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DETERMINANTS OF RESTRUCTURING PROCESS IN DEEP DECARBONIZATION OF STEEL INDUSTRY IN POLAND

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Reasons and purpose: Decarbonizing economies is the primary goal of EU climate policy. The European Union has committed member states to achieving climate neutrality by 2050. The industry's transformation to "net zero" will require changes in many industries, including the steel industry. Decarbonization is necessary to stop global warming. Its main challenge is investment in new zero-carbon technologies. Approaching the strategic goal of 'zero emissions' of greenhouse gases by the world's economies by 2050 will require restructuring activities of economic processes, which, due to the scope of the subject matter, has been called decarbonization restructuring. The purpose of this paper is to present the determinants of steel industry restructuring in the process of climate transition.
Design/methodology/approach: The article is a conceptual analysis of the determinants of decarbonization of the Polish steel industry.
Findings: Based on decarbonization approaches, key restructuring issues were presented and framed as questions. These questions can be used to further discuss industrial restructuring in the implementation of the Net zero strategy.
Originality/value: Decarbonization is a very current industry issue. In Poland, the main source of electricity is coal (about 70% of energy is generated from the natural raw material). Deep changes are driven by the need to move completely away from steel produced from fossil fuels to sustainable steel (the term sustainable steel refers to steel produced with low-carbon and, in the future, zero-carbon technologies). The policy of moving away from coal will radically change technological processes in many industries. Among the industries included in the decarbonization program is the steel industry (coal is a reducer in the metallurgical process of the blast furnace). Global capital groups in the steel market have already initiated research and testing of new technologies for producing zero-carbon steel.

Keywords: decarbonization, steel industry, restructuring process.

Type of paper: Viewpoint.

1. Introduction

Decarbonizing the economy is a key objective of EU climate policy. Implementing the Paris Agreement of 2015, the European Union committed in December 2019 to achieving climate neutrality by 2050. This means that all economies must radically reduce greenhouse gas emissions according to the "Net Zero" strategy proposed in the European Green Deal. Achieving "net zero" is a challenge for many industries in the European market. The announced policy, which is called "Deep Decarbonization", has left no blank space on the map of transformation of the economies of the member states. Deep decarbonization is be achieved across all energy-intensive industries, as well as transport, energy, agriculture, construction and other carbon footprint industries. All economies that are described as "Green Economy", must be free of greenhouse gas emissions. The changes will be radical and profound, due to the amount of investment and the level of innovation. Carbon-neutral technologies and technologies to capture carbon dioxide from the atmosphere (CCU) have to be developed. In the coming years, CO_2 emission reductions will accelerate strongly. The adopted direction of environmental policy will force radical restructuring changes at many companies in the industrial markets.

Industrial restructuring is not a new concept in the Polish economy. In the 1990s, many sectors of industry that were strategic for the country's economy were undergoing radical restructuring process, which was a necessity to reform the economic system. That restructuring process that was enshrined in the government's recovery programs and was based on internal recovery measures. Restructuring, at that time, had a wide scope because it concerned both the company's assets and their sources of financing (Gajdzik, 2009). The form of restructuring, dating from the 1990s, was mandatory, i.e. imposed on companies by statutory provisions. Recovery programs were instruments for implementing the government's policy in the transformation of the economic system. After the completion of the radical restructuring, the companies embarked on a development restructuring, in which the existing quantitative restrictions (staff reduction, expenditure reduction, outsourcing, asset sale, production volume reduction, withdrawal of uneconomic technology) were replaced by qualitative measures (staff development, production assortment development, process optimization, insourcing, etc.) (Gajdzik, Ocieczek, 2015). That industrial restructuring enabled companies to restore, through fundamental changes, fundamental internal and environmental equilibrium (with political, legal, economic, environmental, technological and social requirements) (Borowiecki, 1997; Bitkowska, 2010).

After three decades since the introduction of the free market economy, due to the very strong interference of regulation, in European climate policy, forcing technological changes that would have progressed much more slowly on their own, interference is probably necessary, companies in many industries will be forced to carry out a renewed remedial restructuring. What will be

the characteristics of decarbonization restructuring of industries? To answer this question, a case study of decarbonization of the steel industry in Poland was used. The conditions were used to formulate rhetorical questions about the extent of deep corporate restructuring in the transformation of Polish steel industry according to the European Climate Policy.

