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INTEGRATION OF ECONOMIC, TECHNICAL AND CHEMICAL SCIENCES FOR SUSTAINABLE DEVELOPMENT

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INTEGRACJA NAUK EKONOMICZNYCH, TECHNICZNYCH I CHEMICZNYCH NA RZECZ ROZWOJU ZRÓWNOWAŻONEGO

STRESZCZENIE: W artykule omówiono genezę rozwoju zrównoważonego, który uznano za narzędzie ekologizacji gospodarki. Przywołano dyskusję dotyczącą definiowania pojęcia rozwoju zrównoważonego w ekonomii, w której wykształciła się kategoria zielonej gospodarki. Także nauki techniczne i chemiczne wykorzystują efekt „zazielenienia". Omówiono ważniejsze przejawy zainteresowania się rozwojem zrównoważonym przez zieloną chemię, zieloną inżynierię, które wpisują się w rozwiązywanie dylematu tzw. potrójnej linii przewodniej w działalności gospodarczej. Artykuł zamyka próba uzasadnienia potrzeby integracji wiedzy, pochodzącej z różnych dziedzin i dyscyplin nauki dla potrzeb postawienia i rozwiazywania dylematu rewolucji energetycznej.

SŁOWA KLUCZOWE: paradygmat, nauka, rozwój, zrównoważony, zielona gospodarka, zielona chemia, zielona inżynieria

Introduction

The paradigm of sustainable development is linked with the knowledge-based economy. This concept has many dimensions, but in Poland, the European Union and the world it is mostly reflected in political declarations. In the EU sustainable development was the subject of Europe 2020, a strategy for smart, sustainable and inclusive development. In Poland, sustainable development has become a constitutional duty of the State and the essence of the new plan for responsible development of the economy. Despite the strong activity of scientists and politicians in defining and implementing sustainable development, it is hard to resist the impression that progress has been achieved so far only in terminological terms.

The aim of this article is to approach sustainable development as a scientific category (and not only a political one) requiring and using knowledge from various scientific disciplines. The hypothesis put forward in this article is that sustainable development is an interdisciplinary issue and cannot be a stand-alone subject of study of a single scientific discipline. The study shows links between sustainable development and economic sciences (growth, development, economy), engineering (technical progress, technologies and methods of process management) and chemistry (properties and transformations of substances in natural and industrial processes). Environmental protection, which is usually identified as an element of sustainable development, is an integral part of each of these scientific disciplines[1].

The origins of sustainable development, a tool for the greening of the economy, has also been discussed. A reference to the discussion on defining sustainable development in economics, including the characteristic category of the green economy, has been made. The greening effect is also used in engineering and chemical sciences. The paper also discusses important aspects of sustainable development in green chemistry and green engineering, which contribute to solving the triple bottom line dilemma in economic activity. The article ends with an attempt to justify the need to integrate knowledge from different fields and disciplines of science to emphasize and solve the dilemma of revolution in the energy sector.

The paper presents references to Polish and foreign publications, as far as possible, considering the size of the paper and the knowledge and experience of the authors of the research. This article offers a transition from discussions on the category of sustainable development in the political dimension, including environmental policy and climate change, to an interdiscipli-

[1] These disciplines have been chosen due to the competence of authors, but the list of disciplines necessary for the complete description of sustainable development is still open.

nary scientific discussion on development in general, for a better future for people, the economy and the environment.

Sustainable development – a tool for the greening of the economy

The category of sustainable development, treated as a new paradigm in economics, has its origins in the exploration and use of knowledge regarding barriers (limits) to production growth, the ecological barrier in particular. Understanding the rules of nature and the limits of growth related to them, and realising the importance of ecosystems and the need to respect them have created interest in science, economics and politics in processes called greening[2].

The concept of greening is related to silviculture, hunting, fishing, beekeeping and agriculture. Greening involves incorporating natural mechanisms to enhance economic processes, and as such is termed 'primary greening'. The current ecological movements use the rules of greening that were already established in the past, over 200 years ago, in response to the unprecedented plundering and wasteful exploitation of forests that could have led to the complete destruction of forests, which were already far from their natural state. Modern European silviculture was a rational attempt to bring to order and protect the sustainability of forests.

