of Polish regions in terms of both time and space. Depending on the selection of variables for the research, the synthetic measure, and the research period, the results differ in terms of the ranking of regions.

areas of *social inclusion* and *public safety* in 2013, where for most voivodeships the situation should be considered as *favourable*.

In 2013, in relation to 2005, most beneficial changes associated with the improvement of the situation of all voivodeships and the increase of territorial cohesion were observed in the areas of *social inclusion* and *public safety*, where each region shifted in the direction of the pattern of development in these areas, whereas the growth rate was varied. In the area of *social inclusion,* the greatest progress was made by Pomorskie, and in the area of *public safety,* the most progress was made by Zachodniopomorskie. Most adverse changes related to the deterioration of the situation of all voivodeships were observed for the area of *sustainable production and consumption*, while the largest regression occurred in Lubuskie. In the other areas, the development was uneven: the situations of some voivodeships improved and those of others worsened.

Differentiation of rankings and differentiation of synthetic measure values within the subject areas prove that Poland is still at the stage of developing a coherent policy that would foster harmonious social development of individual regions in the country. In-depth analysis of individual indicators and synthetic measures of social development on a regional basis may be helpful in determining the direction and strength of social development of the region using its specific conditions or resources.

Contributions of the authors to the creation of the article:

prof. Ewa Roszkowska, PhD – contributed the concept of the studies and participated in conducting research and producing results

Marzena Filipowicz-Chomko, PhD – carried out the data collection and participated in carrying out research and producing results, the study has been conducted under project No. S/WI/1/2014 and financed from the science fund of MNiSW

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ECONOMIC AND ENVIRONMENTAL ASPECTS IN MODELLING MONTHLY WATER DEMAND IN BIAŁYSTOK – A CASE STUDY

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CZYNNIKI EKONOMICZNO-ŚRODOWISKOWE W MODELOWANIU MIESIĘCZNEGO ZAPOTRZEBOWANIA NA WODĘ NA PRZYKŁADZIE BIAŁEGOSTOKU

STRESZCZENIE: W pracy zaprezentowano wybrane czynniki mające potencjalny wpływ na miesięczne zapotrzebowanie na wodę w białostockim systemie wodociągowym. Początkowo rozważono czynnik ekonomiczny tj. cenę za wodę i odprowadzanie ścieków. Następnie przeanalizowano zależność pomiędzy miesięcznym zużyciem wody a czterema wybranymi aspektami środowiskowymi. Ostatecznie, oszacowano pięć liniowych modeli ekonometrycznych. W pierwszym modelu, opisującym zmienność zużycia wody od września do kwietnia, jako zmienną objaśniającą przyjęto tylko cenę za wodę. Pozostałe modele dotyczą miesięcy od maja do sierpnia i uwzględniają, oprócz ceny za wodę, również zmienność parametrów meteorologicznych (opadów oraz temperatury powietrza). Opracowane modele charakteryzuje bardzo dobre dopasowanie danych teoretycznych do danych rzeczywistych.

SŁOWA KLUCZOWE: miesięczne zapotrzebowanie na wodę, miejski system wodociągowy, regresja liniowa

Introduction

The basic element in the planning, design and operation of water supply systems is the analysis of water use aimed at the identification of relationships and trends characteristic for the analysis process[1]. There are many methods for the analysis of variability and forecasting water demand, including time series analyses, indexing methods and correlation methods[2]. The latter method allows for the determination of the relationship between the volume of water supplied by the water system in the past, and factors determining this volume. Long-term and medium-term water use are often characterised and forecasted using econometric models based on linear regression[3].

Analysis of the demand for water in urban areas is particularly important because of the declining trend in the volume of used water, which has persisted for many years[4]. This decline in water use is indirectly caused by technical, social and economic changes[5], determined by such factors as reduced number of system failures[6], gradual modernization of water supply systems and their effective monitoring by means of integrated IT systems supporting the management of waterworks companies[7]. The decreasing water use is also a consequence of raised awareness of the value of water, its price, and the increasing affluence of citizens, which, for example, allows them to buy water saving appliances and good quality sanitary fittings. In addition, the annual, monthly and daily water demand is also affected by environmental factors such as changes in meteorological parameters, particularly rainfall and average air temperature[8].

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The aim of this study was to analyze the impact of meteorological factors (air temperature, air humidity, monthly rainfall and cloud cover) on the monthly water demand in the water supply system for the city of Białystok. Linear econometric models of monthly water use were created taking into account weather conditions, but also an economic factor – the price of water and sewage treatment in the area of Białystok. The purpose of the designed mathematical models was to identify future trends in water use and the effect of external factors shaping demand for water.

Monthly water use in Białystok

In this analysis, the monthly water demand was calculated as the arithmetic mean of daily measurements in a given month, multiplied by 30, i.e. the average number of days in each month. The analysis at this level covered years 2001–2013, including a total of 156 elements of the time series (months). The necessary baseline data were provided by the Białystok waterworks company (Wodociągi Białostockie sp. z o.o.).

The analysis of time series for monthly demand for water showed a clear decreasing trend. The figure illustrating monthly water use in 2001–2013 clearly shows descending broken lines correlated with time. For the purpose of clarity the figure shows only data for odd years. The mean monthly demand for water in 2001–2013 was 1.34 million m^3. The highest mean monthly value of the analysed variable was 1.54 million m^3 (in 2001) and the lowest was 1.19 million m^3 (in 2013). A slightly increasing trend between January and April was found, as well as clearly increased water use from May to August, followed by a decrease in water use until the end of the year (Figure 1).

Previous analyses of monthly demand for water in Białystok identified three specific seasons during the year[9]:

- Season one: from January to April;
- Season two: from May to August;
- Season three: from September to December.

A decomposition of the time series was carried out to calculate the percentage of individual systematic components of the time series. The greatest variability in water demand was found for season 2, between May and

No. 37, pp. 2333–2341; P.K. Tuz, J. Gwoździej-Mazur, K. Barbarczyk, *Wybrane aspekty prognozowania zużycia wody w budownictwie wielorodzinnym*, „INSTAL" 2003 No. 5, pp. 40–43.

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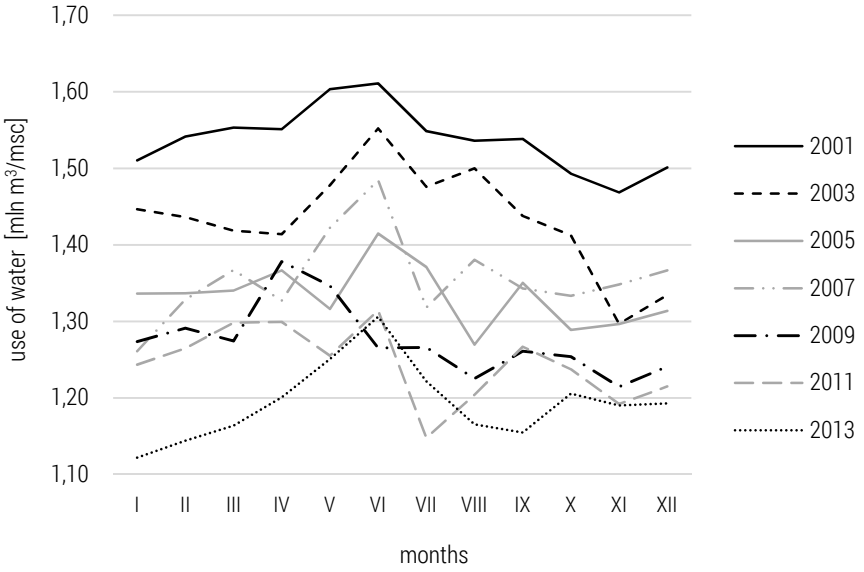

Figure 1. Total monthly demand for water in 2001–2013

Source: author's own analysis based on data from Wodociągi Białostockie.

August[10]. Throughout the year, water use was affected by the declining trend, persisting for many years, in water use, while from May to August additional and greater seasonal and random fluctuations than in other months were recorded (Figure 2).

Effects of individual factors on the use of water

Detailed analysis of monthly water use included one economic factor (price for water and sewage treatment [PLN/m^3]) and four environmental factors (air temperature [C], air humidity [%], rainfall [mm], and cloud cover [oktas]). Research by the author on annual water use indicates that long-term directional changes in water use are determined largely by the growing prices for water and sewage treatment. In 2001–2013 an almost two-fold increase in these prices was observed (from 3.13 PLN/m^3 in January 2001 to 6.42 PLN/m^3 in December 2013). The correlation coefficient for the mean annual prices for water and sewage treatment and the annual demand for water was-0.95.

10 Ibidem.

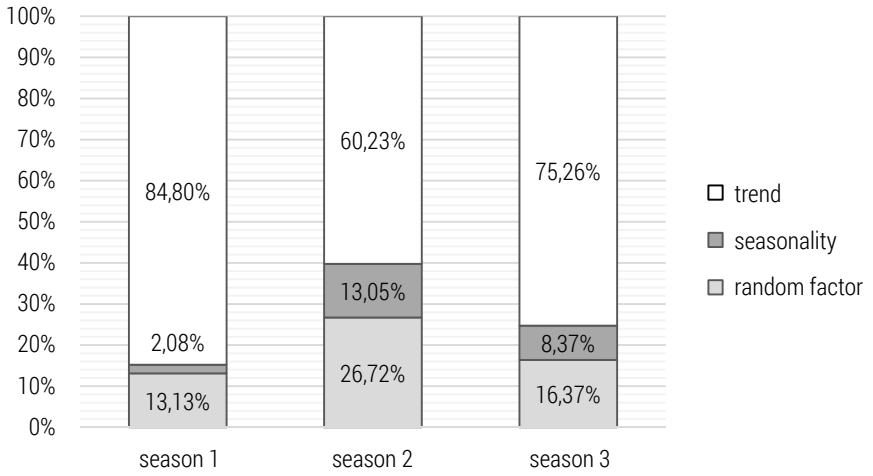

Figure 2. The share of systematic components in the three identified seasons

Source: based on: M. Kolendo, *Zmienność zapotrzebowania na wodę w systemie wodociągowym Białegostoku* in: A. Dzięgielewski, D. Szychowski, J. Wernik (eds), *Wybrane problemy techniki*, Płock 2015, pp. 228–237.

In addition, the independent variables in the model were chosen with a focus on the greatest variability of water use between May and August. Therefore, a detailed analysis was carried out for the fluctuations in the volume of used water and changes in meteorological conditions in these months. To identify seasonal fluctuations the monthly series of water use were transformed into a stationary time series to eliminate directional changes. Due to the fact that the trend is one of the factors interfering with the stationarity, the non-stationarity of the time series was identified by a simple visual analysis. The first increments of the series were calculated in order to achieve the stationarity. The created order 1 integrated time series was created ($Y_tI(1)$), and shows only seasonal and random fluctuations (the effect of the trend was eliminated).

In order to identify the relationship between increased seasonal and random fluctuations from May to August the values of an integrated series of monthly demand for water [million $m^{3]}$ were compared to meteorological parameters, i.e. average monthly air temperature [C], rainfall [mm], air humidity [%] and cloud cover [oktas]. Meteorological data for the station in Białystok (WMO index – 12295) were acquired from the OGIMET web service[11].

[11] Statistics from www.ogimet.com [10/07/2015].

Calculated values of the correlation between meteorological parameters and the average monthly water demand in 2001–2013 are presented in Table 1. The calculated correlation coefficients were generally lower in winter, early spring and autumn months than in late autumn and the summer months. This was taken into account in the further analysis focused on the effects of individual meteorological conditions on water use in season 2.

Season 2 was characterised by the strongest correlation between monthly demand for water and weather conditions, which confirmed earlier findings. The increased cloud cover, rainfall and air humidity caused a decrease in water demand. The strongest correlation between these parameters and use of water was recorded in June. The analysis of the relationship between monthly demand for water and average monthly air temperature revealed the highest value of Pearson's correlation coefficient in May (r = 0.84), (Table 1).

Table 1. Correlation coefficients for meteorological parameters and an integrated time series (Yt I(1)) for average monthly water use in 2001–2013

Months/parameters		Temperature [°C]	Air humidity [%]	Rainfall [mm]	Cloud cover [oktas]
Season 1	January	-0.33	-0.12	-0.55	-0,13
	February	-0,55	0,27	-0,43	0,21
	March	-0,04	-0,39	-0,53	-0,21
	April	0,23	-0,25	-0,34	-0,47
Season 2	May	0,84	-0,34	-0,61	-0,71
	June	0,24	-0,76	-0,61	-0,70
	July	0,66	-0,60	-0,54	-0,73
	August	0,47	-0,63	-0,84	-0,60
Season 3	September	0,58	0,31	-0,15	-0,17
	October	0,11	0,48	-0,40	0,04
	November	-0,37	-0,16	0,00	0,06
	December	-0,45	-0,54	-0,06	0,23

Source: author's own analysis based on data from Wodociągi Białostockie.

The significant effect of weather conditions on the use of water in season 2 was characterised using the example of May (Figures 3 and 4). In May the correlation between water demand and air temperature was the strongest. The increase in average monthly air temperature in May caused a noticeable increase in water demand. The largest increase in water use was found in May 2002. The average monthly air temperature in May 2002 was also the highest (about 16°C) considering all the 13 analysed years. A clear correlation between air temperature and use of water was found, as demonstrated in the figure below (Figure 3).

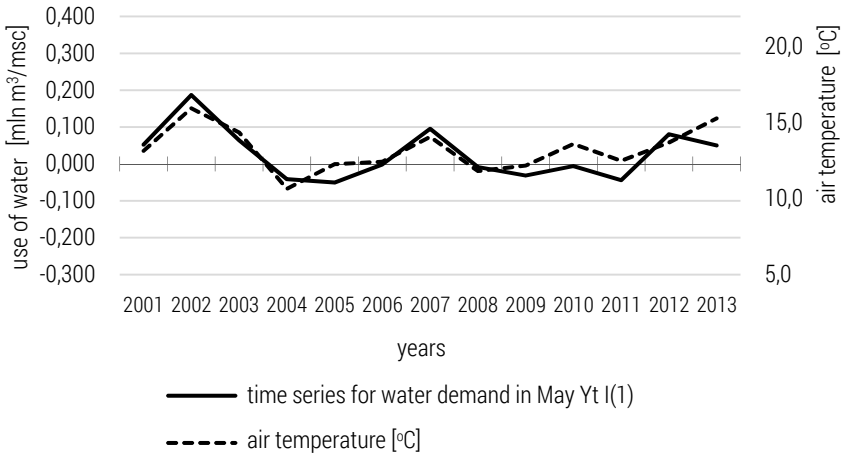

Figure 3. Time series for water demand $Y_t I(1)$ and the average monthly air temperature in May in years 2001–2013.

Source: author's own analysis based on data from Wodociągi Białostockie and www.ogiment.com.

In May the use of water was also significantly determined by rainfall. The correlation coefficient for these two variables was –0.61. In the study period the minimum rainfall was recorded in 2002 (Figure 4). In the same year the greatest increase in water demand (by 0.187 million m^3) was also recorded compared to 2001. Of note is that 2002 was characterized by extremely low levels of rainfall and high air temperature, which resulted in a significant increase in water demand. Figure 4 shows decreased water use at the time of higher rainfall.

The above analysis demonstrates that weather conditions had a significant impact on the use of water between May and August (season 2), and at that time the demand for water was the highest and also characterised by the

strongest fluctuations. Therefore, the inclusion of meteorological variables is particularly recommended when designing a monthly model of water demand for season 2.

Model of monthly water demand

The above analysis demonstrates that throughout the year water demand is affected by the declining trend, persisting for many years, in the use of water, largely explained by the growing price for water, while from May to August additional and greater seasonal and random fluctuations than in other months are recorded (Figure 4).

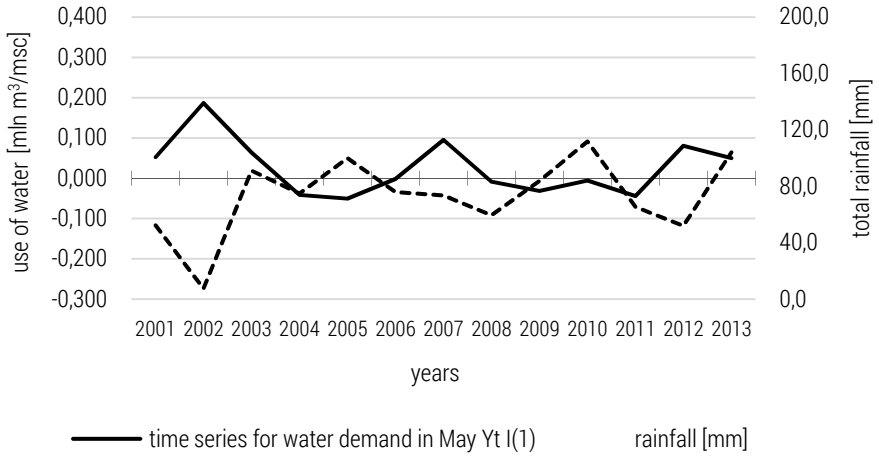

Figure 4. Time series for water demand $Y_t I(1)$ and the total rainfall in May in years 2001–2013.

Source: author's own analysis based on data from Wodociągi Białostockie and www.ogimet.com

Bearing in mind the previous considerations regarding the identification of three distinctive seasons, an attempt was made to describe these periods using separate models. It was concluded, taking into account the percentage of individual systematic components in the distinguished seasons, that due to the small share of the seasonal and random fluctuations in seasons 1 and 3 it would be sufficient to describe the months from January to April and from September to December using a single linear model including only the

price for water and sewage treatment as an independent variable. The inclusion of meteorological factors is justified only for the second season (from May to August). Using the Classical Least Squares (CLS) method the following linear model for seasons 1 and 3 was estimated:

$$\mathbf{Y = 1{,}762 - 0{,}1822\ X_1}$$
$$(0{,}0195)\ (0{,}00786)$$

where:

X_1 – price for water and sewage treatment [PLN/m^3].

The above equation shows that from September to April the price for water increased by 1 PLN/m^3 and results in a monthly decrease in water demand by 0.1822 million m^3. This model explained 85.04% of the variability in water demand in the indicated months of the analysed period. All structural parameters were statistically significant. Estimation errors were small: 1.1% of a structural parameter for the constant term, and 4.3% for a parameter with variable X_1.

Separate models were also considered for seasons 1 and 3, which had similar compatibility between simulated and real data. The coefficient of determination for season 1 ($Y = 1.786 - 0.1893\ X_1$) was R^2=85.45%, and for season 3 ($Y = 1.729 - 0.1720\ X_1$) was R^2=83.04%. Linear trend models were also considered in the study, and they provided comparable results because of the relatively steady growth of the price for water and sewage treatment over time.

In analyses related to season 2 different econometric models and a diverse range of external factors were considered. The best compatibility of simulated and real data and the lowest errors of the estimate for parameters were obtained using a linear approximation model, CLS method and a different model for each month from May to August. Parameters and errors of the estimate obtained for individual months are presented in Table 2.

Considering the above results, linear models for individual months were expressed by the following equations:

MAY: $\mathbf{Y = 1{,}4796 - 0{,}1818\ X_1 + 0{,}0344\ X_2 - 0{,}0017\ X_3}$

JUNE: $\mathbf{Y = 1{,}9134 - 0{,}1763\ X1 - 0{,}0008\ X_3}$

JULY: $\mathbf{Y = 1{,}0973 - 0{,}1687\ X_1 + 0{,}0383\ X_2 - 0{,}0006\ X_3}$

AUGUST: $\mathbf{Y = 1{,}0275 - 0{,}1929\ X_1 + 0{,}0486\ X_2 - 0{,}0009\ X_3}$

Table 2. Structural parameters of econometric models for individual months

Variable	May		June		July		August	
	b	bł. z b	b	bł. z b	b	bł. z b	b	bł. z b
Constant term	1,4796	0,1189	1,9134	0,0646	1,0973	0,1199	1,0275	0,2607
Price X_1	-0,1818	0,0253	-0,1763	0,0007	-0,1687	0,0170	-0,1929	0,0253
Temperature X_2	0,0344	0,0082	-	-	0,0383	0,0055	0,0486	0,1295
Rainfall X_3	-0,0017	0,0005	-0,0008	0,0285	-0,0006	0,0002	-0,0009	0,0003
R^2	0,9280		0,8660		0,9703		0,9374	

Where: b – value of a structural parameter; bł. z b – standard error of the estimate for a structural parameter

All structural parameters of linear models were statistically significant at the adopted level of confidence $\alpha = 0.10$. In the case of June, due to the large error of the estimate for the parameter (68.13% of the structural parameter) with variable X_2 describing air temperature, the model included only fluctuations in the prices for water and total monthly rainfall. The validity of the removal of variable X_2 from the model was also justified by a small (about 0.025) difference in the coefficient of determination for both analyzed econometric models.

The analysis of the values of the obtained structural parameters (Table 2) showed a correlation between the increase in prices for water and a decrease in water use in the range from 0.1687 to 0.1929 million m^3/month. The increase in air temperature had a positive effect on the increase in water demand, and this trend was most pronounced in August (b=0.0486). The impact of fluctuations in total rainfall was strongest in May. The structural parameter at the level of 0.0017 indicates that an increase in rainfall by 1 mm results in a decrease in water use by 0.0017 million m^3/month. This index is almost two-fold higher for May compared to other months. The factual verification of the calculated parameters of econometric models indicated that they are consistent with general knowledge. The correctness of the obtained multiple regression equations is also supported by the compliance between parameter signs and Pearson's correlation coefficients, implying the coincidence of models.