2. Decarbonization of the Polish steel industry in strategic directions

The policies of the European Union indicate the very difficult path of transformation that the Polish and European metallurgy (steel industry) must take. The inevitable need to produce "green" steel means abandoning steel smelting using coke. In Poland, steel is produced using two technologies: blast furnace and converters (abbreviation: BF+BOF) and electric-arc furnaces (abbreviation: EAF). In the country, more than 50% of steel per year is produced in integrated mills, i.e. mills with blast furnaces, and slightly less than 50% in electric steel mills. The steel mills with the largest production potential are owned by global capital groups (the result of the restructuring of the iron and steel industry and the privatization of steel mills in the 1990s and beyond) (Gajdzik, 2009; Gajdzik, Sroka, 2012). The Polish steel industry employs more than 20 thousand people, a significant part of them work in integrated steelworks, i.e. strongly emitting CO_2. The largest employer on the Polish steel market is a metallurgical company established on the basis of the Polish Steelworks (during the restructuring of the iron and steel industry in Poland) and currently owned by foreign capital. In recent years, the Polish steel market has been shaken by two events: 1) the COVID-19 pandemic, which resulted in the disruption of supply chains, 2) the war in Ukraine and the restriction of supplies from that country, as well as the blockade of supplies and trade with Russia. The pandemic period was not as difficult for steel mills as the war in Ukraine. At the end of the pandemic (the third and fourth quarters of 2020), steel production increased, and the pandemic crisis itself, in terms of the volume of steel produced in Poland, was milder than the economic crisis of 2009 (the aftermath of the U.S. real estate and banking crisis in 2008) (Gajdzik, Wolniak, 2021). The outbreak of war in Ukraine and the continuation of hostilities, caused a higher increase in material and energy prices than in the crisis, and as a result, a high increase in the cost of steel production (Podsiadło, 2023). Steel prices were reaching maximum levels and there was still a shortage of products. The market was unable to accept the new prices and the biggest problem was the implementation of long-term contracts, which had to be renegotiated. In conditions unfavorable to the development of the steel market in Poland, steel mills are beginning to decarbonize technological processes.

Steelmaking is expected to produce "green" steel. As of today, there is no universally accepted definition of the term, and it is most often used to describe steel products that are produced in sustainable production (e.g. high recycling rate - use of steel scrap or use of "green"

energy). In recent years, the term "green" steel refers primarily to the use of new steelmaking technologies that reduce the balance of CO_2 per ton of steel (current ratio: 2t CO_2/1t steel) (IEA, 2020). Steel production from iron ore is carried out using coke in a blast furnace. "Green" steel in this case means reducing the carbon footprint by implementing alternative production technologies based on "blue" hydrogen, and ultimately on "green". The reference point for "green" steel is the concept of “Carbon Footprint”. The Product Carbon Footprint (PCF) defines the total greenhouse gas emissions generated by a product, from raw material extraction to the end of product life. It is measured in carbon dioxide equivalents (CO2e). Unfortunately, today there is no market for green steel, which means it has to be created from scratch, especially in coal-based countries, of which Poland is one (Kawecka-Wyrzykowska, 2022). In Poland, coal is a major source of greenhouse gas emissions, largely due to its key role in various areas of economic activity, particularly in the production of electricity and heat. In 2020, installed coal-fired electricity capacity accounted for 66% of all electricity generation capacity (of which hard coal accounted for 48% of capacity and lignite for a further 18%), renewables for 27% of capacity and gas for 6% (IEA, 2022, p. 105). Thus, Poland's electricity comes mainly from coal, although between 2010 and 2020 the share of this fuel declined from 87% to 69% (IEA, 2022, p. 121). The steel industry is one of the most energy-intensive and carbon-intensive industries. The production of one ton of steel produces two tons of CO_2 (World Steel Report, 2022). In Poland, the high carbon intensity of steel mills, is a result of the economy's high dependence on fossil fuels, especially coal. It has a dominant share in the production of electricity and heat, and is the reductant used in blast furnace technology For smelters in Poland, the move away from coal-based blast furnace technology, whose reductant is coal, and replacing it with a new Direct Iron Reduction technology (DRI) (Gajdzik et al., 2023). The phasing out of blast furnace technology will cause the world's steel industry to convert to electric production. Smelting steel in an electric furnace means building at least several such furnaces in Europe. In addition, electric furnace steelmaking technology is based on steel scrap, so the question: Will scrap suppliers be able to provide steel mills with a steady supply of this raw material? Scrap metal is becoming a strategic raw material, and it is doing so on a global scale, as trade in it has become global. The global nature of the raw material has caused scrap prices to soar in recent years. Currently, the price of scrap metal is able to exceed 2 thousand PLN, for comparison, in the 1990s, 100 PLN were paid for a ton of scrap metal. In addition to scrap in recent years, energy prices have risen from 0.3 euro/kWh to 0.6 euro/kWh, variable gas prices as a result of the deliberate actions of Gazprom artificially limiting supply in the Union market (gas quotes for TTF oscillated in the spring of 2021 in the range of $250-300 per thousand cubic meters, at the end of the summer of 2021 they exceeded $600, and in the autumn already $1,000 as well as CO_2 prices (in April 2020 they were at 20 euros per ton, in February 2022 it was almost 100 euros, in September they fall to approx. 65 euros per ton, and the average for 2022 is about 84 euros per ton (Gajdzik et al., 2023).