The still poorly defined principle of sustainable development (preservation of resources for future generations) can be better explained through the following statement 'If you cleared an old forest and planted a new one in its place, it does not mean that you have kept the natural balance or that this balance will be restored when the young forest grows. You will never restore the old forest. It is impossible to recreate, copy, or repeat such an aged wood stand with its density, shade and scent, with its internal network, connections and relations. When you cut down a forest, a part of our world dies out for ever'[3]. Some part of ourselves dies, since when we turn forests into 'timber yards, we not only lose rare beetles, mosses, fungi or birds'[4].

The struggle with the plundering of forests for the sake of restoring rational forest management, meant that the first stage of greening has been achieved. The same degree is applied to all methods of the semi-culture of plants and semi-breeding of animals, modern agriculture, as well as rational

2 Further reading: M. Kożuch (ed.), *Ekologizacja gospodarki*, Kraków 2015.

3 R. Kapuściński, *Lapidarium III*, 1997, pp. 174–175, quoted after: M. Zaremba-Bielawski, *Leśna mafia. Szwedzki thriller ekologiczny*, Warszawa 2014, p. 7.

4 Book introduction: M. Zaremba-Bielawski, op. cit., p. 11.

game management and fishery. The increase in the variety of crops and wood stands, and the use of natural mechanisms of biological resistance against damage means a higher degree of greening[5], which can ensure the greater sustainability of natural capital.

Primary greening also applied to agriculture which attempted to stop degradation, and concerned the discovery of crop rotation that replaced natural succession. Greening in agriculture refers to the universal rules of nature, where every effect has its cause and where there is overall coherence, some things are more important than others, and awareness decides harmonised development[6].

The concept of greening was revived in the second half of the 20th century. In a broad sense it was used to describe the strategy for social and economic growth, called sustainable development[7]. When defining it, one's attention is drawn to the domination of ecological (natural) conditions in establishing development goals, next to social and economic goals.

The understanding of the core and processes of greening is necessary to correctly apprehend sustainable development. Greening does not only mean respecting ecological limits and the need to protect nature, but also to consider all social aspects related to human beings. This is reflected in the emergence of the green economy, a system that optimizes the flow of products and services to maximize the use of raw materials and minimize the amount of waste (hence the necessary involvement of economic sciences).

The green economy categorizes resources into biological and technological. Biological resources include food, plant waste material, wood and textile fibres, which are consumed and then returned to the environment as compost or fertilizer to restore nutrients in soil, and/or are processed to generate energy from renewable sources. Technological resources are preserved, reused, restored or recycled many times in a closed loop system. This system is energy-saving and maximizes the use of renewable energy sources to lower greenhouse gas emissions (here chemical sciences are involved). The green economy requires withdrawal from production based on the 'take-make-dispose' approach. This creates new development challenges in all sectors. A demand for innovation in design and production is emerging because people want to create new-generation products with a longer life cycle, reus-

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5 The state of studies and their results concerning the greening of silviculture and its effect on the economy is presented in: S. Zając, A. Kaliszewski, *Ekonomiczne aspekty ekologizacji zagospodarowania lasu,* VI Sesja Zimowej Szkoły Leśnej, Instytut Badawczy Leśnictwa, Sękocin Stary 18–20 March 2014.

6 S. Kozłowski, *Droga do ekorozwoju,* Warszawa 1997, pp. 55–64; B. Smolorz, *Kierunki procesu ekologizacji na świecie*, „Ekologia i Technika" 2005 No. 1, pp. 27–31.

7 Cf. e.g.: A. Skowroński, *Zrównoważony rozwój perspektywą dalszego postępu cywilizacyjnego,* „Problemy Ekorozwoju" 2006 No. 2, pp. 47–57.

able, repairable and multicomponent, so their elements can be reused or recycled (here engineering sciences need to be involved).

Greening of the economy can help achieve the goals of sustainable development through structural changes in the whole economy and transformation of its individual sectors in order to lower the consumption of energy, raw materials and water, and to reduce the amount of waste and its negative impact on the environment. Greening of the economy is primarily about changing the goals of policies, including environmental policy[8], and secondly about organizational and technical measures[9].