The analysis of the obtained values of the coefficient of determination (Table 2) revealed that all the estimated models are characterised by a very good compatibility between simulated and empirical data. The linear model describing changes in water demand in July, taking into account three independent variables (prices for water, air temperature, rainfall), explained 97.03% of the variability in water demand in this month. The R^2 coefficient

for May and August was about 93%, and the lowest value of this parameter was found in June (R^2=0.8660%). Compatibility between simulated and empirical data is presented in Figure 5.

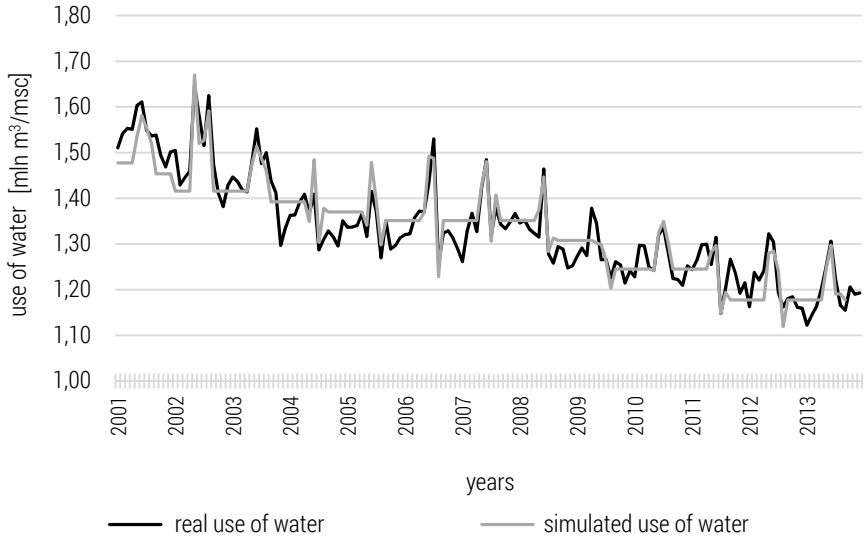

Figure 5. Real vs simulated data on water demand.

The study also considered a seasonal model of monthly water demand including all months between 2001 and 2013 (156 observations). Estimation was carried out for a model with constant seasonal dummy variables (Z_1, Z_2, Z_3) and three external variables: the price for water (X_1), air temperature (X_2) and rainfall (X_3). The obtained model explained 84.77% of the variation of the dependent variable. All the estimated structural parameters of the modified model were statistically significant, but a relatively high error of the estimate was found for seasonal variables. A similar analysis was also carried out for the seasonal linear model which did not include external variables X_1, X_2 and X_3. The model estimated with the generalized least squares (GLS) technique explained 79.88% of the variation, and therefore the elimination of three dependent variables reduced the coefficient of determination by about 0.05.

Conclusions

Considering all the above findings on the modelling of monthly water demand in Białystok, a combination of five linear functions, i.e. a linear model for seasons 1 and 3 and four linear functions for each month of the season 2 (May – August) was assumed as the best mathematical description of the analysed process. The introduction of meteorological variables, i.e. total monthly rainfall and air temperature is justified only in the period from May to August, while in the remaining months a declining trend clearly prevails and is largely determined by the increasing price for water and sewage treatment.

The obtained linear models are characterised by very good compatibility of simulated and real data. Coefficients of determination for all obtained linear models are higher than 85%. The lowest value of R^2 (85.45%) was found for the model describing water use in autumn and winter months. This may be attributed to the fact that only the economic factor (price for water) was considered. About 15% of variability of the analysed process unexplained by the model can be attributed to many different factors, including the increase in the metering of water use and reduced failure rate of the water supply network.

The analysis of variability of water use in water supply systems showed relationships and trends in the analysed process and allowed for the development of a mathematical model describing monthly demand for water. The developed models can be applied for the forecasting of water use in the analysed area, which is an important issue in view of the optimised control of the general process of water supply.

Acknowledgements

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REGIONAL-SCALE SUITABILITY ANALYSIS FOR WIND ENERGY DEVELOPMENT IN LIGHT OF SELECTED CONDITIONS

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REGIONALNA ANALIZA PRZYDATNOŚCI TERENÓW DO ROZWOJU ENERGETYKI WIATROWEJ W ŚWIETLE WYBRANYCH UWARUNKOWAŃ

STRESZCZENIE: W ostatnich latach notowano rosnący wzrost zainteresowania krajowych i zagranicznych inwestorów lokalizacją obiektów energetyki wiatrowej w różnych rejonach Polski. Wśród nich, województwo podlaskie charakteryzuje się korzystnymi warunkami wietrzności i znaczną dostępnością terenów predysponowanych do rozwoju energetyki wiatrowej. Obszary predysponowane można uznać za użyteczne, niemniej jednak w kontekście pewnych uwarunkowań, niektóre z nich mogą odznaczać się wyższym stopniem przydatności do pełnienia założonej funkcji.

W pracy zaproponowano procedurę oceny stopnia przydatności terenów predysponowanych do rozwoju energetyki wiatrowej w skali regionalnej na podstawie wybranych uwarunkowań.

SŁOWA KLUCZOWE: GIS, energetyka wiatrowa, wielokryterialne wspomaganie decyzji

Introduction

A rising trend resulting from the presence of strong political and economic stimuli has been observed both in the global production, as well as the consumption of energy from renewable resources[1]. After the Polish accession to the European Union an increasing level of investment of domestic and foreign capital in the wind energy sector was noted[2]. Nevertheless, because of the collision risk, wind turbines cannot be placed in random locations[3], which generates the need for ongoing research on this problem.

One of the commonly used solutions in this area is the implementation of modern IT tools offered by the rapidly developing discipline of Geographic Information Science and Technology (GIS&T)[4]. Due to the interdisciplinary nature of the discussed problem, GIS technology is often combined with the methods of multi-criteria decision support. The popularity of this type of solution is evidenced by numerous Polish[5] and foreign publications[6] on the optimal location of wind power structures.

This paper proposes a methodological approach allowing for the assessment of the suitability of land predisposed to the development of wind energy in the light of a wide range of conditions. Results from the study were confronted with the existing locations of wind turbines.

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1 B. Bożętka, *Pozyskiwanie energii wietrznej a zmiany krajobrazu. Konsekwencje dla funkcji rekreacyjnej*, „Krajobrazy rekreacyjne – kształtowanie, wykorzystanie, transformacja. Problemy Ekologii Krajobrazu" 2010 Vol. XXVII, p. 49.

2 M. Kistowski, *Propozycja metodyczna oceny środowiskowych uwarunkowań lokalizacji farm wiatrowych w skali regionalnej,* „Przegląd Geograficzny" 2012 No. 84(1), p. 5.

3 J. Swofford, M. Slattery, *Public attitudes of wind energy in Texas: Local communities in close proximity to wind farms and their effect on decision-making,* "Energy Policy" 2010 Vol. 38, pp. 2508–2519.

4 J. Kozak, *Jerzy Bański: Jaka geografia? – uwarunkowania i spojrzenie w przyszłość: głos w dyskusji,* „Przegląd Geograficzny" 2013 No. 85(3), p. 456.

5 W. Synowiec, M. Luc, *Wielokryterialna ocena przydatności terenu do rozwoju energetyki wiatrowej na przykładzie gminy Rymanów*, „Przegląd Geograficzny" 2013 No. 85(3), pp. 323–352; M. Szurek, J. Blachowski, A. Nowacka, *GIS-based method for wind farm location multi-criteria analysis*, "Mining Science" 2014 No. 21, pp. 65–81.

6 J.R. Janke, *Multicriteria GIS modeling of wind and solar farms in Colorado,* "Renewable Energy" 2010 Vol. 35, pp. 2228–2234.

Study area

The presented case study concerns Podlaskie province in north-eastern Poland. Previous analyses by the author[7] demonstrated that Podlaskie province is characterised by advantageous wind conditions and has a significant reservoir of areas predisposed to wind energy development. Based on a set of exclusion criteria, considering infrastructural, environmental, socio-cultural and hydrogeological aspects, ranges of areas predisposed to the development of wind energy, representing approximately 30% of the studied area, were identified. Considering the whole province, most of the available predisposed areas (more than 40% of the total area) were found in the districts of Suwałki, Wysokie Mazowieckie, Bielsk Podlaski and Kolno.

Areas predisposed to the location of wind energy structures may be considered useful, but in the light of additional factors some of them may offer more favourable conditions for this function. Further sections of this paper present a comprehensive analysis of the conditions that determine the features of land predisposed in the context of its suitability for future investment related to the use of wind energy.

Material and methods

The spatial character of the undertaken research problem and the need to take into account a number of different conditions are the reasons to use GIS spatial analysis integrated with multi-criteria decision support techniques.

The soft computing criteria (parameters or factors) considered in this study[8] may determine the suitability of land in Podlaskie province predisposed to the predefined function to a different extent, and thus their hierarchy has to be identified. The preference for individual criteria and subcriteria was investigated using one method of multiple criteria decision-making – the Analytic Hierarchy Process (AHP), for which theoretical foundations were developed by the American mathematician T.L. Saaty[9]. AHP is a popular tool for solving interdisciplinary research problems, as confirmed by

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7 Ł. Kolendo, *Przestrzenno-środowiskowe determinanty rozwoju energetyki wiatrowej w województwie podlaskim*, „Ekonomia i Środowisko" 2015 No. 3(54), pp. 42–55.

8 B. Hejmanowska, E. Hnat, *Wielokryterialna analiza lokalizacji zabudowy na przykładzie gminy Podegrodzie*, „Archiwum Fotogrametrii, Kartografii i Teledetekcji" 2009 Vol. 20, pp. 109–121.

9 T.L. Saaty, *How to make a decision: The Analytic Hierarchy Process*, "European Journal of Operational Research" 1990 No. 48, pp. 9–26.

numerous works devoted to both the theoretical and practical aspects of this method[10].

The next level in the hierarchical model (PII) includes the main criteria related to anemometric, geomorphological, environmental, social and infrastructural conditions. In the process of the decomposition of the investigated decision-making problem a total of 17 subcriteria for assessment (PIII) assigned to the main criteria of level II were identified. At level IV (PIV), additional ranges of variation were defined within individual subcriteria. Due to the nature of the principal objective, i.e. the global assessment of suitability, there was no need to create the last level (PV) of the structure, corresponding with decision-making variants (hypothetical locations of wind farms).

In the next step global and local preferences were determined through a series of paired comparisons of individual criteria and subcriteria at each predefined level of the hierarchical model. The comparisons were carried out using the 1–9 fundamental scale of absolute numbers developed by Saaty (where 1 means equal importance and 9 means extreme importance). The consistency of comparisons was assessed based on the value of the consistency ratio.

The necessary calculations related to the implementation of the AHP method for the analysed problem were carried out in suitably prepared MS Excel sheets.

The second part of the proposed procedure involved the use of spatial analysis conducted using open source GIS[11]. Relevant spatial data had to be gathered for that purpose, and they are presented in Table 1.

At first GIS technology was used to create a database including layers with a spatial representation of the 17 assessed subcriteria (PIII). The individual layers were mainly generated using a buffering operation. Different size buffer zones were adopted, depending on the nature of the analysed spatial layer and sizes proposed by other authors, and in other cases the size of equidistants was determined arbitrarily by the author.

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10 M. Dytczak, *Wybrane metody rozwiązywania wielokryterialnych problemów decyzyjnych w budownictwie*, Opole 2010, pp. 63–65.

11 P. Netzel, *Analizy przestrzenne z wykorzystaniem GRASS*, „Rozprawy Naukowe Instytutu Geografii i Rozwoju Regionalnego Uniwersytetu Wrocławskiego" 2011 No. 15, p. 7.

Table 1. Spatial data used for analysis

Database name	Format	Source
Baza Danych Obiektów Ogólnogeograficznych (BDOO) (General Geographic Database)	*.gml	Centralny Ośrodek Dokumentacji Geodezyjnej i Kartograficznej w Warszawie (Central Documentation Centre of Geodesy and Cartography in Warsaw)
Państwowy Rejestr Granic (State Register of Borders)	*.shp	
Vector map of soil and agricultural land, scale 1:25 000	*.shp	Wojewódzki Ośrodek Dokumentacji Geodezyjnej i Kartograficznej w Białymstoku (Provincial Documentation Centre of Geodesy and Cartography in Białystok)
Legal forms of nature protection	*.shp	Regionalna Dyrekcja Ochrony Środowiska w Białymstoku (Regional Directorate for Environmental Protection in Białystok)
Important Bird Areas (IBA)	*.shp	www.birdlife.org
SRTM terrain model with a resolution of 1 second (approx. 30 m)	*.GeoTIFF	www.earthexplorer.usgs.gov

It was also assumed that the generated buffer zones should cover the entire study area (land predisposed to the development of wind energy in Podlaskie province). The proximity analysis included such elements as the network of protected areas, surface water bodies and forests, linear infrastructure (power lines, roads), as well as buildings and existing wind turbines.

Geomorphological factors taken into consideration included primary topographic attributes[12] shown in the maps of slopes and aspects, determined directly from the terrain model. Assessment also included wind zones[13] and conditions related to the value of agricultural production space determined based on the system of soil classification. All subcriteria adopted for assessment (PIII), and the corresponding ranges of variation (PIV) are shown in Tables 2 and 3.

The final suitability of land predisposed to fulfil the expected function was determined as the sum of global preferences at the lowest level (PIV) of the hierarchical structure, and results were presented for a basic plot size of 10x10 m. Then, 6 contractual suitability categories were identified based on the spatial distribution of the results. In the last phase of the proposed analytical process the obtained data on the suitability of areas were confronted with the existing distribution of wind power structures in Podlaskie province.

12 J. Urbański, *GIS w badaniach przyrodniczych*, Gdańsk 2008, p. 158.

13 H. Lorenc, *Atlas klimatu Polski,* Warszawa 2005.

A hierarchical structure of the research problem

Global weights (WG) and local weights (WL) at each level of the model were identified after the decomposition of the investigated decision-making problem into a model of hierarchical structure and subsequent stages of AHP (Tables 2 and 3).

Of all the five primary groups of criteria (PII) analysed in this study the highest rank was given to the conditions of the natural environment. The key importance of environmental factors is mainly dictated by their large number (10 of 17 examined subcriteria at level PIII of the structure). Among the subcriteria of level PIII the environmental factors with the greatest impact on the primary objective of the analysis included the distance from protected areas, especially important bird areas. One of the above environmental parameters under assessment is the agricultural production space, where poor soils and wasteland are the preferred locations for wind power structures.

Further analysis of data in Table 2 and 3 revealed that in addition to environmental factors, social and infrastructural parameters also have a high priority. With respect to social conditions for wind power development in the analysed area a key role is attributed to the distance between the hypothetical investments and built-up areas. In this group the lowest priority was given to the distance between the hypothetical wind power structures and the existing wind turbines, assuming that a lower priority should be given to areas where a cumulative effect could be achieved (concentration of the planned and existing wind power infrastructure).

As with other elements of infrastructure in the study area, greater importance in the context of achieving the primary objective was found for the distance between wind power infrastructure and power lines. The accessibility of power lines is closely correlated with the profitability of wind energy investments.

At the level of the main assessment criteria (PII) the lowest preferences with respect to level PI was given for anemometric and geomorphological conditions (with designated global weights of 0.0612 and 0.0670, respectively). However, anemometric conditions are one of the key elements determining the cost-effectiveness of this type of investment. Due to the lack of detailed anemometric data, only a general regionalization of the studied area into four wind zones was considered in the analysis. Because of the high degree of uncertainty of these data, anemometric conditions were given a lower rank compared to other groups of parameters at level II.

Table 2. Global weights (WG) and local weights (WL) for individual levels of the hierarchical structure in the light of anemometric, geomorphological and environmental conditions

PI	PII	WG	PIII	WL	WG	PIV	WL	WG
SUITABILITY ANALYSIS FOR WIND ENERGY DEVELOPMENT	Anemometric conditions	0,0612	wind zone	1,0000	0,0612	zone I	0,4673	0,0286
						zone II	0,2772	0,0170
						zone III	0,1601	0,0098
						zone IV	0,0954	0,0058
	Geomorphology	0,0670	slope [degrees]	0,5000	0,0335	0-7	0,5462	0,0183
						7-12	0,2323	0,0078
						12-15	0,1377	0,0046
						> 15	0,0838	0,0028
			aspect [degrees]	0,5000	0,0335	N, NW, flat	0,5396	0,0181
						N, NE, S, SW	0,2970	0,0100
							0,1634	0,0055
	Natural environment	0,4586	agricultural production space	0,1095	0,0502	class I-III	0,0551	0,0028
						class IV	0,1301	0,0065
						class V-VI	0,2640	0,0133
						wasteland	0,5508	0,0277
			distance from forest borders [m]	0,0775	0,0355	0-200	0,0652	0,0023
						200-1000	0,1128	0,0040
						1000-3000	0,2257	0,0080
						> 3000	0,5963	0,0212
			distance from the borders of a landscape park [m]	0,1165	0,0534	within borders	0,0416	0,0022
						0-500	0,1414	0,0076
						500-1000	0,3122	0,0167
						> 1000	0,5047	0,0270
			distance from the borders of a protected landscape area [m]	0,0411	0,0188	within borders	0,0954	0,0018
						0-500	0,1601	0,0030
						500-1000	0,2772	0,0052
						> 1000	0,4673	0,0088
			distance from the borders of a Natura 2000 site (SPA) [m]	0,1390	0,0638	0-500	0,0613	0,0039
						500-1000	0,0948	0,0060
						1000-5000	0,2589	0,0165
							0,5850	0,0373

SUITABILITY ANALYSIS FOR WIND ENERGY DEVELOPMENT	Natural environment	distance from the borders of a Natura 2000 site (SAC) [m]	0,0715	0,0328	0-500	0,1047	0,0034
					500-1000	0,2583	0,0085
					> 1000	0,6370	0,0209
		distance from the borders of IBA [m]	0,1443	0,0662	within borders	0,0783	0,0052
					0-500	0,1517	0,0100
					500-1000	0,2628	0,0174
					> 1000	0,5073	0,0336
		distance from the borders of a national park or nature reserve [m]	0,2013	0,0923	0-500	0,1047	0,0097
					500-1000	0,2583	0,0238
					> 1000	0,6370	0,0588
		distance from the borders of other protected areas* [m]	0,0538	0,0247	0-500	0,1634	0,0040
					500-1000	0,2970	0,0073
					> 1000	0,5396	0,0133
		distance from watercourses and surface water bodies [m]	0,0456	0,0209	0-500	0,1634	0,0034
					500-1000	0,2970	0,0062
					> 1000	0,5396	0,0113

* other protected areas include ecological sites, nature and landscape complexes and documentation sites

Use of Geographic Information Systems

The use of Geographic Information Systems was a key element in the solving of the analysed problem. Global preferences from level IV of the hierarchical structure identified through the implementation of AHP were used for the polarization of the study area in the context of the 17 analysed subcriteria of assessment (PIII). Examples of spatial layers, created through the reclassification of raster images representing selected criteria for the assessment of the suitability of predisposed land in Podlaskie province are shown in Figure 1.

The final suitability of predisposed land can vary in theory from 0.0869, if a certain location (10x10 m plot) is given the lowest rating in light of the evaluation criteria, to 0.5410 if the situation is the opposite. In practice, such

Table 3. Global weights (WG) and local weights (WL) for individual levels of hierarchical structure in the light of social and infrastructural conditions

PI	PII	WG	PIII	WL	WG	PIV	WL	WG
SUITABILITY ANALYSIS FOR WIND ENERGY DEVELOPMENT	Social conditions	0,1896	distance from buildings [m]	0,8000	0,1517	500-1000	0,0524	0,0079
						1000-2000	0,1157	0,0176
						2000-3000	0,2586	0,0392
						> 3000	0,5733	0,0870
			distance from the existing wind turbines [m]	0,2000	0,0379	< 1000	0,1634	0,0062
						1000-5000	0,2970	0,0113
						> 5000	0,5396	0,0205
	Infrastructural conditions	0,2236	distance from power lines [m]	0,7500	0,1677	250-2000	0,4673	0,0784
						2000-5000	0,2772	0,0465
						5000-10000	0,1601	0,0268
						> 10000	0,0954	0,0160
			distance from roads [m]	0,2500	0,0559	< 500	0,0688	0,0038
						500-1000	0,5447	0,0304
						1000-2000	0,2286	0,0128
							0,1579	0,0088

extreme values of land suitability were not recorded. Końcowa przydatność terenów predysponowanych może teoretycznie wykazywać zmienność od 0,0869, w przypadku uzyskania w danej lokalizacji (pole 10×10 m) najniższych ocen w świetle stosowanych kryteriów oceny, do 0,5410 przy założeniu sytuacji odwrotnej. W rzeczywistości nie odnotowano wskazanych wcześniej skrajnych wartości przydatności terenu.