Decarbonization is a process of moving away from coal, which means that the Polish steel industry will have to consume more electricity, gradually abandoning the use of coal and coke. The production of green steel requires gigantic amounts of electricity, both to melt the raw material in the furnaces and to produce hydrogen. In deep decarbonization, coal cannot be the source of energy because it emits CO_2. Poland need green energy to change the industry but diversification of energy sources in Poland is poor. Poland does not have a nuclear power plant capable of supplying energy-intensive industries. So far, the investments are still at the project stage. Will nuclear power solve the problem of energy supply for energy-intensive industries in Poland?

The target direction of decarbonization of metallurgy is the use of "green" hydrogen in steel manufacturing but to obtain hydrogen (hydrogen as a reducer in steel processes) is needed "green" energy. Experts estimate that the decarbonization of metallurgy could cause an almost double increase in energy demand (Dzienniak, Zagórska, 2021). The rapid increase in energy demand will occur during the first stage of decarbonization of steel production, the transition from blast furnace technology to electric technology. The new DRI-EAF technology needs an energy supply. The development of DRI-EAF technology is a key strategy for the steel industry's participation in a climate-neutral Europe, and this strategy needs renewable energy to achieve the Green Deal goal of "net zero" (Eurofer, 2022).

In addition to investments directly related to the replacement of steelmaking technology, the steelworks will also be involved in the process of capturing carbon dioxide from the atmosphere. Carbon Removal (CDR), Carbon Capture and Storage (CCS) and Carbon Capture and Utilization (CCU) technologies will help industry achieve climate neutrality. Decarbonization also requires improved energy efficiency in this industrial sector. While this is not enough to decarbonize industry, energy efficiency will significantly reduce energy-related emissions (Gajdzik, Sroka, Vveinhardt, 2021).

3. Restructuring in deep industrial decarbonization strategy

Restructuring is a complex, interdisciplinary phenomenon of interest to many researchers. In the Polish literature, restructuring issues are dealt with, among others, by: R. Borowiecki, A. Bitkowska, S. Lachiewicz, A. Nalepka, B. Pełka, C. Suszyński, Z. Sapijaszka, Z. Malara, I. Durlik. In foreign literature we can mention such authors as: E.H. Bowman, H. Singh. Modern restructuring is a part of the Green Growth assumptions, as restructuring reforms leading to development in line with the Green Economy assumptions (macroeconomic perspective). European studies are available on this subject, e.g. Cevik and Jalles (2023) and international (Wiese et al., 2023). In addition, individual sectors of the world's economies adopt detailed rules for sectoral restructuring, e.g. the publication on the restructuring of the energy sector in

Japan (Jonesi, Kimi, 2013), as well as individual regions (Jakobsen et al., 2021), Isaksen et al., 2019). The growing popularity of restructuring process in recent years relates to the development of so-called green technologies and green conomies (Fløysand, Jakobsen, 2017). The word "green" in the last two decades has been a determinant of the development strategies of economies, industries and companies (Grillitsch, Hansen, 2019). In companies, the restructuring process involves a range of activities, from rescue (which is the most common application), to adjustment and development. The restructuring process can be implemented in selected areas of activity (e.g. human resources, the sphere of management and organization, the structure of fixed assets or operating costs), as well as it can cover all areas of the company's activity. It can be of the following nature: ad hoc, or adaptive, related to the preservation of the company's existence; or prospective, or anticipatory, related to the creation of conditions for the long-term development of the company. The main objective of the restructuring process is to obtain a better strategic position of the enterprise in the market and achieve more favorable economic results (Suszynski, 1999). The determinant of restructuring is the business environment, which has recently been very turbulent (Reilly et al., 1993). In the very dynamic environment, restructuring process is constantly the company's response to signals coming from the environment (Gajdzik, 2012). In restructuring process, companies undertake radical measures enabling them to maintain their strategic position on the market while ensuring competitiveness against other market participants (Spiżyk, 2017). If the process is carried out effectively, companies can reverse unfavorable trends and improve their economic situation. Once the restructuring process is completed, the enterprise again has a foundation and opportunities for growth. Restructuring changes can involve a single enterprise, be related to the continued development of business or the failure of previous investments. It can also involve the entire sector or certain segments of it. In the process of decarbonization, there are clear differences between sectors, with some more susceptible than others to the pressures of decarbonization (such sectors include the iron and steel, cement, chemical and petrochemical, pulp and paper, fertilizer, glass, ceramics, oil refineries and non-ferrous metals (mainly aluminum) industries (Opinion of the European Economic and Social Committee, 2022). An analysis of the industry's decarbonization force field can be implemented using these industries as an example. Such analyses will influence their internal restructuring course.