Debates on sustainable development in economics

Sustainable development is a commonly used term. This popularity does not mean the term is used always in the same sense or is correctly interpreted from the theoretical and practical point of view. Hans Carl von Carlowitz was the first to clearly formulate the concept of sustainability in forestry in his work published in 1713[10].

Definitions of sustainable development used in publications and in ecological politics have a normative character. They are based on the norm of development towards sustainable society established by the UN in 1975. Sustainable society was then defined as a 'society respecting the supremacy of the environment that must not be disrupted by civilization progress and cultural and economic growth, capable of self-control of its development in order to maintain homeostasis and symbiosis with nature, thus respecting the economical production and consumption and the use of waste, caring about the future consequences of actions and thus also about the needs and health of future generations'[11]. Current activities should ensure the availability of resources for future generations and leave them with the same chances

8 Objectives of environmental policy are usually focused on the reduction of pollution. Some approaches propose that this reduction should be considered at three levels: absolutely required, ensuring minimum ecological safety and the optimized level of pollution. Cf. E. Broniewicz, *Analiza ex ante efektywności kosztowej polityki ekologicznej*, Białystok 2015, p. 27.

9 Greening, as well as sustainable development, are concepts sometimes used to create 'innovative' terminology. The most unusual phrases with greening given by different authors include: greening of government, greening of work efficiency, greening of restructuring, greening of legislation, greening of subsidies.

10 It was the book *Sylvicultura Oeconomica* (*Economy of silviculture*). It appreciates the fertility of forests and describes the art of using peat for fuel. Modern edition: H.C. von Carlowitz, *Sylvicultura Oeconomica, Hausswirthliche Nachricht und Naturmäßige Anweisung zur Wilden Baum-Zucht*, Reprint der zweiten Auflage von 1732, Remagen-Oberwinter 2009.

11 *Ochrona środowiska człowieka – humanitarne widzenie świata*, „Prace Naukowe PKE" 1984 Vol. 1, p. 37.

that we had. From such a perspective development has to be sustainable. According to the Brundtland Commission[12], 'sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs'[13]. Strong and weak sustainability are sometimes distinguished. The first approach is focused on the preservation of the total value of human, environmental and economic wellbeing, while in the second approach trade-offs between the three are accepted[14].

Sustainable development is usually translated into Polish as *rozwój zrównoważony*, and *sustainability* is the equivalent of *trwałość rozwoju*[15]. Some economists recommend the use of *rozwój trwały* instead of *rozwój zrównoważony*, and even consider it more appropriate than the first term. From the methodological point of view *zrównoważenie* (sustainability) and *trwałość* (long-lasting effect) are complementary but different from each other. Science has not reached a clear operationalization of these concepts.

Sustainable development and long-lasting development require a measure of values now and in the future. In modern methodology sustainable development is measured with wellbeing[16]. It usually comes down to a com-

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12 The World Commission on Environment and Development, known as the Brundtland Commission, was organized in 1983 by Gro Harlem Brundtland, who was appointed the chairperson by then UN Secretary General. The Commission is best known for developing a broad political concept of sustainable development, and the publication of the report *Our Common Future* in April 1987. The Commission's activities contributed to the convening of the Earth Summit 1992 in Rio de Janeiro.

13 V. Hauff, *Unsere gemeinsame Zukunft – Der Brundtland – Bericht der Weltkomission für Umwelt und Entwicklung*, Greven 1987, p. 47.