Statistical analysis of the final map of suitability defined as the sum of global preferences at the lowest level of the hierarchical structure indicated that the actual range of variation of the investigated feature was from 0.1611 to 0.5188. Considering the above, 6 contractual suitability zones were established: class I (> 0.46), class II (0.41-0.45), class III (0.36-0.40), class IV (0.31-0.35), class V (0.26-0.30), and class VI (< 0.25) (Figure 2).

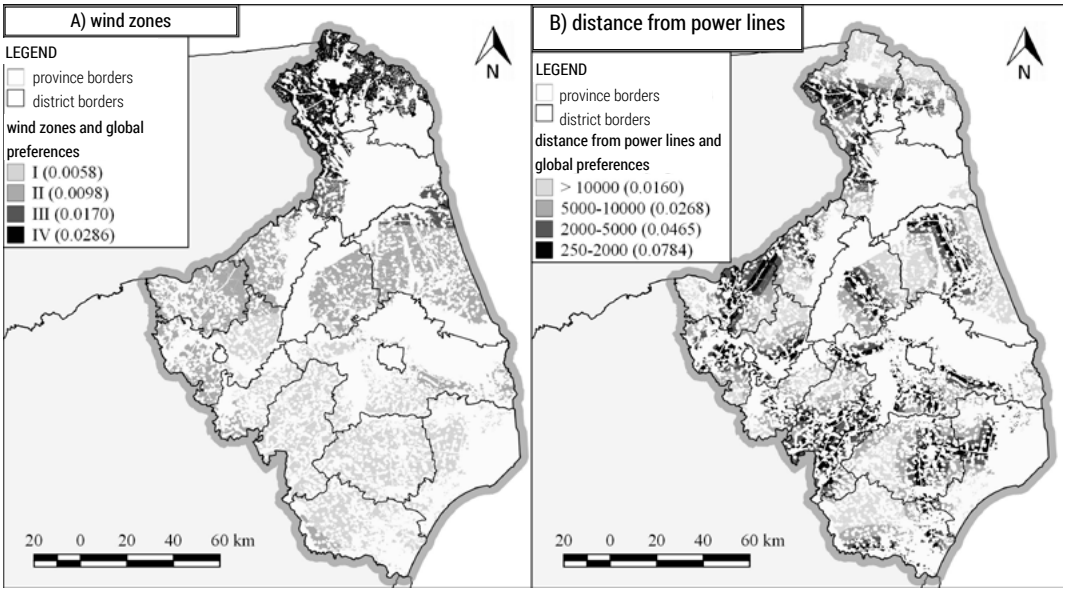

Figure 1. Wind zones (A) and global preferences and ranges of the distance from power lines (B) with corresponding global weights

Among the areas predisposed to the development of wind energy in Podlaskie province, the largest space is occupied by areas of suitability class IV (Table 4). They cover 51.71% of all the predisposed area and 15.42% of the total area of the province. The most suitable class I covers only 1.50% of predisposed land (0.45% of the total area of the province). In Podlaskie province areas of suitability class I-III cover about 2,400 km^2, which accounts for 11.86% of the total area of the province.

The analysis of data presented in Figure 2 shows a significant difference in the distribution of areas representing the identified classes of suitability in the districts of the province. The majority of areas classified in the course of the analysis as the most suitable for wind energy development (suitability class I-III) are located in districts where this type of investment has already been made[14] (Table 5). These include areas in Suwałki district (dominant position in the field of wind energy investments), and Wysokie Mazowieckie and Grajewo districts, where the total share of class I-III areas is from 12.22% to 34.76% of the total district area.

14 Map of renewable energy sources based on licenses granted by the President of the Energy Regulatory Office and entries in the register held by the President of the Agency for Regional Development (ARR), www.ure.gov.pl [06/01/2016].

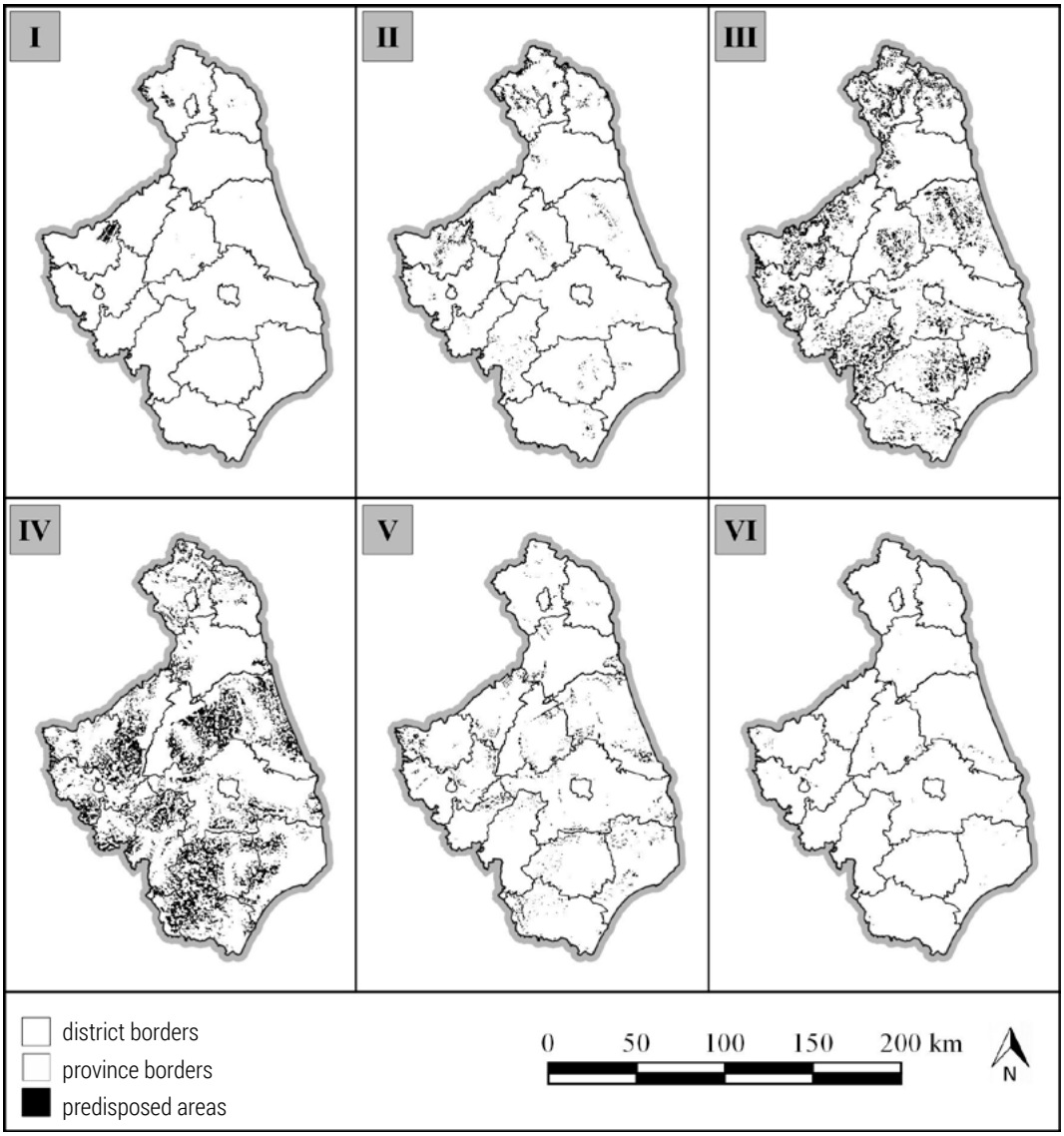

Figure 2. Distribution of areas predisposed to the development of wind energy in Podlaskie province, with indication of individual suitability classes

Different conditions can also be observed proving the existence of investment potential, but this is not reflected in the actual utilisation of this potential and construction of wind power structures. For example, in Kolno and Sejny districts, characterised by relatively large potential for the development of wind energy, no such investments have been made.

Table 4. Areas of individual classes of suitability and their share in the area of predisposed land and total area of the province

Class	Area [km^2]*	Share in predisposed land [%]	Share in total area of the province [%]
I	90,55	1,50	0,45
II	361,55	6,00	1,79
III	1942,72	32,25	9,62
IV	3114,32	51,71	15,42
V	477,40	7,93	2,36
VI	36,51	0,61	0,18
Total:		100,00	29,83

* area calculated as the product of the number of raster cells for a given suitability class and surface area of the basic plot used for calculation (10×10 m)

Location of wind energy structures in the context of study results

Current statistics from the Energy Regulatory Office[15] show that Podlaskie province is characterised by a significant use of wind power compared to the whole country. The 27 wind farms installed in Podlaskie province generate in total 181.41 MW. This information was used to verify the effectiveness of the proposed analytical procedure. It was assumed that investments made to date in the field of wind energy were implemented in line with legislation while maximizing return on investment. Therefore, the existing wind turbines should be located within the boundaries of predisposed areas having big advantages in terms of their suitability.

One–hectare plots[16] around the existing wind turbines higher than 30 m were analysed. The data on their location were acquired from the General Geographic Database (BDOO). There was good compatibility between the characteristics of each area: most of the existing wind farms are situated within the boundaries of predisposed and highly-suitable areas. Over 91% of the analysed wind power structures are located within the predisposed areas. The existing wind power structures are situated in areas of moderate level of suitability (0.38, suitability class III, 48.44% of wind turbines). 17.18% of all turbines are located in class IV areas, 29.69% of turbines in class II areas, and 4.69% – in the most suitable class I areas.

15 Ibidem.

16 M.J. Banak, *Lokalizacja elektrowni wiatrowych – uwarunkowania środowiskowe i prawne*, „Człowiek i Środowisko" 2010 No. 34(3–4), p. 120.

Table 5. Zestawienie procentowego udziału klas przydatności w powierzchni całkowitej poszczególnych powiatów oraz zainstalowanej mocy elektrowni wiatrowych

District	Power of wind farms [mw]	Share of the class in the total area of the district [%]					
		I	II	III	IV	V	VI
Sejny	0,00	0,22	4,07	11,17	6,44	0,47	0,04
Wysokie Mazowieckie	5,60	0,00	1,38	19,46	19,35	0,76	0,15
Łomża	2,00	0,00	0,60	10,34	24,02	2,99	0,29
Augustów	0,00	0,00	0,54	3,52	5,41	2,18	0,08
Białystok	0,60	0,00	0,08	5,53	8,59	1,57	0,08
Mońki	0,00	0,05	1,12	8,58	19,05	2,89	0,45
Suwałki city	0,00	0,00	0,89	9,08	3,59	0,07	0,00
Sokółka	4,10	0,00	1,28	10,23	22,16	4,09	0,36
Zambrów	0,00	0,00	0,16	5,33	17,09	3,78	0,01
Białystok city	0,00	0,00	0,01	0,42	0,01	0,00	0,00
Bielsk Podlaski	28,50	0,00	0,75	10,81	27,51	1,60	0,08
Łomża city	0,00	0,00	0,00	2,81	0,15	0,02	0,07
Grajewo	25,30	0,05	1,17	11,00	15,61	3,28	0,18
Suwałki	114,71	2,87	10,88	21,01	10,59	0,70	0,03
Hajnówka	0,60	0,00	0,41	4,41	9,28	2,47	0,22
Siemiatycze	0,00	0,01	0,55	4,78	23,10	2,58	0,11
Kolno	0,00	5,29	7,12	19,78	14,23	5,05	0,50

Conclusions

The methodological approach integrating GIS techniques and the multi-criteria decision support proposed in this study allowed for a comprehensive assessment of the suitability of land predisposed to the development of wind power infrastructure in Podlaskie province. The use of spatial data available for the whole of Poland indicates that this approach can be successfully implemented in relation to other regions.

In the context of the obtained results it should be noted that Podlaskie province is significantly polarized in spatial terms and suitability of particular areas for the development of wind energy infrastructure. There are examples where the identified potential has been utilised through the installation of wind farms, but there are also other areas potentially suitable for this type of investment.

Despite the significant benefits of this type of solution in the sector of RES, one should bear in mind the limitations of the proposed method, which are related, among other things, to the regional scale of the analysis. The geographical space covered by the study was large, and this determined the use of generalised data sets, as well as simplified analysis of certain phenomena and issues. This particularly concerns anemometric conditions in the study area, as well as the assumption that existing investments in the sector of wind energy were implemented in locations ensuring maximum economic profit while fully maintaining the legal requirements. Considering the advantages and some limitations of the proposed approach it should be emphasized that it can still be widely applied to analyse the discussed problem on a regional scale. This method can successfully support regional spatial planning procedures to optimise the directions of development of the renewable energy sector.

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PHOTOVOLTAIC SYSTEMS AS AN EXAMPLE OF ECONOMICALLY JUSTIFIED PROSUMER OPERATIONS

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INSTALACJE FOTOWOLTAICZNE JAKOPRZYKŁAD UZASADNIONEJ EKONOMICZNIE DZIAŁALNOŚCI PROSUMENCKIEJ

STRESZCZENIE: Instalacje fotowoltaiczne są przykładem odnawialnych źródeł energii wykorzystujących energię słoneczną. Zaprezentowano przykładową analizę zastosowania instalacji fotowoltaicznej wykonaną dla rzeczywistego przedsiębiorstwa znajdującego się na terenie Lubina, przedstawiającą efektywną wartość uzyskanej energii oraz rozkład kosztów i zysków. Instalacja fotoogniw to jedna z metod włączenia się do energetyki prosumenckiej, wspieranej między innymi w działaniach 3.1 i 3.2 RPO WD oraz przez NFOŚiGW.

SŁOWA KLUCZOWE: fotowoltaika, energia słoneczna, prosument

Introduction

The progress of civilization is a factor driving the increasing demand for energy. This creates the need to seek alternative energy sources which do not rely on the combustion of organic fossil fuels. Alternative energy can come from renewable and non-renewable sources. Renewable energy is collected from naturally replenished resources such as hydropower, wind power, biomass, biogas, sunlight and/or geothermal heat contained in the environment[1]. The safest source of energy not raising social concerns is solar power. It can be utilized in two ways: in thermal solar panels used primarily for domestic hot water, and in photovoltaic cells, which generate electricity. Photovoltaic cells seem to be a more cost-effective solution.

This study shows the potential benefits to users of photovoltaic systems in the context of prosumer energetics, and is aimed at analysing the legitimacy of photovoltaic cell installation.

Photovoltaic cells

A photovoltaic (PV) cell is a device that converts the energy of visible and infrared light into electricity. The conversion is possible because of the use of semiconductors – solid materials in which charge carriers move within a crystal lattice. There are two types of semiconductors: n-type (negative) and p-type (positive); these can be, for example, silicon semiconductors doped with arsenic and aluminium, respectively. The electrical field on the p-n junctions is formed because of the opposite electrical charges: free electrons on the valence band in the n-type semiconductor and valence holes on the p-type semiconductor. Solar power in the form of photons reaching the p-n junction generates electron-hole pairs in the junction. The separation of these pairs results in an exchange of the excess of electrons and holes between p-type and n-type semiconducting materials. The product of this process is charged ions, which results in an electrical field when the circuit is closed[2].

The performance of PV cells declared by manufacturers is given for standard test conditions (STC), that is irradiance of 1000 W/m^2 and cell temperature of 25^{o}C[3].

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1 H. Foit, *Zastosowanie odnawialnych źródeł ciepła w ogrzewnictwie i wentylacji*, Gliwice 2013, p. 17.

2 I. Góralczyk, R. Tytko, *Fotowoltaika: urządzenia, instalacje fotowoltaiczne i elektryczne*, Kraków 2015, p. 191.

3 I. Góralczyk, R. Tytko, op. cit., p. 195.

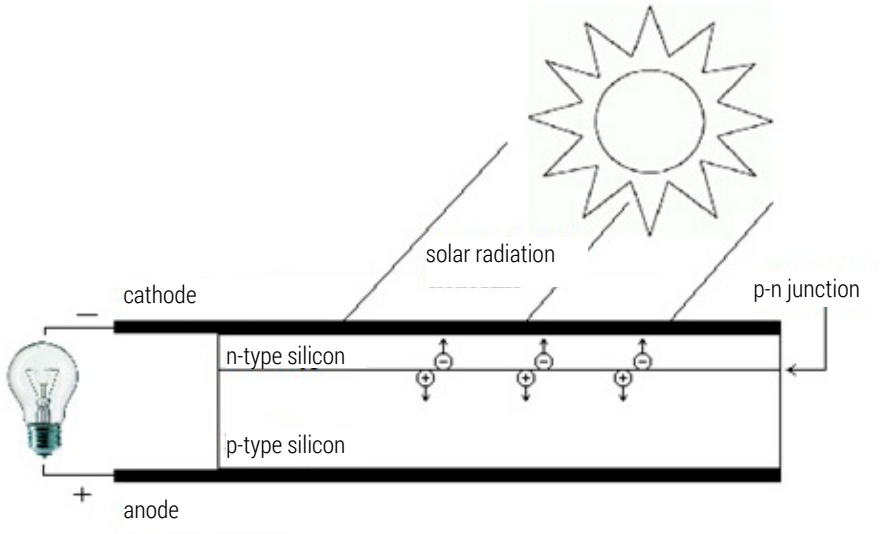

Figure 1. Schematic representation of a photovoltaic cell

Source: authors' own elaboration based on I. Góralczyk, R. Tytko, *Fotowoltaika: urządzenia, instalacje fotowoltaiczne i elektryczne*, Kraków 2015, p. 191.

The performance of different types of PV cells is presented in Figure 2[4].

Modern PV cells are characterized by a decrease in performance over time: in the first year this decline can be up to about 5% (then the device reaches a stable performance level), and in the perspective of 25 years the decline may be as much as 20% of the initial performance rate[5]. The above information should be considered when analysing the cost-effectiveness of a specific system.

The solar radiation that reaches the Earth's atmosphere can be direct, most important for the operation of PV cells, diffuse, which can still be utilised by PV systems on cloudy days when sunlight seems to be completely blocked, and reflected, not considered when designing photoelectric systems because of its unpredictable angle of reflection. The total power of solar energy reaching the Earth is about $81{,}000 \cdot 10^6$ MW. In Poland alone the potential level of energy that can be generated from solar radiation is 1,340 PJ (peta joule, 10^{15} J); however, it has been estimated that after 2020 only 20 PJ will be

4 Ibidem, p. 192.

5 Ibidem, pp. 196–197.

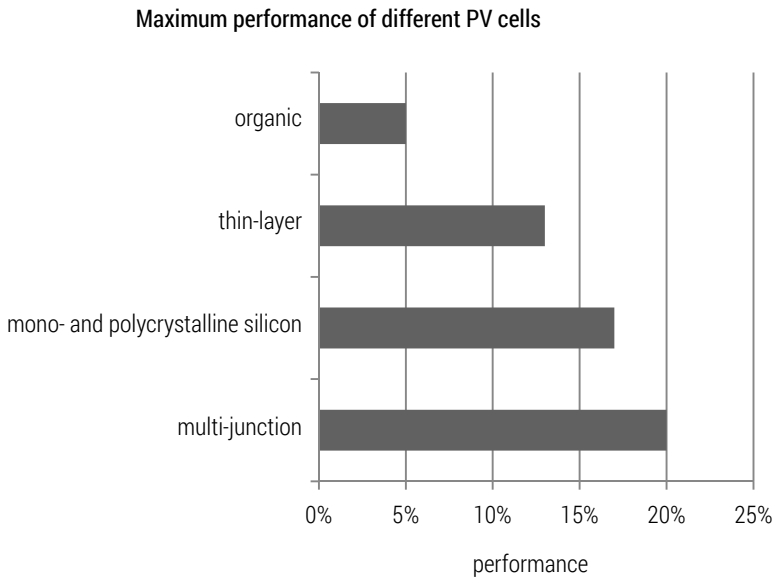

Figure 2. Performance of different types of PV cells

Source: authors' own elaboration based on I. Góralczyk, R. Tytko, op. cit., p. 192.

effectively used (less than 1.5%)[6]. This indicates the theoretically unlimited development of the national solar energy sector. The average level of solar radiation in Poland is about 1,000–1,100 kWh/m^2 with 1,600 hours of sunlight per year. The average radiation power is about 1,000,000/1,600 = 625 W/m^2 [7]. Considering countries with a climate similar to Poland, the greatest interest in photovoltaic systems is observed in Germany, where more than 2 million PV cells of 7 kW each were installed from July 2011 to the end of 2012[8].

One of the environmental benefits arising from the use of photovoltaic cells is about 1,300 tonnes of avoided CO_2 emission per year (for a 1 MW power plant)[9].

6 Ibidem, p. 185.

7 Ibidem.

8 J. Popczyk, *Energetyka prosumencka jako skutek konwergencji postępu technologicznego i rozwoju społecznego*, „Biblioteka źródłowa energetyki prosumenckiej" 2014, p. 2.

9 I. Góralczyk, R. Tytko, op. cit., p. 189.

Types of PV systems

A PV system consists of several components that allow for the supply of electricity to the utility grid (Figure 3).

Figure 3. Elements of a PV system

Source: authors' own elaboration based on I. Góralczyk, R. Tytko, op. cit., pp. 241–262.