In decarbonizing industries, the scope of restructuring will be broad. According to the scope, micro-, macro- and sectoral restructuring were distinguished. The division was proposed by B. Pełka in the 1990s (Pełka, 1992) in the restructuring process of the Polish economy. Decarbonization at the micro level is implemented at specific power plants, steel mills, mines and other plants (factories) that use coal, either as a source of energy supply or in technological processes. Macro-restructuring is aimed at achieving long-term climate policy goals of zero CO_2 emissions by 2050. The domain of this restructuring will be profound transformations in individual divisions of the national economy, not only in industry, but also in agriculture, transportation, services, such as tourism. Energy transformation is inevitable for climatic,

economic, health, national security reasons, also the rapidly aging current coal-based infrastructure. Sectoral restructuring is positioned between micro- and macro-restructuring. One of the key scopes of sectoral restructuring is the (already happening) decarbonization of the steel industry, decommissioning of mines, ways and sources of energy supply (distributed grids, green energy), and in the future construction of micro nuclear power plants in Poland.

The restructuring process in the decarbonization strategy is strongly linked to technological change. The deep decarbonization of industry is a complete shift away from carbon-emitting technologies to "green" technologies, i.e. low- and zero-emission technologies. Poland is one of the most energy-intensive and high-emission EU Member States (15% of total EU greenhouse gas emissions come from Poland) (Kawecka-Wyrzykowska, 2022). For Polish companies, adaptive or corrective restructuring must be carried out in the process of decarbonization. Failure to carry out structural changes in a timely manner, or to carry them out only piecemeal, will be the main cause of transformational delays in the Polish economy.

The restructuring process at the company level (steel mills, mines, power plants, thermal power plants, cement plants, chemical plants, etc.) must be implemented at all operational levels. C. Suszynski (1999), in a former division, points to financial and ownership restructuring in addition to operational restructuring. Operational restructuring is implemented at the level of production, trade, procurement, distribution. Operational changes are related to the company's processes and resources (people, physical assets, organization). Decarbonization forces changes in manufacturing and/or power technologies in the production process. In broad terms, the restructuring process requires changes in entire supply chains, e.g. coal (mine), energy (thermal power plant), steel mill (steel producers), cars (automotive plants).

During technological restructuring, high-emission technologies will be phased out and new, high-tech, green and energy-efficient technologies will be introduced. Within it, the modernized - radically changed - machine park will be. Technological investments will be accompanied by changes in the production profile (new raw materials, new materials and products). Additive manufacturing already makes it possible to manufacture products with high functional and quality parameters. As decarbonization intensifies, investment in technological innovation will be very high, which may result in financial and ownership restructuring. SMEs will find it more difficult to invest in new technologies than strong capital groups, which is why the SME sector needs government support during the decarbonization period.

Entering companies into deep decarbonization already requires changes in their strategies. Deep decarbonization is geared towards achieving long-term effects and is a complex process involving the transformation of entire economies, with relevant provisions appearing in business strategies. Due to the seriousness of the problem, deep decarbonization must not take place under conditions of uncertainty and pressure of time, but must be a planned action structured and implemented in many areas of business activity of companies and institutions, concentrating the organizational effort on researching new technologies and their commercialization. A technology audit will be a helpful tool for companies on their way to

a net zero strategy (Gajdzik, 2022). However, in order for companies to be able to achieve deep decarbonization at home, they need to be given the opportunity to achieve zero-emission technology. In Europe's climate policy, it is assumed that deep decarbonization will be implemented comprehensively over the next decades. New manufacturing technologies, new energy sources, new energy infrastructure, etc. In companies, decarbonization will be based on the concept of reengineering (Durlik, 1998) , i.e. creating companies from scratch, but this time taking into account new principles of "deep" engineering aimed at rapidly reducing CO_2 emissions.