14 M. Burchard-Dziubińska, *Zielona gospodarka jako nowy obszar zainteresowania ekonomii*, in: B. Fiedor (ed.), *Nauki ekonomiczne. Stylizowane fakty a wyzwania współczesności*, Warszawa 2015, pp. 338–339

15 These terms were introduced into the English language in the 19th century. However, there are works in Polish where *sustainability* is translated as *zrównoważenie rozwoju*, as well as *ekorozwój*, cf. A. Zaleśna, *Relacja między misją a wizją a zrównoważonym rozwojem (sustainability) – ujęcie teoretyczne i praktyczne*, in: J. Ejdys (ed.), *Społeczna odpowiedzialność i zrównoważony rozwój w naukach o zarządzaniu. Aspekty teoretyczne i praktyczne*, Toruń 2016, pp. 280–285. In this paper, the term *sustainability* is also considered as a synonym for corporate social responsibility (CSR). Authors agree with a statement according to which the correct translation of the term *sustainable development* is *rozwój podtrzymujący*, but this is a neologism in Polish. Therefore, it is widely agreed to use the translation *rozwój zrównoważony* [balanced development], but this, on the other hand, is a self-contradictory term (development cannot be balanced) and does not express the main idea of G. Brundtland: to leave future generations with the same chances that we had. *Rozwój trwały* [long-lasting development] is, thus, a better translation, cf. A. Pawłowski, L. Pawłowski, *Warunki trwałego, zrównoważonego rozwoju ludzkości,* „Przyszłość" 2013 No. 2.

16 Cf. M.E. Zalewska, *Jak mierzyć zrównoważony rozwój Polski*?, in: E. Mączyńska (ed.), *Modele ustroju społeczno-gospodarczego. Kontrowersje i dylematy*, Warszawa 2015, pp. 397–412.

bination of *per capita* GDP, taking into account the Gini coefficient as a measure of inequality of income. The use of GDP for that purpose has been criticised, but so far no better option has been proposed. The International Commission on the Measurement of Economic Performance and Social Progress[17] concluded in its report with reference to the suitability of GDP in measuring wellbeing and sustainable development that 'since the time of the Brundtland Commission sustainable development has become a very comprehensive concept covering all dimensions of the future and current economy, as well as social and environmental wellbeing'[18]. One of the problems analysed by the Commission was whether sustainability can be long-lasting. The report distinguishes between an assessment of *current wellbeing* and an assessment of *sustainability*, and whether this can last over time. GDP is a measure of market production but it cannot be a measure of sustainable development, and it does not allow for an assessment of future changes in the level of wellbeing.

Distinguishing the aspect of sustainable development in economic theory makes sense, since for a long time economics was preoccupied with the role of fundamental growth factors – capital, labour and technical progress. Ecological (environmental) factors, such as environmental pollution, climate change, natural resources and their depletion, and limits of environmental resistance influenced the processes of production and consumption alongside progress in social and economic development, increasing income disparities, overpopulation in areas of poverty, and aging of affluent societies.

Both neoclassical and Keynesian economics are considered insufficient when it comes to solving environmental problems and barriers to economic growth related to them. These barriers result from the fact that the environment is a public good (The Tragedy of the Commons), and from the specific nature of the market in general. The most important market problems regarding environmental pollution are externalities. An externality is a consequence of activity undertaken by a private individual or a business experienced by unrelated individuals or businesses that are not compensated by a relevant payment. It can be said that environmental pollution and other social phenomena, creating externalities (negative and positive), is a sign of market failure, and they can be solved through the use of tools of institutional economics. Economics related to environmental issues and natural resources, as proposed by T. Żylicz, a supporter of the category of sustainable

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17 The Commission was established by the President of the French Republic in 2008, in response to increasing doubts about the adequacy of current measures of economic performance, in particular those based on GDP.

18 J.E. Stiglitz, A. Sen, J.P. Fitoussi, *Błąd pomiaru. Dlaczego PKB nie wystarcza*, Warszawa 2013, p. 115.

development[19], emerged from the neoclassical paradigm. Environmental economics must not withdraw from the neoclassical paradigm based on the model of perfect competition and the *homo oeconomicus* model. This has been indicated by S. Czaja and B. Fiedor, who concluded that the model of perfect competition and the *homo oeconomicus* model are methodological fiction, and those who use these terms in the concept of environmental economics have failed to carry out a sound comprehensive analysis of works on neoclassical economics and other trends rejecting the paradigm of the first one[20]. This paradigm has been denied by the creators of both ecological economics and sustainable development economics.

