Tadeusz PINDÓR

NON-RENEWABLE NATURAL RESOURCES AS THE KEY FACTOR IN CIVILIZATIONAL DEVELOPMENT

Tadeusz **Pindór**, PhD – *AGH University of Science and Technology*

Correspondence address:
Faculty of Management
Gramatyka Street 10, Krakow 30-067, Poland
e-mail: tpindor@zarz.agh.edu.pl

ABSTRACT: The paper provides an overview based on results of qualitative research into transformations of the structure of the global economy. The main purpose of the paper is to show the importance of non-renewable natural resources as the key factor, beside entrepreneurship and innovativeness, of civilizational development. The paper characterises raw materials and consumables acquired from environmental resources, i.e. nanomaterials as well as critical elements and raw materials as the basis for the new technologies and new products. It also defines the concept of reindustrialization in conditions of creating and implementing the principles of permanent and sustainable development. In particular, it indicates and analyses the factors that enable transition to a low-emission economy, and in the future to a circular economy. The paper characterises contemporary changes in the economic map of the world by identifying new growth and competitiveness poles. Against this background, the civilizational challenges facing the Polish economy have been presented.

KEY WORDS: non-renewable natural resources, civilizational development, sustainable development, reindustrialization

No. 4(67) 2018 • pages: 200-211 JEL: O300, O310

Introduction

Natural resources are considered to be among the basic factors of production, beside labour and capital.

Among the many classifications of natural resources, one of crucial importance, from the environmental and economic points of view, is the division into renewable and non-renewable resources.

Non-renewable resources make up part of the natural resources whose formation process has been completed and the quantity of which can be found on the Earth is physically finite. Systematic use of them leads to their depletion. Once consumed, they do not regenerate in a time encompassed by human experience.

Non-renewable resources include, above all, the resources of metal ore deposits and native metals, and also the resources of primary energy carriers, i.e. coal and lignite, natural gas, crude oil and fissile materials. They can be divided into two groups, i.e. recyclable and non-recyclable (Mikoś, 2008; Pindór, 2017b).

This paper focuses on an analysis of the economic utilisation of the resources of precious and semi-precious metal ores, iron ores as well as other resources considered in modern times to be critical elements along with raw materials, and also on such resources that are used to obtain materials of nanometric dimensions, i.e. at the level of single atoms and molecules. These materials underlie the formation and development of nanotechnology, a new field of knowledge and technology with a remarkable development dynamic (Jankowska-Kłapkowska, 2001; Nanotechnology, 2017; World, 2017).

The use of nanomaterials and nanotechnologies, critical elements and raw materials, as well as disruptive technologies for the purpose of commencing exploitation of shale gas resources has been recognised as a process of the modern reindustrialisation of the economy in the most highly developed countries of the world (Pindór, 2017a).

The author of this paper has defined reindustrialisation as a process of innovative development and structural changes in the economy which, taking into account the criteria of balanced and sustainable development, enables the achievement of such major objectives as:

- an increase in the share of industry in creating GDP,
- an increase in the export of industrial products, including technologies,
- a lasting increase in employment (Pindór, 2016).

This process denotes the trend of development of the global economy respecting the criteria of the protection of resources, functions and components of the environment and leading to a low-emission economy, and further on to a circular economy.

The significance of non-renewable natural resources for civilisational development

Metals and their alloys

A particularly prominent share of the materials sourced by man from natural resources comprises metals and metal alloys.

The earliest discovered metal was copper. The recognition and first use took place ca. 7000 BC in Egypt. The physical and chemical properties of copper enabled the commencement of the manufacture of some objects of crucial importance to man, such as tools, weapons, vessels and ornaments, and also for minting coins.

Beside copper, gold is one of the metals earliest recognised by man. For thousands of years, gold has been a symbol of purity, excellence, indestructibility and prestige. It is the rarest element on the planet, which additionally emphasises the uniqueness of this metal. The global centre of exploration and exploitation of gold was, as in the case of copper, Egypt. So far, over 100 ancient gold mines have been identified within the borders of this country (Wielka, 2008).

The discovery of tin and the creation of copper and tin alloys, i.e. bronze, and then the discovery of zinc and the creation of copper and zinc alloys, i.e. brass, greatly expanded the range of applications of these materials by man.

The Bronze Age saw the development of mining and processing of ores, metal smelting as well as moulding and processing objects, which gave rise to an era of specialisation in the manufacturing process (Agricola, 2000; Mikoś, 2008).