Technological restructuring should be supported by organizational and personnel changes. Green restructuring needs new competencies of employees and even new professions. Green employment is an opportunity for the development of the human factor (COM2014). The expansion of "green" jobs is considered in relation to the prospects of combining concern for growth, equity and sustainability with proactive urban and regional policies (Stilwell, Primrose, 2010). Green jobs are defined as direct employment created in economic sectors and activities that reduce environmental impacts and ultimately bring them down to levels that are sustainable (Poschen, 2008).

During the transition of the industry to "net zero" in the market, there will be companies that will be successful i.e. their restructuring will be active. The second group will be formed by companies that will block or postpone the implementation of changes. In such companies, restructuring will be passive, especially during the initial period of transition. The third group will be companies that actively participate in the transformation, but do not achieve economic or social efficiency (ambiguous restructuring) (Wawrzyniak, 1999). Deep decarbonization is inductive, that is, it is forced on companies by superior policies, so restructuring is also inductive - the company is forced to change. Autonomy of restructuring is strongly subordinated to inductiveness, which means that restructuring processes must have (and some already have) the support of superior institutions, in the form of funding for research and testing of new technologies, participation in technological projects and work of expert teams according to EU program initiatives (H2020, Eureka, SPIRE and others).

4. Key problems of industrial decarbonization on the example of steel industry in Poland

The steel industry is currently one of the major emitters of CO_2 (7% of global emissions). CO_2 emission indices for Polish steelworks are currently among the lowest in the world, regardless of the geographical location of the plant (REASteel). In the context of the phase-out of coal, steelworks will have to radically change their technological processes in the coming years. The radical changes are due to the need to completely move away from blast furnace

technology (more than 50% of steel in Poland is produced using blast furnace and converter technology, i.e. integrated smelters), towards electric furnace technology. On the European market, projects of key importance for the steel industry are being implemented based on direct reduction using hydrogen.

The main challenges of the energy transition are the very high costs of carrying it out. Businesses may experience a lack of a long-term implementation concept and legal loopholes that make it difficult to implement. Access to external financing for investment is particularly important for economic activity in the process of deep decarbonization, as the necessary adjustments involving investment may be delayed or hindered by limited access to external funds. Such access to finance is affected not only by capital markets or public financial support, but also by other regulatory factors, e. g. job creation for restructured steelworks, mines, power plants, etc. About 10% of people in Poland are employed in sectors that will undergo radical decarbonization changes. Poland is at the forefront of EU countries in this respect, ahead only of Slovakia, Czech Republic, Slovenia and Romania (Spotdata, 2019).

However, the European Commission's experience to date on the course of restructuring processes in Europe shows that practices in this area are reactive rather than anticipatory and proactive; they may take place too late in the decision-making process and do not involve external actors at a stage early enough to enable them to carry out restructuring effectively (KOM, 2012). J.E. Bethel, J. Liebeskind (1993) see the main reason for passivity as the intensification of radical changes in a short period of time, based mainly on assumptions of theory without practical solutions. Changes based on the conflict of interests of the principal and the agent do not bring the expected results. As part of the social dialogue, the Commission wants to hear the views of all stakeholders on good practices for decarbonizing specific industries. The restructuring process must be based on (1) anticipation of decarbonization trends, (2) preparation and management of restructuring processes based on the latest methods and techniques, including simulation and computer models (digital twin), (3) evaluation and reporting; (4) the role of social dialogue and (5) review of the situation and activity of decarbonization efforts.

With regard to the adopted directions of transformation, questions arise concerning the steel industry in Poland (based on: spotdata.pl/blog/2019).

1. Will the capital groups – owners of steel mills in Poland, be investing in new technologies in Polish steel mills?
2. Will steel mills be able, in a carbon-based economy, to realize of decarbonization with the success?
3. Will steel mills receive strong support from governmental institutions during the deep decarbonization?
4. How many workers, so far employed in the largest steelworks in Poland, will lose their jobs?
5. How will the steel market in Poland change?