According to ecological economics, 'sustainable development aims to realize adequately high ecological, economic and socio-cultural standards within the limits of the natural capacity of the earth for current and future generations, thus enforcing the principle of intra- and intergenerational justice'[21]. This definition emphasizes an interesting principle and feature of development – justice, and thus goes beyond ecological references to sustainability. The search for appropriate language and conventions describing sustainable development has brought it down to the category of integrated order. 'Order corresponds with human nature and the nature of things; order exists wherever there is measure and balance'[22]. According to T. Borys, sustainable development is characterised by an integrated order as the target system in which social, economic and ecological orders are merged in a consistent way[23].

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19 T. Żylicz, *Ekonomia środowiska i zasobów naturalnych*, Warszawa 2004. Environmental policy – according to T. Żylicz – should provide not only environmental protection, but also sustainable development. Each concept of sustainability consistent with Brundtland's definition requires a priori acceptance of measures of social wellbeing (for the internalization of externalities) and a discount rate decreasing over time. Cf. T. Żylicz, *Polityka ekologiczna a gospodarcza*, in: S. Czaja, A. Graczyk (eds), *Ekonomia i środowisko*, Wrocław 2016, pp. 289–290.

20 S. Czaja, B. Fiedor, *Ekonomia środowiska i ekologiczna jako filary ekonomii zrównoważonego rozwoju*, in: B. Poskrobko (ed.), *Ekonomia zrównoważonego rozwoju*, Białystok 2010, p. 39.

21 H. Rogall, *Bausteine einer zukunftsfähigen Umwelt und Wirtschaftspolitik*, Berlin 2000, p. 100.

22 W. Eucken, *Podstawy polityki gospodarczej*, Poznań 2005, p. 412.

23 T. Borys, *Personifikacja organizacji jako nowa forma wyrażania istoty nowego paradygmatu rozwoju*, in: S. Czaja, A. Graczyk (eds), op. cit., p. 87, ibidem.

Engineering and chemical sciences vs triple bottom line

The complexity and ambiguity of the concept of sustainable development caused confusion in its public perception. In the 1990s John Elkington, one of the first researchers dealing with sustainable development, coined the phrase 'triple bottom line' to promote sustainable development, particularly among business organisations, by a clear and understandable description of its major goals. According to Elkington, the three most important areas of human life worldwide are: environmental, social, and economic. To maintain a balance between these areas people cannot develop or optimize only one or two, because it will compromise the remaining aspects. The balance, which is delicate and easily upset, is possible to sustain only when a given process or human activity takes into account all three areas without unduly diminishing one of them. It is therefore necessary to consider possible synergies, antagonisms, interferences, areas of common values and contradicting values in order to reach sustainable development in a given area[24]. Such development cannot be achieved without interdisciplinary knowledge, including engineering and chemistry.

Disciplines dealing with the problems of sustainable development are called green sciences[25]. Green technology, green engineering and green chemistry are concepts used for solutions in the field of engineering, chemistry and technology, which are designed to not only obtain a final product with specific characteristics desired by the market, but also focus on the processes used, and aim to reduce emissions of pollutants and toxic substances, waste, and energy consumption, and increase safety for people and the environment, as well as make production more efficient. How do these concepts fit into the framework of the triple bottom line proposed by Eklington? Seemingly, green technology focuses only on environmental aspects (to reduce pollution, toxic substances, waste), which disrupts the balance in other areas: social and economic. It should be noted, however, that components of green technology, such as reduced consumption of natural resources or increased efficiency and productivity have a significant impact on economic

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24 C. Jimenez-Gonzales, D.J.C. Constable, *Green Chemistry and Engineering. A practical Design Approach*, New Jersey 2011, pp. 6–15; J. Elkington, *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*, Gabriola Island, New Brunswick, Canada 1998, p. 416.

25 The concept of the green economy emerged from the idea of sustainable development. Cf. e.g.: B. Ryszawska, *Zielona gospodarka – teoretyczne podstawy koncepcji i pomiar jej wdrażania w Unii Europejskiej*, Wrocław 2013. The green economy is characterized by low emissions, resource efficiency, social integration, and is supported by knowledge from many disciplines of science, but in a particular economics, engineering and chemistry.

activity. On the other hand, the desire to reduce the use of toxic substances and emissions also fosters better safety of workers employed in production, and is important for the comfort of people living near manufacturing plants – and thus the social aspects are included[26].