PV systems can be stand-alone (off-grid) and grid-integrated (on-grid). Off-grid systems can be used when there is difficulty in connecting to the utility grid (e.g. because of large distances). The generated energy is then accumulated and used as needed. An alternative solution is to connect solar panels to the utility grid via an inverter. Then the user can freely use electricity, and is paid back by the operator of the power grid for the unused surplus of energy generated by solar panels[10]. On-grid systems are an example of distributed energy resources, defined by the European Commission as "stand-alone or integrated into the electricity grid small modular conversion units, used by power plants, their clients, private individuals or other parties and offering benefits to the energy sector, specific end-users or both"[11]. Another definition of diffused generation of energy describes these systems as small conversion units (with a rated output of 50–150 kW) integrated directly with the power distribution grid or located within the grid of the user (behind the metering device), also generating energy from renewable sources or electricity in combination with heat[12].

Another beneficial solution involves hybrid solar panels which combine thermal solar panels and PV cells. Increased temperature reduces the performance of photovoltaic cells by about 0.5%/K. To prevent this, a cooling system is used in PV cells (for example water pipes on the bottom of the system working as a heat exchanger), which offers a double advantage: it eliminates the negative effect of high temperature on PV cell and gives the

10 I. Góralczyk, R. Tytko, *Racjonalna gospodarka energią: wybrane zagadnienia, instalacje fotowoltaiczne i elektryczne*, Kraków 2015, pp. 255–256.

11 B. Sedler, *Alternatywne formy generacji rozproszonej, z uwzględnieniem OZE, w tym małej energetyki jądrowej*, in: B. Mickiewicz (ed.), *Najnowsze osiągnięcia z zakresu OZE wraz z przedstawieniem barier we wdrażaniu wyników badań do praktyki gospodarczej oraz sugestiami ich rozwiązań*, Koszalin 2012, pp. 99–128.

12 A. Myczko, A. Kliber, L. Tupalski, *Odnawialne źródła energii a hybrydowe systemy energetyczne*, in: B. Mickiewicz (ed.), op. cit., pp. 81–98.

possibility of using the recovered heat. The performance of hybrid systems depends on the synergy of their components[13].

Prosumer – a new player in the energy market

Prosumer energy is a new sector emerging in the energy market. A prosumer produces and consumes electricity[14]:

Prosumer = **pro**ducer + con**sumer**

According to Popczyk, prosumers are „former end-users who undertake the production of electricity for their own consumption"[15].

Prosumerism is to be promoted primarily by the Act on renewable energy sources passed on 20 February 2015, amending the existing legislation in this area, including the so-called 'small energy tripack'. The Act on RES provides, inter alia, the obligation to purchase electricity from newly constructed, up to 10 kW, RES systems at a feed-in tariff for 15 years, the obligation to purchase the unused electricity at a price of 100% of the average selling price of electricity on the competitive market in the previous quarter, and measuring differences between the amount of electricity used from the grid and the amount of energy supplied by the prosumer to the grid every six months *(*net-metering policy)[16]. The law does not specify whether investors who have received a subsidy for the installation of an RES system will benefit from the feed-in tariff, but after 2016 they can expect profits from the sale of surplus energy (at market price), and the 6-month billing system[17]. The former 'small energy tripack' did not promote the full implementation of EU law, since the proposed price for the purchase of energy from renewable sources generated by prosumers was only 80% of the market price for the previous year[18].

A survey has shown that individual investors (mainly private) are willing to install RES systems because of, for example, the ability to obtain subsidies, the influence of people from their environment, the low failure rate of RES

13 I. Góralczyk, R. Tytko, *Fotowoltaika…*, pp. 209–210.

14 K. Księżopolski (ed.), *Odnawialne źródła energii w Polsce: wybrane problemy bezpieczeństwa, polityki i administracji*, Warszawa 2013, p. 175.

15 J. Popczyk, op. cit., p. 5.

16 Act of 20 February 2015 on renewable energy sources (Dz.U. 2015 item 478); www.nfosigw.gov.pl [20/11/2015].

17 www.nfosigw.gov.pl [20/11/2015].

18 K. Księżopolski (ed.), *Odnawialne źródła energii w Polsce: wybrane problemy bezpieczeństwa, polityki i administracji*, Warszawa 2013, p. 33.

technologies, as well as trends in the development of RES. Another important factor is that many installation companies assume part of the responsibility associated with obtaining co-financing/subsidies for PV systems[19].

Investments are also stimulated by dynamic changes in the PV market. Statistics from the GTM Research report for September 2015 published at odnawialnezrodlaenergii.pl show that the average price of PV systems is expected to drop by 40% in 2020 compared with the current price, which is associated, among other things, with the introduction of feed-in tariffs in Europe. It was also emphasized that the costs of installation (service) are decreasing more slowly than the cost of the PV module (in 2007 in the United States 'soft' costs accounted for 58% versus 75% today)[20]. The decrease in costs is significantly influenced by the advances in PV technology, and above all, the increased system performance. It should, however, be borne in mind that the high performance obtained in standard test conditions does not immediately translate into an increase in the performance of products offered on the market. Nevertheless, reports on performance parameters seem to be very optimistic – for example the French company Soitec achieved 46% performance for concentrated photovoltaic cells (CPV); Soitec has launched onto the market PV cells with 31.8% performance, and its target is 50%[21].

On the other hand, the development of printed PV cells can bring significant savings on the cost of cells and their installation. The new cells printed in 3D on thin films of any shape and size are being produced on a laboratory scale. The performance of printed perovskite PV cells is up to 20%[22]. In addition, flat and flexible films can be installed without any problems on external walls and roofs, which significantly reduces the investment costs associated with their assembly. Currently, many manufacturers of multilayer sheathing boards are testing in their research centres integrated panels made of flexible film as an integral part of facade and roof structures.

However, long-term speculations on changes in electricity prices are subject to large errors. It is easier to verify the forecast for next year – Paweł Owczarski, CEO for Polski Prąd commented in October 2015 that, for example, the stock exchange prices of electricity in 2016 are lower by 5–6% compared to 2015, but their change will be driven by government policies regarding the coal mining sector. In addition, a 1–3% increase in distribution fees is

19 A. Hilarowicz, J. Kozioł (eds), *Odnawialne źródła energii – badania oddziaływań społecznych*, Gliwice 2013, p. 53.

20 www.odnawialnezrodlaenergii.pl [01/02/2016].

21 www.gramwzielone.pl [01/02/2016].

22 Ibidem [14/02/2016].

expected, which in turn cannot create any savings for individual consumers (so-called G sector)[23].

The National Fund for Environmental Protection and Water Management is currently operating a programme supporting investments in RES „Prosumer" for the years 2015–2020[24]. Grants are also provided for the replacement of existing systems with new ones; however, no support is provided for systems using only a heat source. It has been estimated that one of the environmental effects of the implementation of the programme will be a 215,000 t annual reduction in CO_2 emissions. The programme's budget for 2014–2022 is 800 million PLN. Funding is offered in the form of a 15-year loan or a credit up to 100% of eligible costs of the system with a 1% interest rate, or a 15 or 30% subsidy, but the eligible costs must be within the range from 100,000 to 450,000 PLN, depending on the beneficiary and the type of system. Private individuals, communities and housing associations can apply for subsidies through banks (Bank Ochrony Środowiska/Bank for Environmental Protection) or Regional Funds for Environmental Protection and Water Management[25].

Regional Operational Programmes are other sources of funding. Their budget is based on European Union funds, and decisions about the type of co-financed investments are made at the provincial level since each province has its own ROP. The detailed description of priority axes of the ROP for Lower Silesia province indicates, among other things, measures in the area of priority axis 3 "Low-emission economy". Particularly noteworthy are measures 3.1 and 3.2, which aim, respectively, at increased levels of energy production from renewable sources in the Lower Silesia province and increased energy efficiency in small and medium-sized enterprises (thermal modernisation).

Applications for funding can be filed by local administration units, their unions and associations, and enterprises. Due to the autonomous nature of the ROP, applicants willing to raise funds for the investment have to check which areas of technology are supported in a given province[26].

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23 www.energiadirect.pl [01/02/2016].

24 www.nfosigw.gov.pl [20/11/2015].

25 www.nfosigw.gov.pl [20/11/2015].

26 Detailed description of priority axes of the Regional Operational Programme for Lower Silesia Province 2014–2020, Project version 1, Wrocław 2015.

Analysis of return on investment for PV systems

The primary criterion for making a decision to invest in PV systems should be their return on investment (ROI). ROI depends on many factors, such as the type of module installed, its surface area, the orientation, the energy demand of the building, the price of commercial electricity, and the level of funding obtained. The calculations should take into account the forecasted changes in the prices of energy from conventional sources, especially in the context of amendments to the laws which are aimed at supporting the prosumer energy sector. To discuss the feasibility of investment in photovoltaic systems we used example data – calculations made for a Lubin-based enterprise operating in production and commerce. The proposal to install PV stems from a report prepared under a project "Firma XXI wieku to ekologiczna firma"/Green business of the 21st century" (POKL.02.01.01-00-055/13), co-financed by the European Union from the European Social Fund. One of the suggested environmental measures was to reduce the use of conventional electricity by installing a photovoltaic system. The proposal was supported by the SWOT analysis (strengths, weaknesses, opportunities, threats), which justified the installation of photovoltaic cells due to the continuous advances in the production technology and operation of PV, virtually eliminating weaknesses and threats indicated in the analysis[27].

The cost estimate for the planned investment included the calculation of the real output of electricity from photovoltaic cells, taking into account parameters such as, among others, cell type, location of the building, the orientation of panels, and various losses in relation to the final gross energy output. The analyzed system consisted of 80 photovoltaic modules and one inverter. The power of a photovoltaic system of 133.1 m^2 total surface was 20 kWp (p – peak). The table below presents subsequent calculation steps for electrical power possible to generate through the use of modules.

[27] Ł. Szałata, Prepared under the project „Firma XXI wieku to ekologiczna firma" (POKL.02.01.01-00-055/13), Wrocław 2014.

Table 1. SWOT analysis for energy acquired from solar radiation

POSITIVE	NEGATIVE
Strengths	**Weaknesses**
• no greenhouse gas emissions; • high reliability; • fast implementation of investment; • modern technologies	• lack of systems for the storage of surplus electricity and distribution systems for generated energy; • production of silicon-based cells creates a hazard for the environment; • complicated environmental impact assessment procedures (for Natura 2000 sites)
Opportunities	**Threats**
• constant and significant growth in the technological potential for the production of PVT and PV panels; • use of roof surface in urban areas; • increasing social awareness about the need for environmentally-friendly investments; • decreasing costs of the production of panels and modules.	• low-quality technologies; • relatively short useful life of panels; • problems with selling energy to a grid operator

Source: authors' own elaboration based on: Ł. Szałata, Opracowanie w ramach projektu "Firma XXI wieku to ekologiczna firma" (POKL.02.01.01-00-055/13), Wrocław 2014.

The level of solar radiation for the analysed area (Lubin) is 1,089.4 kWh m^2.

A PV system with a peak power of 20 kWp can generate 18,032 kWh of energy (AC), which gives about 902 kWh/kWp of specific profit per annum. Of the generated 18 032 kWh/year, the power supply to the system consumes 5,237 kWh/year, so the demand covered by photovoltaic cells is 12 795 kWh/year. Thus, the energy generated by PV cells covers 42.6% of the estimated demand for electricity (30,022 kWh).

The whole system consists of 40 modules oriented to the east (97°) with an inclination of 10° and a surface area of 66.5 m^2, and 40 modules oriented to the west (277°) with an inclination of 10° and a surface area of 66.5 m^2 (polycrystalline silicon modules, standing on a flat roof). The estimated share of irradiation per module in relation to the angle of global irradiation-total loss does not exceed 10%, as shown in Figure 4. Similar results were obtained for nominal photovoltaic energy (Figure 5).

Table 2. Calculated potential electricity output from the photovoltaic module

Parameters	Energy generated
Global irradiation	**1 089,4 kWh/m²**
Deviation from the standard spectrum	- 10,89 kWh/m²
Orientation and inclination of PV modules	- 10,24 kWh/m²
Reflection from the module surface	- 72,16 kWh/m²
Irradiation per module	**996,1 kWh/m²**
Photovoltaic irradiation	996,1×133,07 = **132 554,3 kWh**
STC conversion for η = 15.06 %	- 112 595,49 kWh
Nominal photovoltaic energy	**19 958,8 kWh**
Other losses	- 1 262,1 kWh
Photovoltaic energy – DC	18 696,7 kWh
Voltage range/MPP adaptation	- 102,51 kWh
PV energy (DC)	18 594,2 kWh
DC-to-AC power conversion and other losses	- 562,1 kWh
Generated photovoltaic energy	**18 032,1 kWh**

The values given in the table are rounded values obtained in calculations and may differ slightly from the real values.

Source: authors' own elaboration based on: J. Jurczyk, Projekt 029/2014.

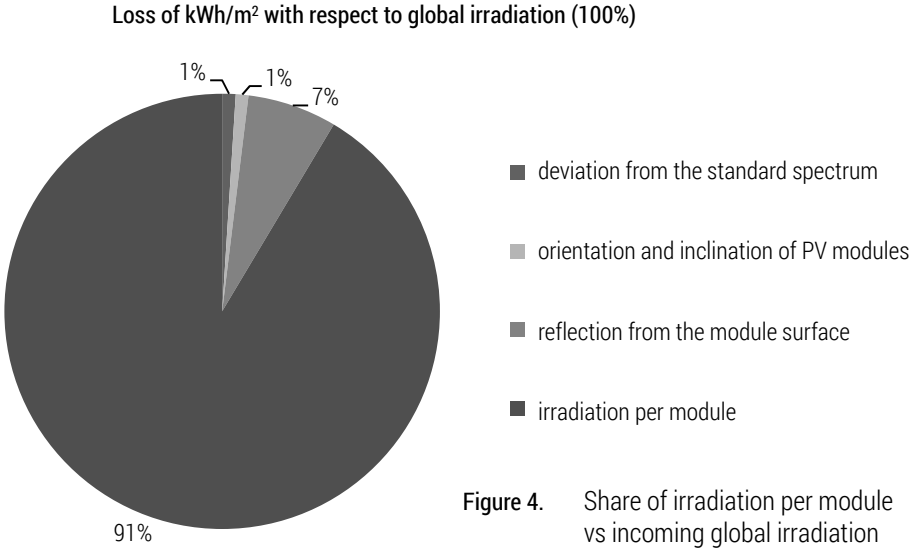

Figure 4. Share of irradiation per module vs incoming global irradiation

Source: authors' own elaboration based on: J. Jurczyk, Projekt 029/2014.

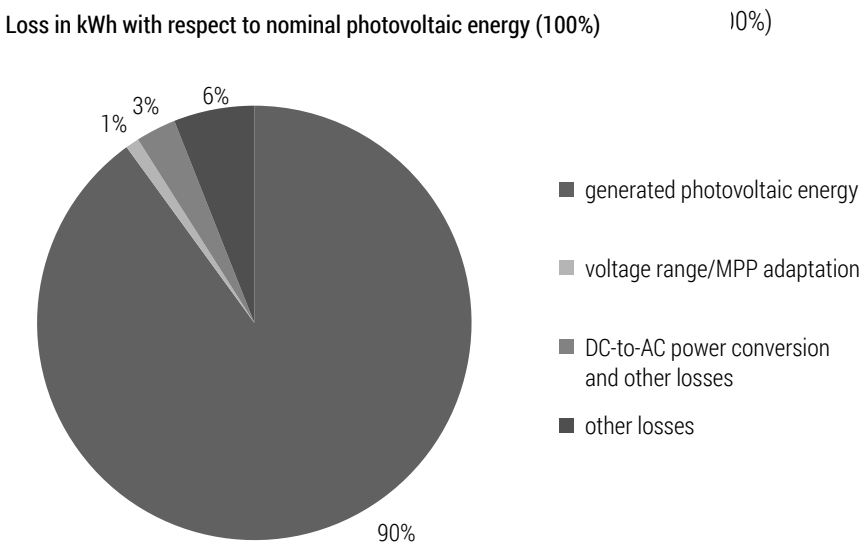

Figure 5. Share of electricity generated by a PV system vs nominal energy
Source: authors' own elaboration based on: J. Jurczyk, Projekt 029/2014.

For the investments valued at 28,400 EUR the estimated amortisation time is less than 10 years, and profit after 25 years of use (producer's warranty) is more than 9,000 EUR[28]. The system can reduce CO_2 emission by 21,613 kg/year, which is roughly consistent with literature data (1,300 t CO_2/year for a 1 MW system, as specified above). The analysis shows that the amount of energy generated by PV cells is always lower than the value given in manufacturer's specifications, and may vary depending on the location of the modules. Therefore, before making a decision on the assembly of a system a detailed cost estimate should be prepared, and the date of payback of expanse should be determined. Undoubtedly, the amortisation time will be much shorter if funding for the project is obtained. The results of analysis of return on investment – the cumulative cash flow for a period of 26 years, taking into account the cost of investment and savings on purchasing electricity are shown in Figure 6.

Major benefits include significant consumer independence from fluctuating electricity prices set by the supplier, as well as reduced risk associated with an increase in additional charges imposed on the users of elec-

[28] J. Jurczyk, Projekt 029/2014.

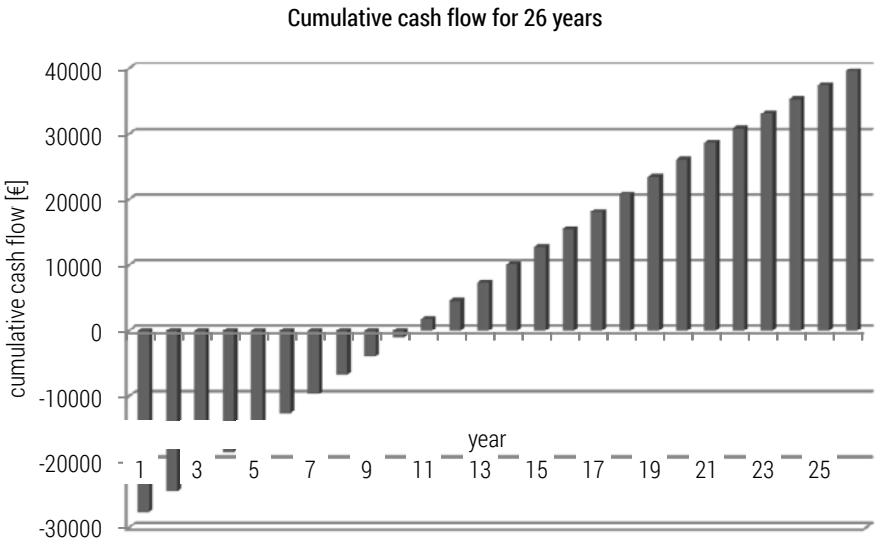

Figure 6. Analysis of return on investment

Source: authors' own elaboration based on: J. Jurczyk, Projekt 029/2014.

tricity. This risk is associated, for example, with unexpected, significant reductions in energy prices, but this is an unlikely scenario.

Investment in PV systems requires the preparation of an individual analysis in a target region to determine the amount of energy that can be generated depending on the orientation of the panels and the incoming irradiation. Less favourable weather conditions may slightly reduce the amount of energy. However, the return on investment can be predicted solely on the basis of geographical location – the orientation of solar panels, their inclination, and the surrounding buildings can be responsible for differences, and thus it is advisable to order a detailed analysis from companies specialized in this field. The value of irradiation in Poland is 900–1200 kWh/m^2, but it is difficult to estimate it precisely for a given location. Meteorological maps can be used for that purpose, but they still may not provide correct information[29].

The forecasted annual savings on purchasing electricity for the analysed company are in the range of 2,148.69 to 2,715.58 EUR. Increase in the costs of electricity (at a 2% growth rate for energy prices) was considered in calculations. The analysis of return on investment by its nature relies on forecasted commercial prices of electricity.

29 www.veelman.com [01/02/2016].

Conclusions

In an era of the depletion of fossil fuels and growing energy prices prosumerism seems to be a favourable solution in economic and ecological terms. The advantages of the installation of photovoltaic cells include the possibility of reselling surplus generated electricity to the grid operator (on-grid systems) and financial support from various sources.

There is a misconception that PV and PVT panels can only work in very sunny climate zones. In fact, PV panels can work even on cloudy days using energy from dispersed sunlight.

Despite all the difficulties, mainly the high investment costs, and regardless of environment-oriented attitudes (or lack of them), one should be aware that due to the general trends in the EU in the coming years, the transition from conventional to renewable energy sources is unavoidable in Poland, and amendments to the law (that of the European Community and Polish) will promote these changes.

Contrary to popular belief, an eco-friendly attitude does not necessarily mean investors have to voluntary cover additional costs for environmental protection. In many cases, the benefits from eco-friendly actions are doubled: profit related to the use of renewable solar energy also means that emissions of harmful gases into the atmosphere are reduced. It should, however, be borne in mind that the whole of human activity has an impact on the natural environment. Reduction in greenhouse gases emission achieved through the use of PV cells must be accompanied by the environmentally friendly technology for their production. For this purpose, a detailed life cycle assessment (LCA) is carried out to demonstrate the stages in the life cycle of the product which have a negative impact on the environment.

A key element influencing the ROI in photovoltaic systems is new technology, which in the coming years may revolutionize the PV market. The price of printed PV cells may be up to 5-fold lower compared to conventional cells, so even if their performance is relatively lower (about 20%), they will be attractive to individual investors.