6. Will decarbonization not cause a sharp increase in the costs of operating on the Polish steel producer market?
7. How will the decarbonization of industry affect the increase in prices of raw materials, energy and final products?
8. What will be the risk of the investment, or are companies able to estimate it, by having access to information on the costs of decarbonizing industry?
9. Does the chosen direction of investment in steelmaking technologies using steel scrap and the switch to steel production based on scrap mean a reduction in the demand for iron ore-based steel?
10. With the increase in demand for steel scrap, will the demand by far exceed the supply, and will the mills be able to ensure the continuity of production?
11. Will the raw materials and energy markets not shake?
12. Will the energy industry be able to supply renewable energy to steelworks?

Production of green steel requires additional energy capacity. In smelters for smelting the raw material in furnaces and (finally) hydrogen production. A further question is therefore justified as to whether excessive political interference in the structure of the energy transition will not make it very costly. The questions formulated may initiate a discussion about the course of deep decarbonization in Poland. How will decarbonization take place in industries and enterprises?

The steel industry is a strategic industry of the Polish economy. Decisions on changes in steelmaking technology in accordance with the guidelines of climate policy must find economic justification. The questions formulated in the publication should be considered in the restructuring of the industry. We should add that moving away from coal and basing the economy on non-carbon sources is not only a high cost, but also an opportunity for Polish companies arising from the need to produce many new products and provide services. The steel sector can produce structures for energy-efficient installations based on new technologies. A significant increase in the role of clean energy sources would also enable employment growth in new areas of production and services related to the operation of new facilities, their programming, monitoring, etc. Renewable sources of energy will not provide all the energy, controllable sources of energy will be needed, and after the elimination of fossil fuels, nuclear energy will appear in Poland for the first time and the nuclear power market will develop.

5. Conclusion

Restructuring, as a process of change and one of the many methods of maintaining the competitiveness of companies in a dynamic environment, is an opportunity for companies to activate corrective, adaptive, or development activities. It is characterized by such features as: the need to adapt the activities of the enterprise (core business) to changing conditions in the environment (especially when the effectiveness and efficiency of the enterprise are at a low level). In decarbonization restructuring, the fundamental changes will be in power supply production technologies, as well as in zero-carbon technologies and CO_2 capture (CCU). The decarbonization of industry will result in permanent changes in the economies of EU countries with a very broad impact on other economies. A peculiar feature of the restructuring changes determining the essence of the decarbonization process is the external driving factor (the European Climate Policy guidelines). Another feature is radical - the state of industries and businesses after a decade (the sub-goal by 2030, referred to as Fit 55) of major restructuring will be significantly different from the state before restructuring. The next decades will intensify the move toward zero greenhouse gas emissions by users. The deep decarbonization enshrined in the net zero strategic goal will be a revolution for many industries - the result of the changes introduced as part of the restructuring process will be the use of entirely new solutions (technologies) that break with the past. The EU's climate neutrality is being implemented comprehensively and multidimensional - restructuring changes will involve all areas of the functioning of economies (restructuring of energy-intensive industries will entail changes in dependent industries and product user markets). Decarbonization of industry is a long-term process - the effects of comprehensive restructuring will be visible over the next three decades. New investments, due to their scope and high level of innovation, are costly - the feature of costliness - restructuring changes are characterized by high costliness and not only in strictly financial terms, but also in social terms (loss of jobs for some employees, the need for retraining, a decline in real wages). The deep decarbonization of the industry leaves no enterprise unchanged, whether directly or indirectly, so its feature is its universality (massiveness) - it will affect virtually every enterprise. Restructuring must be well prepared, and its introduction must be preceded by thorough analysis. Planning - effective introduction of restructuring changes requires careful planning of activities in advance. The above-mentioned characteristics are a conceptual result based on the classification prepared by Innam (2002).

Decarbonization and restructuring will be a symbiosis of remedial changes to the environment, which must be "for us and for future generations" (quoted in the Brundtland Report).