Other inventions from that age, mainly related to communication and transport, were a factor of the development of trade in raw materials and other products over large distances, which, using modern terminology, can be defined as the establishment of the international supply chains of bronze and brass.

The importance of these solutions made metals and their alloys into materials that were initially crucial in satisfying the basic existential needs and later on in prolonging life and improving its quality.

Copper and copper alloys as well as gold, and later on also silver, contributed substantially to the development of the great civilisations of the ancient world, particularly of Egypt and the ancient Near East (Wielka, 2008).

Another important achievement was the smelting of iron. The original sources of this material were probably meteorites, readily available to Man, replaced over time by bog iron ore and limonite mudstones.

The extraction of iron and then the manufacture of steel led to the foundation of the Industrial Age. The volume and dynamics of production and consumption of steel, including stainless steel, in the period 1950-2015 justify the assertion that this period is the second iron and steel age. At the dawn of the 21st century and the new millennium steel remains the main construction material (Industrial, 2017).

In modern times, metals are very deeply processed, which makes it possible to confer a lot of new properties leading to previously undiscovered applications.

The list of the most important products, the manufacture of which is based on the use of metals and their alloys, includes machinery and engineering devices, including heat and power generators, entire manufacturing lines in the process industry, control and measuring apparatus, means of transport, automated devices and robots, along with household appliances.

Metals belong to the basic materials that enable the construction of buildings, bridges, flyovers, power transmission lines, and broadcast equipment and telecommunications transmitters.

Elements and critical raw materials

In 2008, the Committee on Critical Mineral Impacts on the U.S. Economy presented a definition of critical raw materials, which was also adopted by the EU states (Blaschke, Witkowska-Kita, Biel, 2015; Komunikat, 2014; Stefanowicz, 2014). According to this definition, critical raw materials are 'minerals/raw materials that are vulnerable to availability and supply restrictions or disruptions with macroeconomic impact on the nation.' Among other things, this document analyses the notion of criticality based on three groups of criteria:

- the economic consequences of supply restriction,
- the level of vulnerability to supply disruption,
- the environmental risk related to restrictions concerning the availability of raw materials in particular countries due to changes in the legal requirements concerning environmental protection.

Raw materials were divided into three groups with respect to the degree of criticality (Komunikat, 2014; Critical, 2010). The following 14 raw materials were found to be the most critical to the economies of the EU states': antimony, beryllium, cobalt, fluorite, gallium, germanium, graphite, indium, magnesium, niobium, rare earth elements, platinum-group metals, tantalum and tungsten.

Presented below are selected devices and materials in which critical elements and raw materials are used in innovative technologies:

- high-temperature superalloys and lightweight alloys for aerospace applications,
- superconductors, fuel cells, batteries and rechargeable batteries,
- mobile phones, computers, monitors, liquid crystal displays and monitors,
- semiconductors, lasers, solar batteries,
- medicines, medical chemotherapy devices, microchips, orthopaedic implants,
- optical disks and fibres,
- liquid crystal displays and monitors,
- automobile and chemical catalysts,
- water treatment and desalination plants.

Nanomaterials and nanotechnologies

Nanomaterials include all sorts of materials in which there are regular structures at the molecular level, i.e. not exceeding 100 nanometres (Key, 2015).

Nanotechnologies, i.e. the technologies used to manufacture nanomaterials, enable plastics to be obtained with a composition and properties that could not be obtained using previously-known methods.

Nanomaterials have different physical properties as compared with traditional materials. In 2018, fullerenes, graphene, graphane, germanene, silicene and stanene were classified as anthropogenic, i.e. man-made, nanomaterials (Platforma, 2017).

Fullerenes are molecules composed of an even number of carbon atoms forming an enclosed, hollow solid. The chemical properties of fullerenes are in many respects similar to those of aromatic hydrocarbons. The first fullerene model was proposed as early as 1970 in Japan but it is the period of the late 1980s and early 1990s that marks the discovery of this material in the UK and the USA. Fullerenes have already found many practical applications (Postępy, 2017).

Graphene is a flat structure composed of carbon atoms bonded to form hexagons. This material has a thickness of one atom; therefore, with some simplification, it is referred to as a two-dimensional structure. Back in the 1940s, when a theoretical description of graphene was created, a lot of researchers asserted that a two-dimensional material could not exist in nature. A technological breakthrough was observed in 2004 when two groups of scientists in the UK and the USA obtained, independently of each other, a one-atom material with unique properties, mainly electric and mechanical. In many applications graphene is used as a substitute for silica, especially in high-frequency transistors. Sensors made of graphene enable the detection of single molecules of harmful substances, which provides new opportunities for the application of these devices in monitoring and environmental protection (Nanotechnology, 2017).