Summing up:

- subsidies for the installation of PV systems significantly reduce the cost of investment – it is worth applying for subsidies from NFOŚiGW and ROP programmes supporting prosumerism, as well as using other available sources of funding;
- beneficiaries can take advantage of loans, but also non-returnable grants – this gives a chance for a long-term reduction in the cost of electricity, and transition from conventional to renewable energy sources;

- the revised version of the law on RES promotes the use of solar energy and gives prosumers relevant safety solutions ensuring that the surplus of generated energy will be sold to the network;
- in this context criticism has to be expressed about the *Energy policy of Poland until 2030*, where the development of the renewable energy sector based on photovoltaic cells is given very little attention (instead, the share of electricity generated by nuclear power plants is expected to be higher than 10% in 2030), and is particularly marginalised in comparison to energy from biomass and wind power (the policy stresses the need to create at least one biogas plant per municipality before 2020)[30];
- investments in photovoltaic systems can extend the range of diversified sources of energy, and are economically justified prosumer operations.

Authors' contributions to this article:

Łukasz Szałata, PhD Eng. – 33%
Agata Siedlecka, MSc Eng. – 33%
Cezary Lejkowski, MSc Eng. – 33%

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GENERAL ENVIRONMENTAL AND SOCIAL PROBLEMS

PROBLEMATYKA OGÓLNOEKOLOGICZNA I SPOŁECZNA

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RESEARCH METHOD FOR THE SOCIAL ACCEPTABILITY OF IMPLEMENTING A COLLECTIVE SYSTEM OF SEWAGE DISPOSAL AND TREATMENT

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METODA BADANIA SPOŁECZNEJ AKCEPTOWALNOŚCI REALIZACJI ZBIOROWEGO SYSTEMU ODPROWADZANIA I OCZYSZCZANIA ŚCIEKÓW

STRESZCZENIE: W artykule przedstawiono procedurę oceny społecznej akceptowalności realizacji zbiorowego systemu odprowadzania i oczyszczania ścieków opierającą się na metodzie wyceny warunkowej, wykorzystującej badanie gotowości do zapłaty (WTP). Uzyskane tą metodą informacje pozwolą na określenie, ile lokalna społeczność jest w stanie zapłacić za korzystanie z usługi zbiorowego odprowadzania i oczyszczania ścieków. Opracowana metoda oceny społecznej akceptowalności realizacji zbiorowego systemu odprowadzania i oczyszczania ścieków może stanowić instrument wspomagający proces decyzyjny w zakresie kształtowania polityki opłat za usługi wodne w gminie.

SŁOWA KLUCZOWE: kryterium techniczne, kryterium ekonomiczne, zrównoważony rozwój, społeczna akceptowalność inwestycji, pytania WTP

Introduction

In deciding on the implementation of the collective system of sewage disposal and treatment, a commune relies on two criteria: technical and economic. The technical criterion defines the conditions that must be fulfilled for a particular type of wastewater treatment plant and sewerage. However, some solutions, despite ensuring that the environmental requirements are satisfied, cannot be fulfilled due to the second criterion, namely the economic one. This situation occurs primarily in the conditions of scattered housing.

However, public opinion is of great importance when implementing public investments. So far, communal authorities have not had a tool that would enable them to become familiar with residents' opinions. Assessment of the social acceptability of implemented projects is important especially with regard to the construction of collective systems of sewage disposal and treatment, since these are long-term investments and their operating period lasts several dozen years.

The article presents a method of assessing the social acceptability of implementation of the collective system of sewage disposal and treatment based on the contingent valuation method (CVM) using a study of willingness to pay (WTP). Information obtained by this method will make it possible to determine how much the local community is willing to pay for the use of the service of collective sewage disposal and treatment.

The method of assessing the social acceptability of implementing the collective system of sewage disposal and treatment can be a tool supporting the decision-making process in terms of developing a policy on fees for water services in the commune.

Criteria for the selection of sewage disposal and treatment systems

Choosing the appropriate sewage system entails finding the length and configuration of sewage networks discharging wastewater to treatment plants for which one can incur the minimum capital expenditures and operating costs. Sewage systems require large capital expenditures, and therefore selecting the sewage arrangement and system is of fundamental importance for the villagers and for the national economy. Gravitational sewer systems dominate in rural areas, although they are becoming more and more expensive. Collective sewage treatment plants, on the other hand, are characterized by higher efficiency in removing impurities and low individual costs of wastewater treatment.

Choosing the right system of sewage disposal and treatment should be based on four criteria:

1. The technical criterion, which takes into account downslopes, the location of the wastewater receiver, the level of ground water, the character of housing, the existing underground infrastructure, and roads.
2. The economic criterion, which represents the possibility of financing the investments involving building collective systems of sewage disposal and treatment by the commune as well as the operating costs of these devices.
3. The environmental criterion, which includes information on protected areas in the commune and groundwater pollution.
4. The social criterion, which provides all agreements between the authorities and residents of the community as to the implementation and operation of collective systems of sewage disposal and treatment.

In the implementation of public investments, public opinion is of great importance. Society should be aware of the importance of measures taken by local authorities to improve the quality of local water resources.

Until now, communal authorities have not had a tool that would make it possible to become acquainted with residents' opinions. Assessing the social acceptability of implemented projects is important especially with regard to the construction of collective systems of sewage disposal and treatment, since these are long-term investments and their operating period lasts several dozen years.

Application of a contingent valuation method in the valuation of water resources

A CVM appeared in the early 1960s, and after many modifications and experiments it found practical application in the 1980s. The first surveys regarding consumer preferences were conducted in the 1940s. They concerned consumer purchases in research conducted by the US Federal Reserve[1]. Bowen[2] and Ciriacy-Wantrup[3] conducted the first research surveys revealing consumer preferences regarding environmental goods. In the 1960s, Davis[4] presented the first application of this method to the valuation

[1] F.T. Juster, *Consumer buying intentions and purchase probability: an experiment in survey design*, „Journal of the American Statistical Association" 1966 No. 61, pp. 658–696.

[2] H.R. Bowen, *The interpretation of voting in the allocation of economic resources*, „Quarterly Journal of Economics" 1943 No. 58, pp. 27–48.

[3] S.V. Ciriacy-Wantrup, *Capital returns from soil-conservation practices*, „Journal of Farm Economics" 1947 No. 29, pp. 1181–1196.

[4] R.K. Davis, *The value of outdoor recreation: an economic study of the Maine woods,* Harvard 1963.

of environmental goods, calling it the CVM at the same time. In 1980, the United States accepted the CVM together with other research methods concerning the state of the environment, namely the travel cost method, hedonic pricing method, and research methods of reaction effects on the interaction dose. A current overview of research concerning valuation conducted in many developing countries can be found in Biller et al.[5]

The contingent valuation method has also been used, for example, for the valuation of rare and endangered species of plants and animals[6] or for the valuation of activities aimed at reducing flood risk.[7]

In France, surveys based on WTP questions have been conducted. They concerned WTP for improving the water quality in rivers. The studies showed that industry and agriculture do not bear the costs resulting from the pollution of water resources.

The Greek communes of Lappaion, Georgioupolis, and Krionerida used the C to find out how much residents are willing to pay to keep the sea water clean. Information obtained from the survey conducted was to be used by communes while planning the policy of tariffs for wastewater[8].

Research based on the CVM regarding the aquatic environment was also conducted in Poland. Exemplary studies were carried out at Instytut Nauk Rolniczych in Zamość, where a preliminary study concerning the value of the natural environment was undertaken. Questions regarding different issues were included in the surveys, such as environmental pollution by solid and liquid waste, costs of disposing of pollutants, and willingness to pay a certain sum for the possibility of joining the household to the sewage network and maintaining the cleanliness of the surrounding environment[9].

The best known is the „Baltic" study. This study examined the readiness of Polish citizens to pay for stopping the eutrophication of the Baltic Sea.

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5 D. Biller, K. Rogge, G. Ruta, *The use of contingent valuation in developing countries. A quantitative analysis*, in: A. Albertini, J.R. Kahn (eds), *Handbook on Contingent Valuation*, Cheltenham 2006.

6 J. Loomis, D. White, *Economic benefis of rare and endangered species: summary and meta-analisis*, "Ecological Economics" 1996 No. 18, pp. 197–206.

7 L. Shabman, K. Stephenson, *Searching for the correct benefis estimate: empirical evidence for alternative perspective*, „Land Economics" 1996 No. 72(4); T. Liziński, *Problemy zarządzania ryzykiem w kształtowaniu przestrzeni polderowej na przykładzie delty Wisły*, Falenty 2007, p. 139.

8 M. Geniusz et al., *Estimation of willingness to pay for wastewater treatment,* Crete 2005.

9 I. DeJesus, A. Baryła, *Wycena środowiska przyrodniczego i ocena cenności ekologicznej*, in: T.M. Łaguna, M. Witkowska-Dąbrowska (eds), *Ekonomiczne podstawy zarządzania środowiskiem i zasobami naturalnymi*, Białystok 2005, pp. 120–129.

A reduction in the number of closed bathing areas and the renewal of sea life were presented to the respondents as a result of measures undertaken[10].

The social value of the effect of remediation of Ełckie Lake[11] was also identified using the CVM.

The CVM was also used in Lubelskie voivodeship in the commune of Łukowa. The aim of the study was to determine how much the inhabitants of the examined commune appreciate the advantages of the natural environment. In addition, we were acquainted with people's opinions and wishes regarding the sustainable development, their attitudes towards environmental issues, the perception of environmental threats and countermeasures, and responsibility for the environment[12].

The use of the CVM has also been undertaken in the cost-benefit analysis for the implementation of EU Directive 91/271/EEC concerning urban wastewater treatment. The survey was conducted in cooperation with the Public Opinion Research Centre (CBOS).The willingness to pay for improving the quality of surface waters in Poland to the level that would correspond to the condition after the implementation of the Directive on urban wastewater treatment, or to such a condition where one would be able to bathe and fish in most waters that are currently highly polluted was shown in the context of cost-benefit analysis. Apart from that, willingness to pay for ensuring the high quality of tap water in Poland was also examined[13].

In 2007, a study concerning valuation of the quality of surface and tap water was conducted in the form of individual interviews by a professional public opinion research centre on a representative group of adult urban residents in Poland[14].

In 2008–2010, assessment of the social acceptability of the project was carried out. The project concerned the implementation and operation of the collective sewage disposal and treatment systems in three selected communes

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10 T. Żylicz et al., *Contingent Valuation of Eutrophication damage in the Baltic Sea Region*, CSERGE, Working Paper, GEC 95-03, 1995; R.K. Turner et al., *Managing Nutrient Fluxes an Pollution in the Baltic*: *An Interdisciplinary Simulation Study*. CSERGE, Working Paper, GEC 97–17, Norwich 1997; A. Markowska, T. Żylicz, *Costing an International Public Good: The Case of the Baltic Sea*, Warsaw 1996.

11 H. Manteuffel-Szoege, E. Kubicka, *Makroekonomiczna efektywność rekultywacji jeziora*, in: *Uwarunkowania i mechanizmy zrównoważonego rozwoju*, Białystok 2007, pp. 265–274.

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13 A. Markowska, *Zastosowanie metody wyceny warunkowej w analizie kosztów i korzyści*, "Ekonomia i Środowisko" 2006 No. 2(30), pp. 57–67.

14 A. Bartczak, *Wycena korzyści z poprawy jakości wody kranowej i powierzchniowej w Polsce*, „Ekonomia i Środowisko" 2010 No. 2(38), pp. 124–141.

in Podlaskie voivodeship, namely Zbójna, Miastkowo, and Dubicze Cerkiewne. The lack of collective sewage disposal and treatment systems in these communes decided their choice as objects of research[15].

The CVM is based on surveys conducted among respondents interested in a particular good or service. The researcher can ask the respondents a question in the form of:

- WTP (Willingness To Pay), which concerns how much the respondents are willing to pay for access to given goods or services,
  or
- WTA (Willingness to Accept), which concerns the minimum amount of money that the respondents are willing to accept for tolerating adverse changes in the tested element or restricting access to it.

It is generally assumed that WTP is used to estimate the value of environmental projects and profits and WTA is used to determine the ecological losses resulting from the emission of pollutants into the environment[16].

In order to achieve credibility of the information obtained in the questionnaire survey, it is important to select the right kinds of questions.

There are many ways to ask survey questions. The simplest are open questions that generate data in a continuous form and if the answer of the respondent is sincere, the amount of money stated may be treated as WTP[17].

The most commonly used group of questions is closed questions, in which one indirectly obtains information on whether the respondent's WTP lies above or below the amount specified in the question. Usually, surveys are carried out in several variants, differing in the amount, which allows for a more accurate estimation of the distribution of WTP. A variation on closed questions is questions that are doubly closed, where depending on the answer to the first question, another is asked and the amount is reduced in the event of a negative response or increased in the case of a positive response[18].

Knowledge of how to ask survey questions allows one to choose the best method of preparation of a questionnaire survey.

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15 K. Rauba, Społeczna akceptowalność spełnienia zasady zwrotu kosztów usługi zbiorowego oczyszczania ścieków na obszarach wiejskich, „Handel Wewnętrzny" 2012 No. July–August, 2, pp. 258–266.

16 A. Graczyk, *Ekologiczne koszty zewnętrzne. Identyfikacja, szacowanie, internalizacja*, Białystok 2005, pp. 42–49.

17 J. Szyszko, J. Rylke, P. Jeżowski (eds), *Ocena i wycena zasobów przyrodniczych,* Warszawa 2002, pp. 245.

18 M. Czajkowski, *Metody wyboru warunkowego i wyceny warunkowej. Teoria, praktyka i zastosowania w kontekście zarządzania lasami w Polsce*, in: *Wartości nierynkowych korzyści z lasów. Metody wyceny oraz zastosowanie wyników w analizach ekonomicznych*, Warszawa 2011, pp. 29–30.

Method for assessment of social acceptability of implementing the collective system of sewage disposal and treatment

The unit responsible for ensuring collective sewage disposal and treatment for local communities is the commune. It is important that the commune, while realizing its policy in this regard, should take into account the opinion of the residents. In this situation, communal authorities can use a tool based on the CVM.

The developed research procedure to find the social acceptability of implementing collective sewage disposal and treatment is based on questions in the form of WTP.

The proposed method comprises the following steps:

1. Development of the concept of building a sewage treatment plant and the concept of implementing the sewage system
2. Cost analysis of proposed solutions
3. Determination of individual capital expenditures and individual exploitation costs
4. Determination of price levels
5. Development of a questionnaire survey
6. Conducting surveys
7. Statistical analysis of the obtained results.

The first phase of the study does not differ from the standard approach to implementation of investments from a particular range. It is therefore necessary to develop the concept of the technical–technological sewerage system and to conduct a financial analysis of the proposed solutions.

Then, one needs to determine the price for 1 m^3 of wastewater. To avoid cross-subsidization, one should divide the recipients of the service of collective sewage disposal and treatment into groups according to the generated costs. At this stage one may, however, set the same price for all customers especially in the areas where the recipients of the service of wastewater treatment are mainly households.

Prices for wastewater should be designed in variants. By setting particular price levels, one should take into account:

- operating costs,
- depreciation, which constitutes the recovery of capital expenditures,
- profit.

Based on the identified costs, one can determine five possible horizontal prices for wastewater. They result from different policies of communes in relation to implementation of the cost recovery principle of water services associated with the possibility of charging households for the costs of wastewater collection and treatment. The cost recovery principle of water

services was introduced by the Water Framework Directive.[19] The collective sewage disposal and treatment are included in the water services.

Often, in the case of poorer communes, achieving full cost recovery for water services takes time. One should then approach this in stages, going through the subsequent levels of prices.

At level I, the fees will provide only an incomplete recovery of the basic operational costs of the company, namely exploitation costs. This situation should be temporary in the case of aiming to satisfy the cost recovery principle of water services.

In the case of level II, the fees will fully cover the maintenance costs, but the generated revenue will not provide the possibility for new investments.

At level III, apart from operating costs, the price will partially include the capital expenditures in the form of depreciation.

The price for sewage from level IV will provide full coverage of operating costs and depreciation and will thus provide the opportunity to implement replacement and development investments.

Profitability of the project will be achievable only at level V, where the profit will be included in the price in addition to the operating costs and depreciation costs.

Four basic prices corresponding to the levels shown above were adopted in the proposed method of studying social acceptability regarding the collective system of sewage disposal and treatment:

1. Price I, corresponding to the current average cost of sewage disposal in the commune.
2. Price II, corresponding to level II.
3. Price III, corresponding to level IV.
4. Price IV, corresponding to level V.

The values of individual prices can be determined as follows:

1. Price II – full operating costs:

$$C_2 = K/Q \qquad [1]$$

$$K = Ko + Kk$$

where:
K – operating costs of a sewage disposal and treatment system, zl/year;
K_o – operating costs of a sewage treatment plant, zl/year;
K_k – operating costs of a sewage system, zl/year;
Q – amount of wastewater, m^3/year.

[19] Dyrektywa 2000/60/EC Parlamentu Europejskiego i Rady z dnia 23.10.2000 roku w sprawie ustanowienia ram działalności Wspólnoty w dziedzinie polityki wodnej.

2. Price III – full operating costs and depreciation:

$$C_2 = (K+A)/Q \quad [2]$$

where:
K – operating costs of a sewage disposal and treatment system, zl/year;
A – depreciation, set as 2.5% of capital expenditures, zl;

3. Price IV – full operating costs, depreciation, and profit:

$$C_2 = (K+A+Z)/Q \quad [3]$$

where:
K – operating costs of a sewage disposal and treatment system, zl/year;
A – depreciation, set as 2.5% of capital expenditures, zl;
Z – annual profit (set as 20% in the method), zl/year;
Q – amount of wastewater, m^3/year.

The next step in the proposed method is to prepare a questionnaire survey. The questionnaire should be divided into three parts. The first part should contain the initial questions, which will make it possible to assess the level of knowledge of the respondents on the issues of wastewater management in the commune. Information obtained from this part of the study will help to draw conclusions regarding the premises concerning the choice of prices. The second part of the survey should include questions about the preferred amount of money that respondents will be able to pay for using the collective system of sewage disposal and treatment. Therefore, these questions will take the form of WTP questions. Hence, prices I–IV will be used in this part. The initial price will be the money that residents currently pay for wastewater disposal in the commune. Prices I to IV, corresponding to the consecutive levels of reimbursement for providing services of sewage disposal and treatment, will appear in the subsequent questions. In the event that the respondents do not choose any of the proposed prices, they should be given the option to state the price that would be acceptable to them with a justification.

The last part of the questionnaire concerns personal data and the overall socio-economic characteristics of the respondents such as gender, age, income, and education.

The final stage of the procedure is to compile the statistical results obtained from the surveys conducted among the local community.

In the case of using the proposed method as a tool for implementing the wastewater management policy in the commune, a representative sample of residents will be surveyed in the research. The implementation of the project will concern the residents.

An important aspect of methods based on surveys is also the method of interviewing. Surveys are exposed to systematic errors that may contribute to distortion of the results. In order to avoid the occurrence of systematic errors one should adjust the survey according to the principles developed in 1993 by a committee of the American Commission for National Oceanic and Atmospheric Administration (NOAA).[20]

In the case of the proposed research method regarding social acceptability of implementing the collective system of sewage disposal and treatment, conducting research in the form of a direct interview is proposed. The fact that the results obtained in this way have systematic errors is known, but an experienced interviewer can conduct the interview in a right way. With regard to the problem that the method concerns, the ability to explain the aim of the survey is important, namely to what the investment relates and from what the various price levels result.

Summary

When designing investments contributing to environmental protection in rural areas, one must take into account the wastewater treatment plant and the sewer system of a given region with regard to local conditions. Constructing the sewage treatment plant and extending the sewerage system should be related to the financial possibilities of the commune. The cost of building the sewage system bringing wastewater to the sewage treatment plant is often several times higher than the cost of building the plant itself.

It is important for communal authorities to get to know the degree of social acceptability of projects in the field of wastewater management in the commune. In order to become familiar with the views of citizens on the implementation and operation of collective systems of sewage disposal and treatment, one can use the contingent valuation method, using a study of willingness to pay (WTP). The results of the conducted survey based on the WTP question can be used as an instrument for supporting the decision-making process by the communal authorities in determining fiscal policy in terms of fees for wastewater disposal. Information obtained by this method will allow one to specify how much the local community is willing to pay for the use of the services of collective sewage disposal and treatment.

The developed method of assessing social acceptability of implementing the collective system of sewage disposal and treatment can be a tool sup-

20 K. Arrow et al., *Report of the noaa panel on contingent valuation*, "Federal Register" 1993 No. 10, pp. 4601–4614.

porting the decision-making process in terms of shaping the policy of fees for water services in the commune.