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References

1. Bethel, J.E., Liebeskind, J. (1993). The Effects of Ownership Structure on Corporate Restructuring. *Strategic Management Journal*, *12*, 15-31.
2. Bitkowska, A. (2010). Przesłanki procesów restrukturyzacji współczesnych przedsiębiorstw. In: A. Bitkowska (ed.), *Procesy restrukturyzacji warunkiem poprawy konkurencyjności przedsiębiorstwa*. Warszawa: Difin.
3. Borowiecki, R. (1997). *Restrukturyzacja a konkurencyjność przedsiębiorstw*. Kraków: Akademia Ekonomiczna w Krakowie.
4. Borowiecki, R., Nalepka, A. (2003). *Zarzadzanie restrukturyzacją procesów gospodarczych*. Warszawa: Difin.
5. Bowman, E.H., Singh, H. (1990). *Overview of Corporate Restructuring*. New York: McGraw-Hill, p. 28.
6. Cevik, S., Jalles, J.T. (June 2023). *Restructuring Reforms for Green Growth*. International Monetary Fund WP/23/120 IMF Working Paper European Department.
7. Durlik, I. (1998). *Restrukturyzacja procesów gospodarczych: reenginering — teoria i praktyka*. Warszawa: Placet, p. 45.
8. Dzienniak, S., Zagórska, M. (2021). *Droga energia przyczyna¸ niskiej konkurencyjności polskiej gospodarki na przykładzie przemysłu stalowego [Expensive energy as a cause of low competitiveness of the Polish economy]*. Proceedings of the Conference of the PTE. Katowice: PTE O/Katowice, September 2021.
9. Eurofer (2022). *Low-CO2 Emissions Projects in the EU Steel Industry*. Available online https://www.eurofer.eu/issues/climateand-energy/maps-of-key-low-carbon-steel-projects/, 10.03.2023.

10. European Commission (2021). *Speeding up European climate action towards a green, fair and prosperous future*. EU Climate Action Progress Report 2021. Brussels: European Commission.
11. Fløysand, A., Jakobsen, S.-E. (2017). Industrial renewal: narratives in play in the development of green technologies in the Norwegian salmon farming industry. *The Geographical Journal, 183*(2), 140-151.
12. Gajdzik, B. (2009). *Przedsiębiorstwo hutnicze po restrukturyzacji*. Gliwice: Wydawnictwo Politechniki Śląskiej.
13. Gajdzik, B. (2012). *Restrukturyzacja przedsiębiorstw w warunkach destabilizacji otoczenia na przykładzie branży hutniczej*. Warszawa: Difin.
14. Gajdzik, B. (2022). *Diagnoza kierunków transformacji przemysłu stalowego w Przemyśle 4.0*. Monografia, 945. ISBN 978-83-7880-850-3. Gliwice: Wydawnictwo Politechniki Śląskiej.
15. Gajdzik, B., Ocieczek, W. (2015). Soft restructuring process in metallurgical enterprises in Poland. *Metalurgija, Vol. 54, No. 3*.
16. Gajdzik, B., Sroka, W. (2012). Analytic study of the capital restructuring process in metallurgical companies around the World and in Poland. *Metalurgija, 51* (2), 265-268.
17. Gajdzik, B., Sroka, W., Vveinhardt, J. (2021). Energy Intensity of Steel Manufactured Utilising EAF Technology as a Function of Investments Made: The Case of the Steel Industry in Poland. *Energies, 14*(16), 5152; https://doi.org/10.3390/en14165152.
18. Gajdzik, B., Wolniak, R. (2021). Influence of the COVID-19 crisis on steel production in Poland compared to the financial crisis of 2009 and to boom periods in the market. *Resources, 10*(1), 1-17 (art. no. 4). DOI: 10.3390/resources10010004.
19. Gajdzik, B., Wolniak, R., Grebski, W. (2023). Process of Transformation to Net Zero Steelmaking: Decarbonization Scenarios Based on the Analysis of the Polish Steel Industry. *Energies, 16,* 3384. https://doi.org/10.3390/en16083384.
20. *Green Deal for Europe* (Dec. 2019). Retrieved from: https://ec.europa.eu/commission/presscorner/detail/pl/fs_19_6714.
21. Green Employment Initiative: *Tapping into the job creation potential of the green economy*. Brussels, 2.7.2014. COM(2014) 446 final. Bruksela: EC.
22. Grillitsch, M., Hansen, T. (2019). Green industrial path development in different types of regions. *European Planning Studies, 27*(11), 2163-2183.
23. IEA (2020). *Iron and Steel Technology Roadmap*. Paris: IEA. DOI: 10.1787/ 3dcc2a1b-en.
24. IEA (2022). Poland 2022. *Energy Policy Review*. Paris: IEA.
25. Ingram, M. (2002). *Cele i techniki restrukturyzacji przedsiębiorstw*. Katowice: Akademia Ekonomiczna w Katowicach.
26. Isaksen, A., Jakobsen, S.-E., Njøs, R., Normann, R. (2019). Regional industrial restructuring resulting from individual and system agency. *Innovation: The European Journal of Social Science Research, 32*(1), 48-65.