The role of science, especially engineering, in the development of solutions to ensure the sustainable development of civilization was emphasized in *Agenda 21*, a product of the Earth Summit in Rio de Janeiro. Chemistry, as one of exact sciences, has an important role in eliminating the adverse effects of improper human intervention in the natural environment. Chemists have responded to the challenges of the sustainable development paradigm by formulating the concept of green chemistry and the implementation of its principles in manufacturing processes, laboratory practice and research. The term 'green chemistry' was first used by PT Anastas in 1991 in connection with work being done by the United States Environmental Protection Agency[27]. Green chemistry is focused on the designing, developing and implementing of products and chemical processes that minimize or eliminate the use and generation of substances hazardous to human health and the natural environment. The initiators of green chemistry have emphasized that chemists designing and implementing chemical processes must follow the Hippocratic principle: *primum non nocere* (from Latin: first, do no harm), with reference to human beings, but also to the natural environment[28].

Anastas and Warner developed the twelve principles of green chemistry, which are a kind of guideline for chemists on how to design safe chemical processes in order to provide society with products to meet their needs. These principles emphasize, among other things, the need to reduce the use of raw materials, energy, hazard, risk, waste and costs of production. A great role is attributed to the principles of the atom economy and use of renewable feedstocks[29].

The principle of the atom economy aims at the elimination or at least reduction of unwanted by-products of reaction, usually harmful to the environment. The atom economy is achieved by the maximized incorporation of the atoms of the reactants into the final desired product. The 'percent atom economy' can be calculated for a chemical reaction, and if the reaction gives

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26 C. Jimenez-Gonzales, D.J.C. Constable, op. cit., pp. 6–15.

27 B. Burczyk, *Zielona chemia. Zarys*, Wrocław 2014, pp. 22–23; P.T. Anastas, M.M. Kirchhoff, *Origins, current status, and future challenges of green chemistry*, "Accounts of Chemical Research" 2002 No. 35, pp. 686–694.

28 P.T. Anastas, *Meeting the challenges to sustainability through green chemistry*, "Green Chemistry" 2003 No. 5, pp. 29–34; B. Burczyk, *Zielona chemia. Zarys*, Wrocław 2014, pp. 24–25.

29 P.T. Anastas, J.C. Warner, *Green Chemistry: Theory and Practice*, Oxford, New York 1998, pp. 30–32.

100% yield, then the incorporation of reagents has been maximized and the process fully complies with the said principle[30].

Over the last 25 years many processes that meet the principles of green chemistry have been developed and implemented. They incorporate, for example, new catalysts, significantly improving the efficiency of processes (for example, increasing the atom economy), renewable raw materials instead of fossil fuels, solvent-free technologies or water-based solvents instead of organic ones, or new energy sources (e.g. light, microwaves). In addition, new terminological concepts have emerged, such as 'sustainable chemistry' or 'green sustainable chemistry', which are more focused on economic or social aspects in an attempt to match the green chemistry processes with the concept of the triple bottom line. The major problem regarding descriptions of sustainable chemical process is the lack of relevant quantification measures[31], just like in general sustainable development.

Energy revolution – an example of the necessary integration of economic, engineering, chemical and other sciences

The vision of the future which we want to ensure through sustainable development in social, economic and environmental aspects should be consistent across the world and sectors. Analyses of megatrends point to the fact that the choice of the further way of development should focus in particular on energy and its sources, since it determines economic and consumer activity, as well as any kind of life form and sustenance of civilization on the Earth. These problems are addressed by Marcin Popkiewicz – a graduate of the Faculty of Physics, University of Warsaw, scientist, manager, translator, writer, and the author of two interesting books highly regarded by scientists, business people and journalists[32]. In his books Popkiewicz gives a diagnosis of the global energy situation and threats to humankind, and indicates possible ways out. His works outline a holistic vision of the social, economic and environmental future, in line with the approach characteristic for sustainable development. Popkiewicz presents vast historic data, analyses trends and facts, and predicts the consequences of activities, especially those which easily fit the paradigm of large-scale low-emission energetics, such as investments in nuclear power.