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Danuta GUZAL-DEC

THE ROLE OF LOCAL AUTHORITIES IN DEVELOPING PRO-ECOLOGICAL ORGANIZATIONAL CULTURE OF THE COMMUNAL OFFICES LOCATED IN AREAS OF NATURAL VALUE (THE EXAMPLE OF LUBELSKIE VOIVODESHIP)

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ROLA LOKALNYCH WŁADZ SAMORZĄDOWYCH W KSZTAŁTOWANIU PROEKOLOGICZNEJ KULTURY ORGANIZACYJNEJ URZĘDÓW GMIN POŁOŻONYCH NA OBSZARACH PRZYRODNICZO CENNYCH (PRZYKŁAD WOJEWÓDZTWA LUBELSKIEGO)

STRESZCZENIE: Celem pracy było określenie możliwości oraz zakresu oddziaływania lokalnych władz samorządowych na kształtowanie proekologicznej kultury organizacyjnej w urzędach gmin położonych na obszarach przyrodniczo cennych województwa lubelskiego. Wykazano w tym obszarze niski poziom zaawansowania oraz brak kompleksowości i spójności działań władz samorzadowych na wszystkich poziomach zarządzania.

SŁOWA KLUCZOWE: proekologiczna kultura organizacyjna, obszary przyrodniczo cenne, samorząd gminny

Introduction

In the light of economic criteria, areas of natural value are those where biodiversity is or may be (while selecting the correct directions and methods) the dominant factor of economic activity or where it significantly reduces the forms of management contradicting the primary purpose of the existence of valuable natural areas – preserving biodiversity[1]. The limitations connected with the valuable natural areas are an impediment if one understands the development in a traditional way. These limitations become stimulants of development if it is based on the principles of sustainability. Such an approach does not inhibit the socio-economic development but indicates another understanding of it. The valuable natural areas are becoming an important element of the strategy of sustainable development of rural communes[2].

The problem of maintaining environmentally valuable areas in a good condition depends largely on ecological awareness in the individual dimension and on the culture of organizations functioning in the areas of natural value in the public dimension. In these organizations, this culture should be pro-ecological and therefore compatible with the principles of sustainable development. This culture should encourage the attitudes of human responsibility for nature and the need to protect it.

Appropriately developed pro-ecological organizational culture should contribute to a better understanding of the mission of the areas of natural value. This mission is the comprehensive protection of the natural environment, the preservation of the richness of the local culture, and the development of the pro-ecological economic functions that ensure income growth and improve the quality of life of the local community in terms of a compromise between people and nature[3].

The author of this paper assumes that organizational culture is a resource that is subject to influence and formation in the management process. In the context of the foregoing considerations, it should be noted that the formation of pro-ecological organizational culture of communal offices situated in the environmentally valuable areas by local authorities may contribute to improvements in the implementation of environmental policy of the

1 B. Dobrzańska, *Planowanie strategiczne zrównoważonego rozwoju obszarów przyrodniczo cennych,* Białystok 2007, pp. 57–58.

2 S. Czaja, A. Becla, *Ekologiczne podstawy procesów gospodarowania*, Wrocław 2007, pp. 375.

3 Compare: A. Zielińska, *Etyka środowiskowa a zrównoważone gospodarowanie na obszarach przyrodniczo cennych,* in: D. Kopycińska (ed.), *Działania ekonomiczne podmiotów rynkowych, materiały konferencyjne*, Szczecin 2007, p. 162.

commune and the creation of sustainable development at the local level by the self-government.

Therefore the aim of this study was to determine the possibility and extent of the impact of self-governments on the development of pro-ecological organizational culture in the communal offices located in the environmentally valuable areas of Lubelskie voivodeship. It is hypothesized that the formation of pro-ecological organizational culture in the communal offices located in environmentally valuable areas by the local authorities in Lubelskie voivodeship is characterized by a lack of comprehensive, coherent actions at all levels of management and a low level of advancement.

The accomplishment of the stated purpose was possible due to the literature analysis and empirical research. The area of the research in 2013 involved 30 communes[4] from the group with the highest ecological value in Lubelskie voivodeship according to the indicator developed by Danuta Guzal-Dec in the context of research concerning the ecological value of the rural and urban–rural communes of Lubelskie voivodeship[5].

The diagnostic poll method was applied using questionnaire-based interviews. The research materials constitute 30 interviews with the village mayors and employees for environmental protection in the communal offices. The important sources of information were the local development strategies and the websites of the surveyed communes.

Organizational culture as a dependent variable

Many authors formulating definitions of organizational culture suggest such components as values, beliefs, practices, and principles that are common and widespread among the members of a particular organization[6]. One of the

4 A group of 30 local government units selected for the study: Janów Podlaski, Konstantynów, Józefów, Łukowa, Obsza, Dzwola, Janów Lubelski, Modliborzyce, Janowiec, Kazimierz Dolny, Wąwolnica, Kraśniczyn, Wilków, Dębowa Kłoda, Sosnowica, Stężyca, Lubycza Królewska, Susiec, Tarnawatka, Tomaszów Lubelski, Rossosz, Sławatycze, Urszulin, Włodawa, Adamów (zamojski), Krasnobród, Łabunie, Skierbieszów, Stary Zamość, Zwierzyniec.

5 D. Guzal-Dec, *Operacjonalizacja modelu Presja-Stan-Reakcja w badaniu cenności ekologicznej gmin wiejskich na przykładzie województwa lubelskiego*, „Annual Set of the Environment Protection/Rocznik Ochrona Środowiska" 2013 No. 15(3), pp. 2925–2941.

6 V. Jaivisarn, *How organizational culture of Japanese multinationals in Thailand influences Japanese-speaking Thai employees' organizational commitment*, „Journal of International Business and Economics" 2010 No. 10(1), pp. 106–120; K. Singh, *Predicting organizational commitment through organization culture: A study of automobile industry in India*, „Journal of Business Economics and Management" 2007 No. 8(1), pp. 29–37.

most common definitions of organizational culture is the one proposed by E.H. Schein, who described it as a set of dominant values and standards of behaviour characteristic of a given organization, based on the assumptions about the nature of reality and manifesting itself through artefacts – external, artificial creations of a given culture[7].

The complexity of organizational culture is reflected in the emergence of a variety of research trends. L. Smircich identified three basic trends, where the culture is treated as a dependent variable, an independent variable, or the basic metaphor of an organization. The first approach treats culture as one of the organizational resources and as such it may be subject to the process of management, in order to improve the efficiency of the system as a whole. Culture as an independent variable is identified with an intercultural approach. It is characterized as a dimension of an organization's environment and is not subject to its influence. The aim of management actions will be a proper adjustment of the system to the environment and the development of so-called cultural competence. The concept of culture as an indigenous metaphor is taken from the area of anthropology. Researchers representing the current research focusing on the human side of organizations investigate the activities of its participants through the prism of giving meaning to the reality. Culture is considered as a symbolic meaning[8].

Organizational culture is determined by a combination of endogenous and exogenous factors. Internal factors are those related to the organization, that is, vision, mission, strategy, history, and above all creating a culture of people and their values, attitudes, needs, education, experience, and so on. The impact of the environment on the organizational culture is usually defined by social and cultural variables, economic and legal conditions, and national, regional, and local culture[9].

The culture of local administration units is conditioned by the types of tasks performed, by the specificity of public services, and also by the change in the style of management resulting from social expectations. It must encourage the attainment of the objective of sustainable development of the region. Employees have a significant impact on the culture through their professional and life experiences, education, and preferred values. Also the style of governance has an influence on it[10]. The author of this study adopted the view that organizational culture is a resource that is subject to influence and

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7 E.H. Schein, *Organizational Culture and Leadership*, 4th edition, San Francisco 2010, pp. 23–24.

8 A.L. Brenton, G.W. Driskill, *Organizational Culture in Action: A Cultural Analysis Workbook*, UK 2010, pp. 28–30.

9 M. Siemiński, *Kształtowanie kultury organizacyjnej przedsiębiorstw przemysłowych,* Toruń 2008, pp. 73.

10 J. Szaban, *Zachowania organizacyjne. Aspekt międzykulturowy,* Toruń 2007, p. 446.

formation in the management process. Local authorities (executive and legislative) determine the organizational culture of the communal offices in the process of operational management (the village mayor as the head of the process of human resource management) and in the strategic management process through implemented development policies.

Identification of pro-ecological organizational culture of the communal office

With regard to the competence possibilities of local communal authorities, the author identified the distinguishing features of pro-ecological organizational culture of the communal offices according to levels of management. At the strategic level, the culture is formed by:

- a strategy of sustainable development, the current zoning plan of the commune, an eco-physiographic description, and/or natural inventory;
- referring to the idea of sustainable development at the level of strategic records (mission/vision/objectives);
- creating the forms of nature protection;
- taking systematic measures aimed at developing the pro-ecological image of the commune, having a pro-ecological brand.

At the tactical level, pro-ecological organizational culture is determined by:

- the environmental protection programme;
- preparing the organization of the communal office to execute tasks related to the protection of the environment (providing appropriately qualified personnel having environmental education);
- implementing the standardized environmental management system;
- implementing innovative environmental technologies.

At the operational level, the manifestations of the development of pro-ecological organizational culture are:

- training the personnel and authorities in terms of the issues of environmental protection and functioning of protected areas;
- organizing lectures and training for councillors and village administrators on environmental issues by the communal offices;
- acquiring information on environmental threats and potential sources of social conflicts concerning the environment by the offices;
- supporting and promoting the use of local renewable energy sources by the inhabitants and entities operating in the commune by the offices;

- supporting and promoting ecological agriculture and measures to improve the condition of the soil, air, and water;
- promoting so-called public "green purchasing".

Table 1 presents information on the existing characteristics of the pro-ecological organizational culture of the studied communal offices at the strategic level of management.

Table 1. The characteristics of pro-ecological organizational culture of the offices at the strategic level of management

Commune / The characteristics of pro-ecological culture at the strategic level of management	The strategy of sustainable development of the commune	The eco-physiographic description	The natural inventory	Referring to the idea of sustainable development at the level of the strategic records (mission/vision/ strategic objectives)	Creating the forms of nature protection	Taking systematic measures aimed at developing the pro-ecological image of the commune	A pro-ecological brand	A current zoning plan of the commune	The sum of indications of all the activities at the strategic level
Janów Lubelski	0	1	1	1	1	1	1	1	7
Krasnobród	0	0	1	1	1	1	0	1	5
Kazimierz Dolny	1	0	0	1	1	0	1	1	5
Janów Podlaski	0	1	1	1	0	0	0	1	4
Józefów	0	0	0	1	0	1	1	1	4
Modliborzyce	0	0	1	1	1	0	0	1	4
Janowiec	0	0	1	1	1	0	0	1	4
Wąwolnica	0	0	1	1	1	0	0	1	4
Konstantynów	0	1	1	1	0	1	0	0	4
Włodawa	0	1	1	1	0	0	1	0	4
Kraśniczyn	0	0	1	1	1	1	0	0	4
Lubycza Królewska	0	1	0	1	1	0	1	0	4
Zwierzyniec	0	1	1	1	0	0	1	0	4
Wilków	1	1	0	1	1	0	0	0	4

Łukowa	0	0	0	1	1	0	0	1	3
Tarnawatka	0	0	0	0	1	1	0	1	3
Urszulin	1	0	0	1	0	0	1	0	3
Stary Zamość	0	1	1	1	0	0	0	0	3
Obsza	0	0	1	0	0	0	0	1	2
Łabunie	0	1	0	0	0	0	0	1	2
Susiec	0	0	0	1	1	0	0	0	2
Adamów	0	0	0	0	0	0	0	1	1
Rossosz	0	0	0	0	1	0	0	0	1
Sosnowica	0	0	0	1	0	0	0	0	1
Tomaszów Lubelski	0	0	0	1	0	0	0	0	1
Skierbieszów	0	0	0	1	0	0	0	0	1
Dzwola	0	0	0	0	1	0	0	0	1
Sławatycze	0	0	0	0	0	0	0	0	0
Dębowa Kłoda	0	0	0	0	0	0	0	0	0
Stężyca	0	0	0	0	0	0	0	0	0
The sum of indications	3	9	12	21	14	6	7	13	

Source: The author's own compilation based on the research.

The analysis of the actions undertaken at the strategic level of management, which are a manifestation of the development of pro-ecological organizational culture, allows it to be stated that there is serious negligence in the creation of development plans and inventory of local natural resources. In 13 communes, the current zoning plan was drawn for the whole territory of the commune. More than half of local governments did not have eco-physiographic descriptions or natural inventories. Only three communes prepared strategies for sustainable development. At the strategic level, the only positive aspect of this situation is that 21 general development strategies referred to the ideas and principles of sustainable development, which is visible in the formulas of the declared strategic objectives.

Respect for the principles of sustainable development, including the principles of prevention and intergenerational justice, is visible in the creation of the forms of nature protection. In 14 of the surveyed communes (46.7% of the total), the resolutions of the Communal Councils encompassed the objects and areas of natural value after 1990. Detailed information on the forms of protection created in this way is included in Table 2.

Table 2. Establishing the forms of nature protection by the local authorities (the Communal Councils)

The form of protection	The number of communes	The number of objects/areas in the commune
Nature monuments	12	1-18
Documentation sites	1	1
Ecological areas	3	1-2
Landscape-nature complexes	7	1-3

Source: The author's own compilation based on the research.

In six communes (20% of the total), the representatives of the offices participated in competitions to promote the commune as the entity undertaking environmental activities. The reasons for the lack of participation in the case of other local governments, in the opinion of the office personnel, were a low level of human resources and financial constraints – the costs of participation in competitions. Low activity in taking long-term (systematic) actions serving the purpose of developing the pro-ecological image of the commune is reflected in the fact that few local governments have established a pro-ecological brand (seven indications).

All the surveyed communal offices provided the appropriate choice of personnel dealing with environmental issues in terms of education of the employees, but few offices (eight) had the possibility of creating an independent post for environmental protection. The tool for implementing the local environmental policy was the environmental protection programme in 26 offices. Thirteen offices have already implemented innovative environmental technologies involving saving energy and/or changing the energy carrier. The environmental management system has not been implemented in any of the surveyed offices.

Table 3. The characteristics of pro-ecological organizational culture of the offices at the tactical level of management

The characteristics of pro-ecological culture at the tactical level of management / Commune	The environmental protection programme	Creating a post for environmental protection	The office employees dealing with the issues of environmental protection with environmental education	Implementing the standardized environmental management system	Implementing the innovative environmental technologies	The sum of indications of all the activities at the tactical level
Tarnawatka	1	1	1	0	1	4
Janów Lubelski	1	1	1	0	1	4
Janów Podlaski	1	0	1	0	1	3
Konstantynów	1	0	1	0	1	3
Sławatycze	1	0	1	0	1	3
Sosnowica	1	0	1	0	1	3
Urszulin	1	0	1	0	1	3
Józefów	1	0	1	0	1	3
Kraśniczyn	1	0	1	0	1	3
Tomaszów Lubelski	1	0	1	0	1	3
Krasnobród	1	0	1	0	1	3
Łabunie	1	1	1	0	0	3
Wilków	1	1	1	0	0	3
Janowiec	1	1	1	0	0	3
Wąwolnica	1	1	1	0	0	3
Rossosz	0	0	1	0	1	2
Dębowa Kłoda	1	0	1	0	0	2
Włodawa	1	0	1	0	0	2
Łukowa	1	0	1	0	0	2
Lubycza Królewska	1	0	1	0	0	2
Susiec	1	0	1	0	0	2
Adamów	1	0	1	0	0	2

Skierbieszów	1	0	1	0	0	2
Stary Zamość	1	0	1	0	0	2
Zwierzyniec	1	0	1	0	0	2
Dzwola	1	0	1	0	0	2
Modliborzyce	0	1	1	0	0	2
Kazimierz Dolny	0	1	1	0	0	2
Stężyca	0	0	1	0	1	2
Obsza	0	0	1	0	0	1
The sum of indications	26	8	30	0	13	

Source: The author's own compilation based on the research.

Table 4. The characteristics of pro-ecological organizational culture of the offices at the operational level of management

The characteristics of pro-ecological organizational culture of the offices at the operational level of management / Commune	Training the personnel in terms of the issues of environmental protection	Training the authorities in terms of the issues of environmental protection	Training the personnel in terms of functioning of the protected aras	Training the authorities in terms of functioning of the protected areas	Organizing lectures and training for councillors and village administrators on environmental issues by the communal offices	Acquiring information on environmental threats and potential sources of social conflicts concerning the environment by the offices	Supporting and promoting the use of local renewable energy sources by the inhabitants and entities operating in the commune by the offices	Supporting and promoting ecological agriculture or measures to improve the condition of the soil, air, and water	Promoting so-called public "green purchasing"	The sum of indications of all the activities at the operational level
Kraśniczyn	1	1	1	1	0	1	1	1	1	8
Janów Lubelski	1	1	1	1	1	1	1	1	0	8
Modliborzyce	1	1	1	1	1	1	1	0	1	8
Janów Podlaski	1	1	1	1	0	1	1	1	0	7
Konstantynów	1	1	1	1	0	1	1	1	0	7

Józefów	1	1	1	1	1	0	1	0	1	7
Łukowa	1	1	1	1	1	0	1	0	1	7
Stary Zamość	1	1	1	1	1	1	1	0	0	7
Zwierzyniec	1	1	1	1	1	1	1	0	0	7
Rossosz	1	1	0	1	0	1	1	0	1	6
Sławatycze	1	1	1	1	0	0	1	1	0	6
Obsza	1	1	1	1	1	0	0	0	1	6
Susiec	1	0	1	0	1	1	1	1	0	6
Tarnawatka	1	1	1	1	1	0	0	1	0	6
Urszulin	1	1	1	0	0	0	1	0	1	5
Włodawa	1	0	1	0	1	1	1	0	0	5
Krasnobród	1	1	1	1	0	0	0	0	1	5
Dzwola	1	1	1	1	0	0	0	1	0	5
Janowiec	1	1	1	1	1	0	0	0	0	5
Kazimierz Dolny	1	1	1	1	0	0	0	0	0	4
Wąwolnica	1	1	1	1	0	0	0	0	0	4
Stężyca	1	0	0	0	1	0	1	1	0	4
Lubycza Królewska	0	0	0	0	1	0	1	1	0	3
Adamów	1	0	1	0	0	0	1	0	0	3
Łabunie	1	0	1	0	0	0	1	0	0	3
Wilków	1	1	0	0	0	1	0	0	0	3
Sosnowica	0	0	0	0	0	0	1	1	0	2
Tomaszów Lubelski	1	0	1	0	0	0	0	0	0	2
Dębowa Kłoda	0	0	0	0	0	0	0	1	0	1
Skierbieszów	1	0	0	0	0	0	0	0	0	1
Suma wskazań	28	21	24	19	13	11	19	12	8	

Source: The author's own compilation based on the research.

At the operational level, the most common manifestation of the development of pro-ecological organizational culture was training the employees and authorities in terms of issues of environmental protection and protected areas. Unfortunately, organization of lectures and training for councillors and village administrators on environmental issues by the offices was far less

common, with 13 indications. Offices supported and promoted the use of local sources of renewable energy by the inhabitants and entities operating in the commune relatively often, with 19 indications. The practical implementation of the principle of prevention entails gaining information on environmental threats and potential sources of social conflicts concerning the environment and promoting pro-ecological directions of management and environmental protection by the offices. Obtaining information about environmental threats and potential sources of conflicts was carried out by only 11 offices. Twelve declared support for and promotion of organic agriculture. The main reasons for the failure of promotion and implementation of organic agriculture were the assignment of competence in this field to other institutions, limited personnel, and limited financial capacity of the offices.

The studied communal offices rarely (eight indications) attempted to promote so-called „green public shopping." Most often, the offices purchased eco-friendly stationary. In individual cases, they purchased vehicles run on biofuel and adjusted oil boilers to pellet fuel. Communal officials were reluctant to follow such actions, since the tender procedure was not obligatory for them.

Table 5 presents information on the state of advancement of pro-ecological culture according to the level of management.

Table 5. The state of advancement of pro-ecological organizational culture according to the level of management

The state of advancement of pro-ecological culture according to level of management (number of activities) / Commune	Strategic level (maximum of eight)	Tactical level (maximum of five)	Operational level (maximum of nine)	The sum of activities at all levels (maximum of 22)
Janów Lubelski	7	4	8	19
Kraśniczyn	4	3	8	15
Janów Podlaski	4	3	7	14
Konstantynów	4	3	7	14
Józefów	4	3	7	14
Modliborzyce	4	2	8	14
Tarnawatka	3	4	6	13
Krasnobród	5	3	5	13

Zwierzyniec	4	2	7	13
Łukowa	3	2	7	12
Stary Zamość	3	2	7	12
Urszulin	3	3	5	11
Włodawa	4	2	5	11
Susiec	2	2	6	10
Wilków	4	3	3	10
Rossosz	1	2	6	9
Sławatycze	0	3	6	9
Obsza	2	1	6	9
Lubycza Królewska	4	2	3	9
Łabunie	2	3	3	8
Dzwola	1	2	5	8
Sosnowica	1	3	2	6
Tomaszów Lubelski	1	3	2	6
Adamów	1	2	3	6
Skierbieszów	1	2	1	4
Dębowa Kłoda	0	2	1	3
Janowiec	4	3	5	12
Kazimierz Dolny	5	2	4	11
Wąwolnica	4	3	4	11
Stężyca	0	2	4	6

Source: The authors' own compilation based on the research.

The manifestations of pro-ecological organizational culture usually appeared in the studied offices at the operational level of management. Thus, these offices reversed the natural direction of initiating the pro-ecological activities. Few communes exhibit the occurrence of the initial phase of development of pro-ecological culture (out of the total of 22 analysed differentiators, more than 50% took place in only 12 communes, and more than 75% took place in only one). The leading commune was Janów Lubelski, where pro-ecological activities forming organizational culture were undertaken consistently and in a comprehensive manner at all three levels of management.