27. Jakobsen, S.-E., Uyarra E., Njøs, R., Fløysand, A. (July 2022). Policy action for green restructuring in specialized industrial regions. *European Urban and Regional Studies* (Sage Journals), *29*(3), 312-331. https://doi.org/10.1177/09697764211049116.
28. Jest Zielony Ład (…). Web/blog: https://spotdata.pl/blog/2019/12/12/jest-zielony-lad-zaczyna-sie-prawdziwa-rewolucja/.
29. Kawecka-Wyrzykowska, E. (2022). Wyzwania dekarbonizacji polskiej gospodarki: rola węgla. *Społeczeństwo i Polityka, 4*(73). DOI.org/10.34765/sp.0422.a04.
30. Komisja Europejska Bruksela, dnia 17.1.2012 KOM(2012) 7 wersja ostateczna ZIELONA KSIĘGA Restrukturyzacja i przewidywanie zmian: wnioski wynikające z ostatnich doświadczeń {SEK(2012) 59 wersja ostateczna}.
31. Malara, Z. (1998). *Metodyka dokonywania zmian restrukturyzacyjnych w obszarze organizacji i zarządzania przedsiębiorstw*. Wrocław: OWPW.
32. Nalepka, A. (1999). *Restrukturyzacja przedsiębiorstwa. Zarys problematyki*, Warszawa-Kraków: PWN, p. 19.
33. Opinia Europejskiego Komitetu Ekonomiczno-Społecznego (2022). *Rola technologii usuwania dwutlenku węgla w dekarbonizacji europejskiego* (opinia z inicjatywy własnej, 2022/C 486/08).
34. Pełka, B. (1998). *Przemysł polski w perspektywie strategicznej. Polityka przemysłowa, strategia rozwoju i restrukturyzacja*. Warszawa: ORGMASZ, pp. 7-11.
35. Podsiadło, J. (ed.) (2023). *Stan i perspektywy hutnictwa żelaza i stali w Polsce. Nowe wyzwania*. Gliwice: Sieć Badawcza Łukasiewicz.
36. Poschen, P. (2008). *Background Paper-Green Jobs for Asia*. ILO Research Conference: Green Jobs for Asia and the Pacific (21-23 April). Niigata, Japan.
37. Jones, R.S., Myungkyoo Kim (2013). *Restructuring the Electricity Sector and Promoting Green Growth in Japan*. OECD 1069, ISSN: 18151973, https://doi.org/10.1787/18151973.
38. Reilly, A.H., Brett, J.M., Stroh, L.K. (1993). The Impact of Corporate Turbulence on Managers Attitudes. *Strategic Management Journal, 14*, 167-179.
39. Sapijaszka, Z. (1996). *Restrukturyzacja przedsiębiorstwa. Szanse i ograniczenia*. Warszawa: PWN.
40. Singh, H. (1993). Challenges in Researching Corporate Restructuring. *Journal of Management Studies, t. 30,* 147-172.
41. Spiżyk, J. (2017). *Restrukturyzacja naprawcza w małej firmie — specyfika, ograniczenia, metody*. Rozprawa doktorska (Doctoral dissertation). Łódź: Uniwersytet Łódzki. Retrived from: https://dspace.uni.lodz.pl/xmlui/bitstream/handle/11089/23879/Rozprawa%20doktorska.pdf?sequence=1&isAllowed=n.
42. Stilwell, F., Primrose, D. (2010). Economic Stimulus and Restructuring: Infrastructure, Green Jobs and Spatial Impacts. *Urban Policy and Research, 28, 1,* https://doi.org/10.1080/08111141003610046.
43. Suszyński, C. (1999). *Restrukturyzacja przedsiębiorstw*. Warszawa: PWE, p. 22.

44. Wawrzyniak, B. (1999). *Odnawianie przedsiębiorstwa. Na spotkanie XXI wieku*. Warszawa: Poltext, pp. 103-104.
45. Wiese, R., Jalles, J., de Haan, J. (2023). *Structural Reforms and Income Distribution: New Evidence for OECD Countries*. REM Working Paper No. 0256-2022. Lisbon: Research in Economic and Mathematics, University of Lisbon.
46. World Steel Association. *Steel Sustainability Report 2022*. Available online: https://worldsteel.org/media-centre/press-releases/2022/sustainability-indicators-2022/, 10.03.2023.
47. *Zrównoważona produkcja stali*. Available online: https://www.raexsteel.com/pl-pl/sustainable-steel, 15.08.2023.