30 B. Burczyk, op. cit., pp. 25–26.

31 Ibidem, pp. 38–39.

32 M. Popkiewicz, *Świat na rozdrożu*, Katowice 2015; idem, *Rewolucja energetyczna? Ale po co?* Katowice 2016.

He concludes that Poland, like the rest of the world, is on a crossroads and must choose the path of further development in order to survive[33]. The lack of access to energy causes economic crises and increases economic inequalities. The disturbing uncertainty about the future supply of crude oil and other resources (electricity, heat, clean water, food), and the rapid increase in the amount of pollutants released into the environment and extinction of species puts the world's future in doubt. The current trends in energy production and consumption are very unsustainable. The world should aim at ensuring energy supply and fast transition towards low-carbon, effective and environmentally-friendly systems for its production and use, consistent with the principles of the green economy. The problem is, however, the way to achieve a low-emission economy, the costs related to it, and the responsibility of politicians and pollutants. What we need is knowledge about the current situation and measures necessary to make changes. The economic growth and progress in technology, which has been the priority so far, generate problems and threats, so people have to choose technologies more responsibly and wisely. The curve of CO_2 emissions is getting steeper as a rule, since we live in a world of exponential growth. The higher the rates of growth driven by fossil fuels, the faster we will deplete natural resources. The ecological footprint of humankind is now greater than the biological capacity of the environment, or the ability of the biosphere to satisfy our material needs and receive pollution. The largest excesses are seen in the most developed countries (with the highest HDI). Solutions that used to work well in the past when energy was cheap, resources were large and the environment unpolluted, fail today and even become harmful. There is still a lot of crude oil underground, but its extraction is becoming more difficult and more expensive, and requires more costly investments. Growing energy prices bring recession to the world economy. Polish coal from deep mines is outcompeted by much cheaper coal from opencast mines. The contribution of the coal mining industry to economic growth is negative. Billions spent on subsidies for unprofitable coal mines have already reduced social wellbeing, not to mention external costs, mainly related to health and the environment. Natural gas, since access to shale gas has been successfully achieved, is just a bridging energy source, a fuel for the transition period. Nuclear power was to provide cheap, safe and abundant energy. However, this solution makes sense in stable countries with a high technical culture and social responsibility, not in Poland, and a possible disaster related to the use of nuclear power can be much more catastrophic than the worst failure of a wind farm or biogas plant. As with climate, it has always changed, and nobody in the world has so far denied that climate changes are related to human activity. There is a need to

33 Selected reviews from the book: M. Popkiewicz, *Rewolucja …*, pp. 10–268.

reduce energy consumption, thus reducing the scale of the economy – it does not apply to GDP, but the consumption of resources, which must be within the capabilities of acquiring them from the environment. The question of whether goals aimed at reducing emissions should be replaced with goals aimed at reducing consumption of resources ultimately has to be answered by science.

Conclusions

Actions compliant with the idea of sustainable development can be a remedy for our planet, but must be taken wisely, and be widespread and consistent. The paradigm of sustainable development requires a serious revision of goals, strategies, monitoring of actions, their measurement and exercising responsibility for them. Above all we need courage to end the approach to development as a process focused on economic growth, GDP and financial criteria in which organizational, technological and institutional actions are assessed. Rankings comparing the growth of countries based on economic and financial performance, growth rate, investment, and lists of successful businesses by profit have a negative effect on the idea of sustainable development. Most researchers and authors of publications on sustainable development indiscriminately use this 'fashionable term' and choose research areas matching political initiatives and documents. It would be worth linking the paradigm of sustainable development with the knowledge and basic studies in many fields of science. Taking action for a good future for the society, economy and environment needs the integration of economics, engineering, chemistry and many other disciplines of science. Sustainable development treated as a stand-alone category related to just one discipline of knowledge and science, even if it is called green, will not ensure sustainability for the economy and human beings, who are the subject, creator and beneficiary of any developmental changes.

Authors' contributions to this article:

prof. Józefa Famielec, PhD – 50%
Stanisław Famielec, PhD Eng. – 50%

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