Summary

The hypothesis formulated in the study has been positively verified. It has been shown that the formation of pro-ecological organizational culture by local authorities in the communal offices located in the environmentally valuable areas of Lubelskie voivodeship is characterized by a lack of comprehensive, coherent actions at all levels of management and low levels of their advancement. Implementing the concept of sustainable development in the communes that are of natural value in the environmental dimension requires changing the attitudes of local governments towards environmental problems in many areas of their activities in order to create pro-ecological organizational culture.

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BUSINESS ACTIVITY OF THE NATIONAL PARKS IN POLAND

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DZIAŁALNOŚĆ GOSPODARCZA PARKÓW NARODOWYCH W POLSCE

STRESZCZENIE: Podstawowym źródłem finansowania parków narodowych w Polsce, podobnie jak na świecie są środki publiczne, w szczególności dotacje. W związku ograniczeniami środków publicznych szansą na wzrost poziomu finansowania parków narodowych można upatrywać w źródłach rynkowych, w tym w dochodach z działalności gospodarczej. Zapis o możliwości prowadzenia działalności gospodarczej przez parki narodowe znalazł się w znowelizowanej ustawie o ochronie przyrody. Celem artykułu jest analiza obecnego stanu w zakresie możliwości prowadzenia działalności gospodarczej przez polskie parki narodowe. W artykule wskazano na okoliczności uniemożliwiające bezpośrednie prowadzenie działalności gospodarczej przez polskie parki narodowe.

SŁOWA KLUCZOWE: parki narodowe, finansowanie, działalność gospodarcza, ustawa o ochronie przyrody

Introduction

As indicated in the Constitution of the Republic of Poland, the state is obliged to preserve natural resources that are national heritage and ensure ecological security for present and future generations[1]. A national park is one of the forms of conservation of natural heritage. The national park is considered a public good because, for example, the use of it by one individual does not reduce availability to others[2]. National parks being a public good are funded from the public budget. For consumers this means that public goods are available free of charge, or fees are charged only for some services. Therefore, one of the fundamental problems of national parks is their inability of self-financing. Subsidies are the most commonly used sources of funding for national parks, but they are often insufficient to cover all the necessary expenses. Therefore, the need to diversify sources of funding for national parks is gaining in importance. Additional sources of funding could be found, for example, in revenues from the business activity run by national parks.

This article is aimed at analysing the opportunities of Polish national parks to run business as a source of revenue. This issue is relatively rarely addressed in the Polish literature[3]. The article indicates circumstances that prevent the generation of direct revenues from business by national parks, thus proving the illusory nature of provisions regarding this subject in the revised version of the nature conservation act.

This study relies on source materials such as reports from the Central Statistical Office (GUS), and data from the Ministry of Environment and the Supreme Chamber of Control (NIK). In order to provide a comprehensive and objective presentation of this multidimensional problem references to relevant literature and legal acts are also made.

National parks in the system of protected areas

National parks are considered the highest form of nature conservation at the national level. The first national park (Yellowstone) was established in the United States in 1872. Soon after, in 1879, Australia's Royal National Park

1 Konstytucja Rzeczypospolitej Polskiej z dnia 2 kwietnia 1997 r. (Dz.U. 1997 nr 78, poz. 483), art. 74/ The Constitution of the Republic of Poland of 2 April 1997 (Dz.U. of 1997 r. No. 78, item 483), Article 74.

2 S. Owsiak, *Finanse publiczne*, Warszawa 2008, p. 28.

3 Problems related to legal aspects of national parks operation were discussed by: W. Radecki and D. Sześciło, but they did not address financing sources.

was established. It is assumed that in Europe, the first national parks for the protection of nature were created in Sweden in 1909 (Abisko and Sarek national parks), and in 1910 in Russia[4].

In Poland, the idea of a national park was put into practice much later, in 1932. At that time *Leśnictwo Park Narodowy w Białowieży* (Forestry District National Park in Białowieża) and a unit of State Forests *Park Narodowy w Pieninach* (National Park in Pieniny) were established. The first act regulating the issue of national parks was adopted in 1934[5], but only one national park, Białowieża National Park, was created based on its provisions after the end of the Second World War.

As defined in the Polish Nature Conservation Act, a national park "covers an area of outstanding environmental, scientific, social, cultural and educational value, with an area of not less than 1000 ha, which protects the whole of the nature and qualities of the landscape"[6]. In Poland, protected areas cover more than 10.1 million ha, which accounts for 32.5% of the country. In 2013 the total area of all the 23 national parks was 314,600 ha, i.e. 1% of the area of Poland. Other forms of nature conservation in Poland include: nature reserves (166,000 ha), landscape parks (2,531,000 ha), protected landscape areas (7,006,000 ha), ecological areas, documentation sites, and landscape and nature complexes (147,000 ha), as well as over 36,000 monuments of nature. In Poland, a large part of the protected areas, including all the national parks and some landscape parks, are included in the Natura 2000 network. Within this network 845 special areas of conservation (SACs) and 145 special protection areas (SPAs) have been established, and they cover almost 20% of the Polish land, which slightly more than the European average[7].

As specified in the Nature Conservation Act, a national park is created to preserve biodiversity, resources, objects and elements of inanimate nature and landscape values, to restore the proper state of natural resources and components and to reconstruct distorted nature habitats, plants, habitats of animals and habitats of fungi. A national park is a public organisation with a legal personality. National parks are established in particular:

- to carry out conservation activities in the park's ecosystems;
- to make the park area available to the public in line with conservation plans, conservation measures and decisions made by their director;
- to carry out activities for environmental education.

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4 E. Simonides, *Ochrona przyrody*, Warszawa 2008, p. 401.

5 Ustawa z dnia 10 marca 1934 r. o ochronie przyrody/ Act of 10 March 1934 on nature conservation (Dz.U. 1934 No. 31 item 274).

6 Ustawa z dnia 16 kwietnia 2004 r. o ochronie przyrody/ Act of 16 April 2004 on nature conservation (Dz.U. 2004 No. 92 item 880), Article 8 clause 1.

7 *Ochrona środowiska*, GUS, Warszawa 2014, p. 40.

The director of a national park is selected in a competitive procedure and appointed by the minister competent for environmental affairs. A director of a national park has the status of a nature conservation body. An advisory body for the conservation of nature is a scientific council of the national park. According to the Nature Conservation Act of 2004, tasks related to the protection of property and the fight against crime and offences to nature conservation in the national parks are executed by conservation officers who are employed in the unit of the National Park Service.

The area of a national park is accessible to the public inasmuch as it has no adverse affect on the wildlife in the national park. The conservation plan (or a list of conservation measures) specifies sites that are accessible to the public and the maximum number of visitors who can stay at one site at the same time. Financing is the key problem in the implementation of objectives for which a national park has been established.

Financing of the operation of national parks before 2012

The debate on the need to reform the operation of national parks, including their financing model, has been ongoing in Poland for many years. Before 2010, national parks functioned as state budget units[8]. Because the funds from the state budget were insufficient to cover the expenses, parks had to seek other sources of financing for their operation. Due to the fact that the national parks did not have a legal personality they could not run business. This situation was the reason for which each park established an auxiliary enterprise. An auxiliary enterprise was a separated part of the budget unit in organizational and financial terms. Auxiliary enterprises were established by national parks to execute nature conservation tasks using income generated by them from:

- the sale of wood and non-wood products;
- fees for entrance to the park or its parts;
- fees for making the national park or its part available;
- fees for entrance to some facilities in the national park;
- sales of services, for example transportation, repair, construction.

The auxiliary enterprises covered the costs of their operation from self-generated income, which did not include income from rental and lease and other agreements of similar types concluded in relation to the assets of

8 Ustawa z dnia 27 sierpnia 2009 r. o finansach publicznych/ Act of 27 August 2009 on public finance (Dz.U. 2009 No. 157 item 1240).

the State Treasury or local administration units, respectively[9]. Although auxiliary enterprises were allowed to run a business, they could not be treated as companies in the legal sense. This resulted from the fact that they were established under a budget law, and not under the business law[10].

The insufficiency of annual subsidies granted from the state budget to national parks was particularly clear in 2001–2005. According to the financial plans, subsidies in that period dropped from 59.9 million PLN in 2001 to 52.8 million PLN in 2005[11]. Therefore, the burden of financing the national parks under the law at that time was shifted to auxiliary enterprises established by national parks.

This shift in the financial burden was reflected in the revenues of auxiliary enterprises. In 2000–2004 there was a gradual increase in the share of these funds in the total revenue of auxiliary enterprises and budget units. Revenues from the sale of products and services increased in contrast to the decreasing budget subsidies, and reached, for example, 62.3 million PLN in 2004, which accounted for 45% of total revenues generated by national parks and their auxiliary enterprises.[12]

This process has aroused well-deserved criticism. A recognized Polish authority, the State Council for Nature Conservation, in its report prepared in 2007 entitled "The position on the crisis of nature conservation in Poland" indicated, for example, that national parks, „spend almost all of their budget on the very low pay of employees and on maintaining the extensive infrastructure of the management of parks", and „are also lacking funds for necessary conservation and educational measures, as well as environmental monitoring". The report also emphasized that because of the activities associated with the acquisition of timber for sale wood stands in the national parks are starting to resemble production forests[13].

Also, the Supreme Chamber of Control indicated that the national parks, in order to cope with the tasks imposed by the Minister of Environment, face at the same time restrictions arising from the lack of sufficient revenues and inability to adjust the planned revenues to expenditure, and undertake,

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9 Ustawa z dnia 30 czerwca 2005 r. o finansach publicznych/ Act of 30 June 2005 on public finance (Dz.U. 2005 No. 249 item 2104), Article 26.

10 Decision of the Provincial Administrative Court in Warsaw of 6 July 2005, VI SA/Wa 2083/04, in: J. Lipski, M. Nowotnik, A. Szafrański, *Ustawa o swobodzie działalności gospodarczej. Wybór i opracowanie*, Warszawa 2009, p. 21.

11 Budget laws for years 2001–2005.

12 Report of the Supreme Chamber of Control from June 2006, Report from the inspection on the operation of national parks focused on the conservation of nature, sustainable use and renewal of resources, p. 26.

13 State Council for Nature Conservation, *Najważniejsze problemy ochrony przyrody w Polsce*, Warszawa 2007.

through their auxiliary enterprises, activities characteristic for business operators focused on maximizing income. One example of this was the acquisition of timber from national parks in the same manner as it is done from production forests.[14]

Following the provisions of the Public Finance Act of 2005, actions were taken then to consolidate the public finance system and to achieve greater transparency in the spending of budget funds. The first step towards this was the amendment of the Public Finance Act of 2005. As a result, regulations implementing the Public Finance Act were adopted[15] and auxiliary enterprises operating in national parks were liquidated, starting from the end of 2010. Furthermore, the Nature Conservation Act, amended on August 18, 2011, transformed national parks from a state budget unit into a public organisation with a legal personality in line with the definition used in the Public Finance Act of 2005, Article 9, clause 14.

Financing of the operation of national parks after 2012

The reform of the legal form in 2012 based on which national parks operate has not caused any significant transformations in the tasks assigned to parks. However, it introduced a number of changes, for example financial management, preparation of plans and financial reports. Under the current legislation, national parks as public organisations with a legal character can use multiple diverse sources for the financing of their operation. According to the Nature Conservation Act of 2004 (Article 8h, clause 1), the list of revenue sources for national parks is wide, and includes:

- subsidies from the public budget;
- subsidies and loans from The National Fund for Environmental Protection and Water Management (NFOŚiGW) and its provincial funds;
- fees charged for entrance to the national park or its parts, as well as fees for making the national park or its part available;
- fees charged in relation to educational activities of the national park and entry to facilities related to such activities;
- income generated by the rental, lease, or use of premises;
- income from the sales of products gained in relation to the execution of tasks specified in a conservation plan or conservation tasks;

14 Report of the Supreme Chamber of Control of June 2006, p. 26.

15 Ustawa z dnia 27 sierpnia 2009 r. – Przepisy wprowadzające ustawę o finansach publicznych/ Act of 27 August 2009, Regulations implementing the act on public finances (Dz.U. 2009 No. 157 item 1241).

- income from the sales of educational, informational and scientific publications;
- income from the sales of movable assets;
- income from agricultural activity;
- income related to the provision of information on the environment and its protection;
- fees for access to information on natural, cultural and cartographic resources;
- income from punitive damage paid by perpetrators of offences against the environment;
- other revenues not listed above but resulting from the operation of the national park.

In addition, national parks can raise revenues from voluntary contributions in cash, inheritance, bequests and donations in cash or in kind, income from events organized for the benefit of nature conservation, funds from the European Union budget, funds from foreign non-returnable sources other than funds from the budget of the European Union, as well as subsidies from the budgets of local administration units for the implementation of tasks related to the protection of regional natural and cultural assets.

Another major change in the functioning of the national parks is that they can draw credit and loans[16] in the amount of 60% of revenue specified in the financial plan, or 60% of costs for the implementation of tasks of the national park (Nature Conservation Act of 2004, Article 8h, clause 3). But the fundamental change from the point of view of the problem analysed in this paper is that national parks have been allowed to conduct business under the Business Freedom Act of 2 July 2004[17], with some limitations specified in the Nature Conservation Act of 2004 (Article 8b, clause 2).

The scope of business allowed by the Nature Conservation Act is very wide, since "business includes any commercial activity in production, construction, trade, services, prospecting, exploration and exploitation of minerals from deposits, as well as professional activity carried out in an organized and continuous manner"[18]. Limitations on business activity run by national park are specified in the Nature Conservation Act of 2004 (Article 8, clause 2) and relate primarily to types of business inconsistent with the basic objectives for which national parks are established, such as the preservation of the biodiversity, resources, objects and elements of nature. In addition, it is

16 With the permission of the minister relevant for environmental affairs issued after agreement with the minister relevant for public finances in the form of an administrative decision.

17 (Dz. U. of 2010 No. 220, item 1447, as amended).

18 Ustawa z dnia 2 lipca 2004 r. o swobodzie działalności gospodarczej/ Act of 2 July 2004 on business freedom (Dz.U. 2010 No. 220 item 1447), Article 2.

worth noting that business activity should be additional, and not the fundamental activity of national parks, since it was not the reason for which they were created.

According to the Business Freedom Act (Article 14, clause 1), entrepreneurs being individuals may undertake business activities after they have been registered in the Central Register of Entrepreneurs (CEIDG). Other enterprises (including national parks) have to be registered in the National Court Register (KRS). However, the list of enterprises specified in the Act on the National Court Register is closed and does not include national parks[19]. Therefore, national parks cannot be registered in the National Court records, and thus cannot conduct business.

It seems that in the current situation, the only solution for national parks is to establish entities which could be entered into CEIDG (individuals) or KRS (other entities), and thus, to conduct business on behalf of the park. Considering this, it seems reasonable to open further options for financing the operation of national parks through their subsidiaries:

- partnerships under commercial law (for example limited liability company, joint-stock company);
- enterprises running business in the form of public-private partnerships;
- non-governmental organisations operating under the act on public benefit institutions (registered NGOs, foundations).

Conclusions

The analysis provided the following conclusions:

1) Tasks of national parks can be financed from various sources, including revenues from businesses run by them.
2) Revenues from businesses run by national parks cannot be gained in a manner inconsistent with the purpose for which national parks were established.
3) Because of the existing regulations specified in the Business Freedom Act and Act on the National Court Register (KRS), national parks cannot directly exercise the provisions of the Nature Conservation Act allowing them to run businesses.
4) A potential solution for national parks can be seen in running businesses by establishing, for example, partnerships under commercial law, public-private partnership or non-governmental organisations.

[19] Ustawa z dnia 20 sierpnia 1997 r. o Krajowym Rejestrze Sądowym/ Act of 20 August 1997 on the National Court Register (KRS) (Dz.U. 1997 No. 121 item 769), Article 36.

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SERVICE LIFE OF THE ENGINEERING STRUCTURES SUBJECTED TO ENVIRONMENTAL IMPACTS

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TRWAŁOŚĆ KONSTRUKCJI BUDOWLANYCH PODDANYCH ODDZIAŁYWANIOM ŚRODOWISKOWYM

STRESZCZENIE: Niniejszy artykuł przybliża aktualny stan wiedzy na temat metod projektowania konstrukcji budowlanych na okres użytkowania, którego głównym celem jest zapewnienie odporności konstrukcji na przekazywane na nią wpływy środowiskowe. Omówiono metody oceny trwałości konstrukcji i ich weryfikacji zgodne z wytycznymi norm ISO oraz wiedzy technicznej zawartej w literaturze naukowej. Ideą tych metod jest analiza środowiska eksploatacji konstrukcji, mechanizmów transferu, czyli przenoszenia się oddziaływań środowiskowych na elementy budowlane, procesów wewnętrznych i zewnętrznych powodujących ich degradację oraz ilościowych efektów degradacji. Realizuje się to zgodnie z zapisami obowiązujących norm budowlanych, które wykorzystują metody deterministyczne i probabilistyczne. W szczególności analizie poddane zostały istniejące metody probabilistyczne, wśród których można wyróżnić pełne podejście probabilistyczne, podejście półpropabilistyczne z częściowymi współczynnikami bezpieczeństwa oraz metodę stanów granicznych. Zamierzeniem opracowania jest zwrócenie uwagi na istotność doprecyzowania zaleceń projektowania konstrukcji inżynierskich na okres użytkowania.

SŁOWA KLUCZOWE: okres użytkowania, konstrukcje inżynierskie, trwałość, projektowanie, oddziaływanie środowiska

Introduction

Each building structure is exposed to damaging factors such as environmental conditions, natural ageing, deterioration of performance, and damage resulting from construction or operation during the service life cycle. The processes of destruction can lead to a reduction in the utility of components and materials to such an extent that the internal structure of the building will no longer fulfil the relevant design criteria such as the load capabilities and the planned design life will get shorter. To avoid premature destruction of the construction, we can find many useful practical rules and guidance concerning the extension of the life of the structure in the construction standards, for example, the use of a special protective coating of the steel elements of a building that are exposed to an aggressive environmental agent or excessive temperature.

Furthermore, as a result of international research grants, some design procedures have been worked out, making it possible to predict adverse factors affecting the deterioration of the building with regard to constructions made of concrete and reinforced concrete (for example the programme Britt/UERAM[1]).

Limit states design

In line with the basic requirements of design standards, the structure should be designed to absorb all aversive influences of the environment expected during the processes of construction, installation, and usage of the building according to the intended purpose during all of the planned design working life. The construction should fulfil all the requirements with the proper level of reliability without excessive costs.

Properly designed construction should be characterized by the required resistance and durability. In the case of fire emergency, the load capacity of the structure should hold the building for the time necessary for the evacuation. The construction should also be resistant to unpredicted events such as explosions, impacts, or the consequences of human error.

Environmental factors that may affect the durability of the structure should be taken into account in the selection of structural materials, the type of system design, and the technical requirements of the building. To accurately assess the durability of the structure, it is recommended that the method of quantitative assessment of the effects caused by environmental agents be used.

[1] Britt / UERAM Program. DuraCrete 1996–1999. DuraNet 1998–2001. Darts 1997–2004.

These basic requirements for resistance, serviceability, and durability of structures should be met by the selection of appropriate materials and proper system design and also by determining and carrying out the appropriate control procedures at the stage of creation of design, material production, and installation of the elements, and during the use building.

The required durability and reliability of the building must be ensured by designing the structure following the guidelines of the Eurocodes on construction, taking measures to ensure quality. The structure should be designed in such a way that except for the impacts on the building caused by the environmental factors and with the expected level of maintenance of the structure, the building's performance will not decrease below the desired level. Environmental conditions affecting the durability of the structure should already be determined at the design stage so that appropriate preventive measures can be taken in time.

In the current design practice, buildings are designed using deterministic and probabilistic methods. Deterministic methods are based on comparative methods and empirical research methodology. The probabilistic methods can be divided into the full probabilistic approach, the semi-probabilistic approach with partial safety factors, and the method of limit states.

The basic demands of durability can be expressed by Equation (1), in which the lifespan of a structure or its component t_S shall not be less than the period of the project design t_D:

$$t_S \geq t_D \tag{1}$$

In the case in which the structure is protected for a limited time against adverse environmental influence (e.g. galvanized steel parts, protective coatings on wood, …), the life of the structure can be represented by the formula:

$$t_S = t_{start} + t_{exposed} \tag{2}$$

where:

t_{start} – the time needed to initiate degradation of the element,

$t_{exposed}$ – use time after the initiation of degradation.

During the use time t_S, the construction meets the design requirements, and in the project period t_D, which is specified during the stage of planning, the proper functioning of the building or its component is ensured. The numerical value of the project period is usually given in the design Eurocodes (Table 1).

Tabela 1. Orientacyjne okresy projektowe obiektów budowlanych

Object category	The design life (years)	Examples of objects
1	10	Temporary structures
2	10-25	Interchangeable parts for construction of ordinary constructions
3	15-30	Agricultural constructions
4	50	Construction of buildings and other ordinary structures
5	100	Construction of monumental buildings, bridges, and other engineering structures

Source: BS EN 1990: 2002 Eurocode – Basics of structural design.