It is worth emphasising that the original method of producing high strength metallurgical graphene was developed in Poland, which made it possible to obtain patent protection for this product in the United States and the EU states. Another important event in this segment of nanotechnology was the launching of the production of graphene sheets with dimensions of 50x50 cm by the Warsaw-based Institute of Electronic Materials Technology as well as launching large scale graphene in the market by the Nano Carbon company (Surowce, 2017).

Graphane is an organic chemical compound, a two-dimensional polymer formed as a result of the complete hydrogenation of graphene. As a result of such a transformation, graphene, which is a very good conductor, becomes an insulator. Graphane was discovered in the United States in 2007 (Nowy, 2010).

Germanene is a germanium allotrope, a nanomaterial with a flat structure, similar to that of graphene and silicene. Due to its negligible thickness, germanene, like graphene, is considered as a two-dimensional structure. In 2014, two teams of scientists, one European and the other Chinese, announced, independently of each other, that they had succeeded in obtaining germanene. This material displays new semi-conductive and optical properties; in particular, it is expected that it will be possible to apply it in field-effect transistors and other electronic components (Postępy, 2014-2018).

Silicene is an allotropic variety of silica, a nanomaterial with a flat structure, similar to that of graphene and germanene. Silicene structures were first observed in Japan in 2010. The potential areas of numerous applications of silicene include electronics, particularly state-of-the-art semiconductor fabrication, as well as a lot of industrial production processes (Nanotechnology, 2017).

Stanene is composed of a two-dimensional layer of tin atoms with a thickness of one atom of this element, and is the tin equivalent of graphene. It was fabricated in China in 2016 on a layer of bismuth telluride. A unique quality of this material is that it conducts electric current without generating any heat, i.e. without any losses (China, 2017).

The ‘nano’ dimension, i.e. one millionth of a millimetre enables the multiple reduction of specific material consumption in the production of machinery, equipment and manufacturing installations but of special importance is the use of nanotechnologies in the manufacture of some commonly used products, such as mobile communication devices, computers, sensors, radio and television receivers as well as devices used to control household appliances and vehicles.

Nanomaterials and nanotechnologies enable substantial reductions in production costs and consequently, also in the prices of the corresponding products, which appropriately increases the demand for such products obtained as the result of applying innovative technologies (Brynjolfsson, McAffe, 2015; Christensen, 2014).

Despite the great scale of production, measured in billions of pieces of new products annually, introduction of nanotechnologies does not require any increase in the rate of depleting non-renewable mineral resources and is the main factor of sustainable development (OECD, 2016; Opportunities, 2016; Nowy, 2010-2017; Platforma, 2017; Societal, 2016).

Nanomaterials and nanotechnologies have many applications. The currently most important of these include:

- measuring devices,
- electronic medical and environmental systems,
- telecommunications: radiocommunications, particularly mobile, radiolocation and radio navigation, transmission and television, telecommunications networks, including satellite ones,
- computer engineering,
- automated and robotic devices,
- industrial electronics,
- microwave technology.

Natural resources of the future

Natural resources that may be the basis for obtaining tangible factors of economic development in the future include marine mineral resources and seabed resources of primary energy carriers, mainly crude oil and natural gas.

The problems of the management of marine resources has once again gained importance in connection with the concept of sustainable development. The identified and proven marine resources make a large contribution to the global resources of minerals and primary energy carriers (Pindór, Preisner, 2016).

The analysis concerns in particular the determinants, plans and current experience related to the management of metalliferous seabed resources. As a member of the Interoceanmetal Joint Organization, Poland has at its disposal a plot in the eastern part of the Clarion-Clipperton field, containing considerable resources of manganese nodules on the bed of the Pacific Ocean.

The Clarion-Clipperton (C-C) field is located in an open sea area. The nodules in this area are mainly composed of iron and manganese oxides and hydroxides. Manganese nodules forming mineral deposits in this area contain a lot of metals. Their special feature is the increased concentration of such metals as manganese, nickel, copper, cobalt, molybdenum, zinc and rare earth elements. The nodules are solid shapes with diameters of up to 15 cm. The marine deposits in the C-C area are found at depths of between 3,800-5,200 metres. The estimated prospective resources of polymetallic nodules are approx. 34 bn tonnes, of which manganese resources 7,500 m tonnes, nickel 340 m tonnes, copper 265 m tonnes and cobalt 78 m tonnes.