The construction usability period t_S is the result of many factors, such as the time of use of elements and components of design, applied management and control procedures, and current repairs. Parts and components whose planned service life is shorter than the planned design life of the entire structure must be replaced. Renovation or repair of the building components should be included in the design life period.

In the full probabilistic format, the probability of structural damage P is estimated, and then it is checked whether the calculated probability is less than or equal to the target probability P_{target} established in the design stage, according to the following formula:

$$P(t_S < t_D) \leq P_{target} \tag{3}$$

$$\frac{t_{sk}}{\gamma_s} \geq t_D \tag{4}$$

Examining the stability of the structure using this method is based on a comparison of the forecast of the utility period t_{SP} and value of the design life t_D according to the formula:

$$t_S = t_{SP} \geq t_D \tag{5}$$

The method of the limit states currently includes three limit states design. The ultimate limit state (ULS) refers to the construction safety. In the serviceability limit state (SLS), an excessive deformation of the structure disabling its proper functioning is subjected to the assessment. The border span limit state (ILS) corresponds to the beginning of the process of construction deg-

radation[2]. The basic requirement for the ultimate limit state can be expressed by the formula:

$$R(t) \geq Q(t) \tag{6}$$

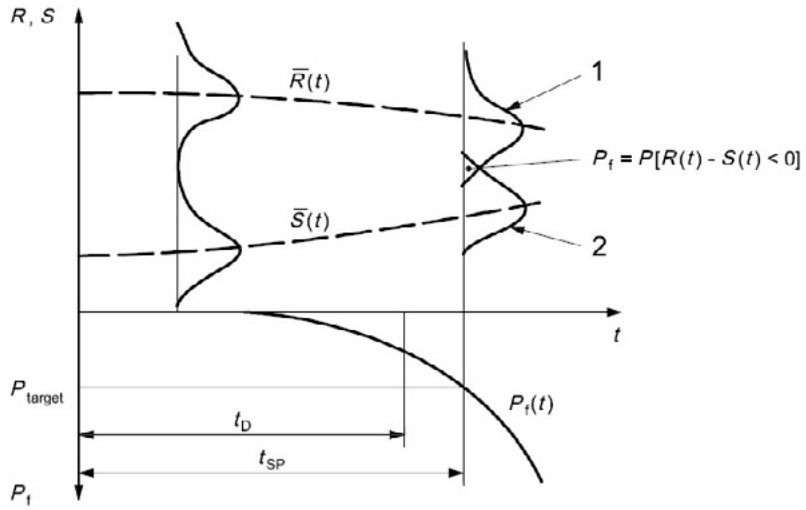
where:
$R(t)$ – working load limit.
$Q(t)$ – the impact on the structure.

In the state of the serviceability limit, the deformation or displacement of structures should not exceed the acceptable values:

$$S(t) \leq S_{lim} \tag{7}$$

The condition for the durability limit state can be presented by Formula (8) and shown in graphical form (Figure 1):

$$P(t) = Pf\,[R(t) - S(t) \leq 0] < P_{target} \tag{8}$$



KEY: 1 probability density function of $R(t)$
2 probability density function of $S(t)$

Figure 1. Mathematical model for predicting service life of the structure t_{sp}

Source: ISO 13823: 2008: General principles of the design of structures for durability.

[2] CIB W80 / RILEM 71-PSL 1987, *Prediction of the service life of building materials and components*, "Materials and Structures" 1987 No. 20, p. 115.

Designing the building structures, focusing on durability

The general requirements for structural engineering for durability using the method of limit states are described in ISO 13823[3]. In this method, the durability of the structure is defined by analysing the environment where the structure is used, the mechanisms of transfer of the natural factors on the elements of the structure such as external and internal processes causing degradation, and the quantitative effects of this processes. A schematic diagram of this method is presented in Figure 2.

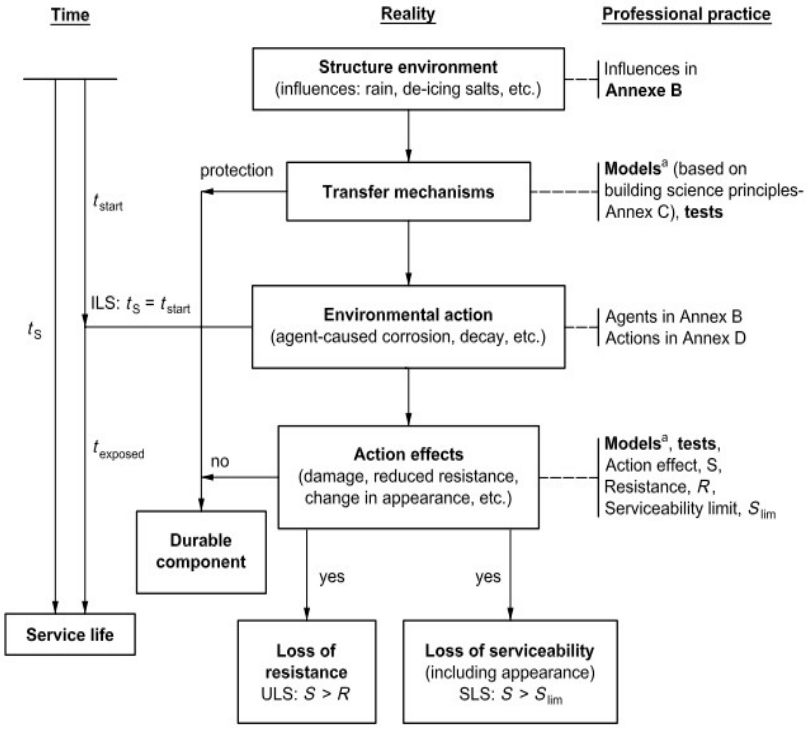


Figure 2. Design durability limit state

Source: ISO 13823: 2008: General principles of the design of structures for durability.

In a first step, it is necessary to specify the operating environment of the structure. This includes all the elements of the environment surrounding the structure, which gives rise to environmental impacts that degrade construction elements such as moisture, temperature, solar radiation, and

[3] ISO 13823:2008: General principles on the design of structures for durability.

others. Examples of types of operating environments of the structures and the corresponding impact on the structures are shown in Table 2, and descriptions of the parameters of the environmental impact are presented in Table 3.

Mechanisms for transferring the environmental impacts onto the structural elements are called transfer mechanisms. These are physical phenomena such as gravity, condensation and drainage, and capillarity actions that accelerate or prevent the degradation processes of structural components.

Table 2. Types of structural environments and exposure conditions

Environment	Environmental agents
Outside – atmosphere	Rain, snow, or ice Air constituents (nitrogen, oxygen, argon) Air pollutants (Chlorofluorocarbons – CFCs) Temperature and humidity Solar radiation
Outside – ground or water	Water Soil constituents Soil spills/leaks Road salt
Inside	Humidity and temperature Contaminating materials Water and sewage Stored chemicals Activities causing wear

Source: CIB W80 / RILEM 71-PSL 1987. "*Prediction of the service life of the building its materials and components*", Materials and Structures, 20 (1987) 115.

Table 3. Description of parameters of agents causing environmental action

Influences	Environmental agents	Examples of parameters
Moisture (constituents)	Solid (ice, snow) Liquid (rain, condensation) Gas (water vapour)	The period of humidity (TOW) Relative humidity (RH)
Moisture (contaminants)	Chlorides, acids, sulfates	Exposure time (TOE) Relative humidity (RH) pH Concentration
Air (constituents)	Oxygen, carbon dioxide	Exposure time (TOE) Concentration

Influences	Environmental agents	Examples of parameters
Air (contaminants)	Oxides, particulates, aerosols	Exposure time (TOE) Concentration
Ground (constituents)	Sulfates and other salts	Exposure time (TOE) Relative humidity (RH) pH Concentration
Air (contaminants)	Chemicals from spills and leaks Chlorides from road salt Induced electrical currents	Exposure time (TOE) Relative humidity (RH) Time (T) pH Concentration
Biological life	Microorganisms, insects, animals, plants	The period of humidity (TOW) Relative humidity (RH) Time (T) Geographical location
Temperature	Freeze–thaw cycles, heating	Number of cycles (F–T)
Solar radiation	UV radiation, IR radiation	Exposure time (TOE) Relative humidity (RH) Time (T)
Use or exposure	Wear, abrasion	Exposure time (TOE) Load

Source: The authors' own study based on CIB W80/RILEM 71-PSL 1987. "Prediction of the service life of building materials and components," *Materials and Structures,* 20 (1987), 115; E. Vesikari, "The effect of coatings on the service life of concrete facades," *Proc. 9th International Conference on Durability of Building Materials and Components* (Australia: Brisbane, 17–21 March 2002).

Modelling of the deterioration process requires an understanding of the transfer mechanisms and environmental actions on the structural components. This should include knowledge of the parameters of the materials and the components and microclimate in the vicinity of the used components. Examples of transfer mechanisms are shown in Table 4.

As a result of the transfer mechanisms of environmental actions in the materials, internal and external processes take place. They may be positive (e.g., by strengthening the natural ageing of the steel material) or negative (e.g. embrittlement of the plastic material under the influence of UV radiation). Degradation processes taking place within the material, such as steel corrosion, biological decay of timber, or concrete shrinkage, are the chemical, electrochemical, biological, and physical actions causing degradation or deformation of the structural components. They are dependent on the properties of building materials and the type of environment surrounding the structure.

Table 4. Transfer mechanisms causing environmental actions

Transfer mechanism	Examples
Direct exposure	UV on exterior surface materials Rain on the roof or wall surfaces Ground moisture
Gravity	Water traps in lap joints Ponding on „flat" surfaces Rain penetration into roofs Staining of building face by water runoff
Air/vapour pressure	Rain penetration into walls Condensation in building envelopes due to air leakage and vapour diffusion
Capillarity or surface tension	Penetration of rain and groundwater through porous materials due to capillarity tension Migration of salts within porous materials
Kinetic energy	Driving rain on wall surfaces and penetration through openings
Permeation	CO2 and water ingress into concrete causing corrosion Vapour transmission through building envelope materials
Convection	Air leakage through gaps in building envelopes
Condensation	Vapour condensation inside thermal bridges
Diffusion	Chloride ingress into hard concrete

Source: The authors' own study based on E. Vesikari, op. cit.

The results of degradation of the structure are the measurable effects of environmental agents (Table 5). They are characterized by one of the limit states – ultimate serviceability or durability – being exceeded. The effects can result in the destruction of structural elements, reduction of the load capacity, additional stresses, or loss of use performance due to excessive deformation.

The most critical factor in the degradation of building structures is acid rain, which is a type of precipitation at pH less than 5.6. It includes fatty acids produced from the reaction of water wit gasses emitted into the atmosphere (sulfur dioxide, sulfur trioxide, nitrogen oxides, carbon dioxide). Industrial pollutants emitted to the atmosphere from fuel combustion or the industry increase the acidity of the environment by decreasing the pH to below 5.0.

The danger level of building walls due to moisture penetration is characterized by the driving rain index for vertical surfaces (DRI) according to DIN ISO 15927–3[4] expressed in metres and the average wind speed in metres per second. The values of the indicator express the safe, average, and heavy levels.

4 PN-ISO 15927–3:2010 Hygrothermal performance of buildings. Calculation and presentation of climatic data – Part 3: Calculation of a driving rain index for vertical surfaces from hourly wind and rain data.

Table 5. The effects of degradation depending on the type of structure

Material	Service environment	Transfer mechanism	Degradation processes	Action effects
Steel	Outside	Humidity condensation	Atmospheric corrosion	Reduction in the thickness of the components
Reinforced concrete	Inside and outside	Diffusion of chloride ions	Carbonation of concrete	Reduction of the cross-section of the reinforcement, reducing the durability of the concrete
Wood	Water	Direct exposure	Fungal decay	Biological decomposition of the material

The time of wetness (TOW) of material is another of the basic parameters of the description of environmental hazards. Corrosion processes occur in the environment where the surfaces of metal structures are covered with a thin layer of water. This happens at above-zero temperatures at a relative humidity of 80 to 90%. The period of exposure to moisture of the external components of the structure depends on the shape, for example, whether the water can flow away from the structure[5].

Exposure of plastics [polyvinyl chloride, polycarbonate, polymethyl methacrylate, polyethene, or polypropylene] that are used for the production of roofs and walls to sunlight has a detrimental effect on their viability. Ultraviolet radiation breaks the chemical bonds of the polymers, causing various types of damage: stiffening, cracking, or discolouration. The exposure time (TOE) of these elements to sunlight is important when assessing the degree of degradation of structural elements[6].

The frost resistance – resistance to cyclic processes of freezing and thawing (FT) – is an important feature of wall materials in the autumn–winter season. This property is crucial in maintaining the sustainability of the building materials and construction. Water that penetrates the centre of a construction subjected to repeated freezing and thawing can affect the properties of the building material, for example, reducing its mechanical durability.

To reduce the impact of adverse environmental actions on structures, it is advisable to take appropriate preventive measures at the stage of design and construction. The most important steps are developing a general concept of

5 J. Bródka, M. Broniewicz, *Design of Steel Structures According to the Eurocodes,* Rzeszów 2014.

6 E. Vesikari, *The effect of coatings on the service life of concrete facades*, Proc. 9th International Conference on Durability of Building Materials and Components, Australia: Brisbane, 17–21 March 2002.

a building with enhanced resistance to environmental influences, the selection of appropriate materials, and the development of construction details and proper construction work, ensuring an adequate quality control system and periodic inspections. It is also crucial to use protective measures, such as shaping the connections and the use of protective coatings. Examples of such measures are presented in Table 6.

Table 6. Examples of design and detailing to minimize environmental actions

Transfer mechanism	Examples
Barrier	Coatings: zinc on steel, protective paint coating on wood Impregnation of wooden components Sealants of joints and contact surfaces Damp-proofing and waterproofing of foundations Waterproof membranes of garages and bridge decks Air/vapour barrier system in building envelopes
Drainage	Detailing to avoid water traps Detailing to avoid rain penetration in building walls Drips to deflect moisture away from lower components Applying dewatering systems
Ventilation	Detailing to promote exchange of moist air with dry air in rooms

Conclusions

The problem of durability of a structure can be described by two basic variables: *R*, the structural integrity against environmental factors causing degradation throughout the design life, and *S*, the environmental impacts on the structure during its service life. At the stage of construction design and selection of materials, it is necessary to check whether the durability of the construction is higher than the design performance requirements and utility demands that may occur during the service life. Both the resistance of the structure *R* and the environmental impacts *S* are time-dependent values. When designing the structure with regard to the aspects of load capability and stability, the time factor is often ignored, and with regard to determining the durability of the construction, time is a very critical element that reduces the structure's resistance.

In general practice, building structures are designed based on a set of rules and recommendations presented in the normative standards of design. The subject of design life of the structure is not yet regulated in appropriate normative acts. As a result of international research grants, some design methods have been elaborated. Moreover, the publication of ISO 13823 was

the first step towards the codification of the problem of determining the durability of building structures exposed to environmental impacts. The ISO norm does not provide strict methods of design life of the structure or introduce any partial safety factors that could reduce the resistance of the structure to external influence due to harmful environmental agents. However, it is an essential element in the overall design assumptions of the project aimed at determining the durability of the design and unifies the conceptual scope associated with this field of design.

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The contributions of the authors in the creation of this article

Prof. Mirosław Broniewicz, PhD Eng. – contributed 40%: the concept of the article and essential input

Filip Broniewicz, Eng. – contributed 30%: a literature review and technical and organizational contributions

Karolina Dec, Eng. – contributed 30%: a literature review and technical and organizational contributions

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DISCUSSION AND REVIEWS

RECENZJE OMÓWIENIA, PRZEGLĄDY

Book review

EKOLOGIZACJA GOSPODARKI

Edited by Małgorzata Kożuch

Publisher: Fundacja Uniwersytetu Ekonomicznego w Krakowie, Kraków 2015

The monograph *Ekologizacja gospodarki* is devoted to important contemporary problems joining economic development with the paradigm of sustainable development. The introduction emphasises that only connecting economic and natural processes offers the opportunity for economic development while minimising ecological, social, health, and economic threats. The philosophy of management should always be an object of economic and ecological analysis.

This monograph includes chapters written by scientific academics connected with Katedra Polityki Przemysłowej i Ekologicznej Uniwersytetu Ekonomicznego w Krakowie, including Prof. Józefa Famielec, Małgorzata Kożuch, Katarzyna Cięciak, Jolanta Stanienda, Ivan Telega, Renata Żaba-Nieroda, Maria Gabryś, and Krzysztof Wąsowicz.

This monograph has a theoretical-empirical point of view. It is multithreaded but coherent and it presents the analysed issues in a logical way. The content is divided into nine chapters, as follows:

1. *Ecologisation as a paradigm of socioeconomic development.*
2. *Natural capital and the process of ecologisation of the economy.*
3. *Ecological objectives concerning the climate and energy policy of the European Union and Poland.*
4. *Ecological dimension of military security.*
5. *Ecologisation of local public transport.*
6. *Meaning of relations in the ecologisation of enterprises.*
7. *Enterprise innovation in the light of the ecologisation of the economy.*
8. *Innovativeness of enterprises in clusters.*
9. *Role of banks in financing the ecologisation of the economy.*

The first chapter thoroughly analyses the category of ecologisation. It describes the historical development and the contemporary understanding of this term. The topic of ecologisation is also considered from the point of view of economic theories, particularly economic growth. The author emphasizes that ecologisation of the growth paradigm offers an opportunity to facilitate economic and social development. In addition, this chapter presents the institutional factors of the economic order of the Austrian and neo-classic schools.

The second chapter introduces the concept of natural capital and it outlines the assumptions regarding the account of material flows in terms of measuring the consumption of natural capital and the degree of ecologisation of the economy.

The third chapter identifies the environmental objectives of the climate and energy policy of the European Union and Poland. The sources of European Union climate policy are presented in a thorough manner. Climate and energy package and emissions trading are also described. Moreover, current problems concerning the ecologisation of the climate and energy policy of the European Union are discussed. This chapter also describes the problems of developing the Polish gas infrastructure.

The fourth chapter analyses the environmental dimension of military security. The fundamentals of ecological and military security are clarified on the basis of the Polish Constitution and the Strategia Bezpieczeństwa Narodowego Rzeczpospolitej Polskiej, which are obligatory in Poland. This chapter attempts to capture the relationship between these two legal documents. This chapter successfully outlines the evolution of ecological security in the Polish national security strategy.

The fifth chapter argues that local public transport companies can have a direct impact on the quality of life, especially of the most vulnerable people in society, such as by facilitating access to education and to health services. In the introduction of this chapter, the author notes that public transport, by gaining passengers who have and can use a car, reduces pollution (such as exhaust emissions or noise), traffic congestion, and the number of accidents.

The sixth chapter uses relations theory to define the ecologisation of entrepreneurship. The author stresses that this approach allows us to treat the ecologisation of enterprises as a problem of participation by people who are interrelated, non-restricted by a financial deficit or lack of material capital, and motivated to respect nature and its laws, as well as people who trust each other and provide mutual goods. The inspiration of this chapter was the economics of three values: sharing, love, and coercion.

The seventh chapter attempts to find what kinds of innovation Polish enterprises have introduced (if any) and the extent to which their innovative activities affect the structural changes in the light of the ecologisation of economy. On the basis of the conducted research, the author stresses that a successfully pursued innovation policy is an essential tool for achieving the objectives of a low-carbon economy and meeting, among other things, the requirements of climate and energy policy. Innovations are conducive not only to change the structure of the national energy balance but they also promote

investment in energy-efficient buildings, fuel-efficient transport, and they favour the effective use of available raw materials in industry and waste management.

The eighth chapter attempts to identify the role of clusters in increasing the innovation activity of enterprises. The authors assumed that the characteristics of enterprise innovation include geographical and sectorial concentration, specialization, cooperation, and partnership. Verification of these assumptions was carried out in Tarnowski Klaster Przemysłowy.

The ninth chapter describes the ecologisation of the modern banking sector. The banking hierarchy of projects for the protection of the natural environment is presented in this chapter, especially those that are directly related to their internal economy. The essential elements of a development strategy based on the assumptions of the business balance are identified. The business balance ensures the sustainability and continuity of the functioning of the bank, which meets the needs of all stakeholder groups in the variability of its internal and external environment. This chapter highlights the microeconomic and macroeconomic functions of banks and the importance of resource information (including forecasts) in their functioning and development.

The issues raised in this monograph are presented in a thoughtful, orderly, and mature manner. The individual chapters are written using the knowledge acquired from the authors' major research achievements and from the extensive review of the current literature that is placed at the end of each chapter.

Due to the importance of the problems of the ecologisation of the economy, this monograph deserves the reader's attention. Apart from substantive values, the well considered preparation of the publication attracts the reader's attention. The authors demonstrate the ability to analyse and connect specific issues, as well as having the ability to bind them together. The excellent scientific preparation of the monograph's authors is worth mentioning. In addition, the language of the study is clear, approachable, and professional.

This monograph is intended for students of economic and ecological faculties, it may also constitute an important source of knowledge for practitioners interested in the problems of the ecologisation of the economy.

The issues raised in this monograph fill an important gap in the publishing market in the category of economic ecologisation.

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