The proven high concentrations of metals in the nodules mean that these deposits can be classified as rich ores.

The resources of metalliferous nodules allow industrial mining at a maximum permissible level of 4.5 m tonnes of wet nodules annually during the licence period, i.e. 20-25 years (Pindór, Preisner, 2016).

The technology readiness level of the economy

Another essential category in the field of competitiveness of the economy is the technology readiness level, which is a measure of the capability of an economy to absorb breakthrough technologies increasing the productivity of manufacturing factors. The technology readiness level concerns particularly those processes and technology transfer channels that trigger a flow of information promoting innovation or increasing the innovation absorption.

Assessment of the technology readiness level in the particular countries is the subject of research being carried out by the World Economic Forum. This institution publishes the results of analyses of conditions for long-term economic development, conducted by an international team of experts, in an annual report entitled the Global Competitiveness Report (Global, 2017). In the 2017 report it was announced that the leaders of competitiveness in the global scale were Switzerland, Singapore and the United States.

With regard to the ranking of the technology readiness level, the World Economic Forum applies a number of detailed indicators, the most important of which include:

- The accessibility and transfer of technology; within this indicator the assessment concerns above all the availability of the latest technologies; Poland's rank: 68th,
- The national enterprises' capability for absorbing technologies; Poland's rank: 65th,

- The value of direct foreign investments enabling transfer and dissemination of new technologies; Poland's rank: 49th.

According to the overall assessment of technology readiness, Poland ranks 46th in the world (Strategia, 2017).

The low detailed indicators and the low overall score concerning technology readiness as indicated in the Global Competitiveness Report 2016/2017 represent a key civilisational challenge for Poland.

A new field of growth and competitiveness in the global economy

The last two decades of the 20th century and the first few years of the new century have brought about fundamental structural changes to the global economy.

Thanks to the unprecedented concentration of human resources with the highest qualifications as well as material and financial capital on searching opportunities for the application of new solutions from the field of basic research in the economic practice, a large number of technologies were developed for obtaining new materials, and then, consequently, new products as well.

The remarkable dynamics of the new technological advancement on a global scale was accompanied by processes of profound restructuring of the economy of the People's Republic of China representing the active response of people in the PRC to the appeal 'Get rich!' announced by the political and economic leaders in 1978 (China, 2017; Industrial, 2017).

The most important consequence was the formation and then rapid development of the Chinese middle class. As a rule, this sector of society displays a high level of education and also of independence of their own views and decisions, and, above all, a high level of entrepreneurship and innovativeness. The historical changes taking place in the PRC are essentially the result of the transformation of the society's mentality, from disciplined but passive executors of commands into dynamic and creative entrepreneurs.

The way towards the transformation of the PRC into the factory of the world and the world's greatest exporter has been education at the higher level as well as in increase in expenditure on research and development, like the urbanisation processes for the migration of 600m people in 1990-2025 from rural environs to cities and the industrialisation on an unprecedented scale (Industrial, 2017).

Urbanisation and industrialisation made the PRC into the global pole of growth and competitiveness.

Conclusion

1. Innovative technologies essentially boost the demand for allotropes of carbon, silica, germanium and tin, and for critical elements and raw materials.
2. The most important effects of the implementation of breakthrough materials and technologies include:
   - a reduction of the specific consumption of materials, including raw materials, and secondary energy in manufacturing processes,
   - a reduction of the specific costs of production and consequently the prices of products manufactured as a result of the application of innovative technologies,
   - expanding the demand for innovative products,
   - a reduction of the anthropogenic pressure on the environment by reducing the rate of depletion of non-renewable mineral resources and primary energy carriers despite the large scale of production,
   - rapid spreading of technological achievements,
   - widespread access, on a global scale, to such developmental factors as:
     - information,
     - knowledge, including new knowledge and databases,
     - technical capabilities of social communications.
3. Ground-breaking materials and technologies can be classified as key anthropogenic factors of sustainable development both on a global scale and at the level of individual regions of the world and countries.
4. The miniaturisation of devices, the testing and control of instruments, sensors and above all mobile communication devices and household appliances, enable substantial reductions in the amount of gaseous and dust pollutants as well as the volume of waste created in the manufacturing process.
5. Widespread use of highly recyclable materials is the key factor of transformation into low-emission economy, and a circular economy in the future.
6. The utilisation of materials obtained from non-renewable natural resources, thanks to breakthrough technologies, opens a new chapter in the civilisational development.
7. The range and dynamics of the spread of breakthrough products involve a lot of civilisational threats on a scale resulting from the global availability of these goods. Only a few societies have implemented systemic processes of identifying and analysing the new threats and also of forming the ethics and mentality of the current and potential users of innovative

products. These actions, as a rule extremely unpopular, are a prerequisite for mature use of the achievements of inventors and manufacturers.

Acknowledgments

The article has been prepared within the AGH statutory research grant No. 11/11.200.350.

Literature

Agricola J. (2000), *O górnictwie i hutnictwie dwanaście ksiąg*, Jelenia Góra

Blaschke W., Witkowska-Kita B., Biel K. (2015), *Analiza możliwości pozyskiwania krytycznych surowców mineralnych*, „Rocznik Ochrona Środowiska" No. 17(1), p. 792-813

Brynjolfsson E., McAfee, A. (2015), *Wyścig z maszynami. Jak rewolucja cyfrowa napędza innowacje, zwiększa wydajność i w nieodwracalny sposób zmienia rynek pracy*, Warszawa

China Tech Market Outlook for 2017 to 2018. Business Technology Accelerates Digital Transformation in China (2017), Beijing

Christensen C. M. (2014), *Przełomowe innowacje*, Warszawa

Critical Raw Materials for the European Union – Report of the Ad-hoc Working Group on defining Critical Raw Materials (2010), EU Commission – DG Enterprise and Industry

Global Competitiveness Report 2016/2017 (2017), Geneva, World Economic Forum

Industrial Development Report 2016. The Role of Technology and Innovation in Inclusive and Sustainable Industrial Development (2016), Vienna, UNIDO

Jankowska-Kłapkowska A. (2001), *Społeczeństwo informacyjne a nowa gospodarka*, in: R. Pajda (ed.), *Wybrane zagadnienia współczesnej ekonomii*, Kraków, p. 11-18

Key Nanotechnology Indicators (2015), OECD

Komunikat Komisji Europejskiej do Parlamentu Europejskiego, Rady, Europejskiego Komitetu Ekonomiczno-Społecznego i Komitetu Regionów w sprawie przeglądu wykazu surowców krytycznych dla UE i wdrażania inicjatywy na rzecz tych surowców (2014), Bruksela

Mikoś T. (2008), *Górnicze skarby przeszłości. Od kruszcu do wyrobu i zabytkowej kopalni*, Kraków

Nanotechnology Market Reports – Trends, Analysis & Statistics (2017), London

Nowy Przemysł (2010-2017)

OECD (2016), *Opportunities and Risks of Nanotechnologies*

OECD Science, Technology and Innovation Outlook 2016 (2016), Paris, Directorate for Science, Technology and Innovation OECD Publishing

Pindór T. (2016), *Reindustrializacja Legnicko-Głogowskiego Okręgu Miedziowego*, „Barometr Regionalny: Analizy i Prognozy" No. 14(1), p. 103-109

Pindór T. (2017a), *Innovative methods of natural gas exploitation as a factor of sustainable development of world economy,* „Ekonomia i Środowisko" No. 4, p. 205-217

Pindór T. (2017b), *Technologie przełomowe w gospodarowaniu nieodnawialnymi zasobami naturalnymi*, „Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu" No. 491, p. 323-331

Pindór T., Preisner L. (2016), *Zagospodarowanie morskich zasobów mineralnych dla trwałości rozwoju,* in: Ekonomia i Środowisko: księga jubileuszowa profesora Bogusława Fiedora, Wrocław

Platforma Przemysłu Przyszłości (2017), „Nowy Przemysł" No. 5, p. 16-22

Postępy Nanotechnologii (2010-2018)

Societal Implications of Nanoscience and Nanotechnologies (2016), UNESCO Report

Stefanowicz J. (2014), *Surowce krytyczne*, Warszawa

Strategia na rzecz Odpowiedzialnego Rozwoju do roku 2020, z perspektywą do 2030 r. (2017), Ministerstwo Rozwoju

Surowce dla przemysłu – plan działań na rzecz zabezpieczenia podaży nieenergetycznych surowców mineralnych (2017), Ministerstwo Rozwoju

Wielka Historia Świata (2008), Oxford Educational, t. 8-12

World Robotics Report 2017 (2017), Frankfurt, International Federation of Robotics Publishing