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Forecast trends in demand for deficit key minerals for the Polish economy

Introduction

The efficient and sustainable functioning of the modern economy of each country depends heavily on the availability of raw materials, including minerals in particular. Ensuring

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their secure supplies is vital for various industries that produce substances and equipment necessary for meeting the living needs of the population (Galos et al. 2021). Energy generation would not be possible without the use of key fossil fuels such as oil, coal and natural gas. The majority of crucial consumer goods and advanced technology products necessary in everyday life would not be produced without, among others, steel, copper, zinc, nickel and many other metals, as well as various industrial minerals. The development of agriculture, as well as of many areas of the chemical industry, would not be possible without the use of key chemical minerals such as: salt, sulfur, phosphate rock, potassium salts and magnesite. The construction industry cannot function without such building materials as mineral aggregates, cement, lime, and many others (Smakowski et al. 2015; Lewicka and Burkowicz 2018; Galos and Szamałek 2011).

Monitoring the changes and trends in demand for minerals is of fundamental importance in the strategic and long-term assessment of prospects for economic development of Poland. In the case of some minerals persistent downward trends in demand have been observed resulting from, among others, technological advancements. For others, in turn, recent years have brought an increase in consumption related to the development of modern industries that are their main users (Lewicka et al. 2021; Galos and Lewicka 2016).

Due to the diversity of the minerals used nowadays, no country is fully self-sufficient. Poland is no exception. The relatively diversified geological structure of the country makes its mineral resource base sufficient (Szuflicki et al. 2021) to ensure the production of about half of over 140 minerals required. However, the importation of over 70 deficit minerals, including these of high economic importance, is also necessary (Smakowski et al. 2015; Lewicka and Burkowicz 2018; Galos and Lewicka 2016).

The aim of this study has been an analysis of the trends of demand for the most important minerals for the Polish economy, recognized as both key and deficit minerals (according to definitions given in the next chapter). The evaluation of the current consumption of these minerals as well as the forecasts for future needs in the perspective of 2050, have been made by the authors as part of a research work carried out in order to prepare a draft of the Mineral Policy of Poland (Ministry of Climate and Environment 2021).

1. Key and deficit minerals for the Polish economy

Various sources of minerals as well as their diversified importance for the economy make it necessary to individually determine the list of minerals according to the priorities of the given country economy. In each case, the determination of such minerals should be the basis of the mineral policy (Nieć et al. 2014; Ministry of Climate and Environment 2021). In Poland an issue of the so-called key, strategic, critical or deficit minerals determination has also become the subject of discussion in the recent decade (Galos and Smakowski 2014; Kulczycka et al. 2016; Radwanek-Bąk 2016; Galos et al. 2021). As a result, definitions and

the scope of the meaning of key, strategic and critical minerals for the Polish economy have been proposed (Radwanek-Bąk et al. 2018). Thus, the key minerals have been defined as these of fundamental importance for the economy that meet the living needs of the society, and their sustainable supply must be ensured. This group encompasses both minerals of a large domestic resource base and high production as well as important deficit minerals (coming exclusively or in part from third countries).

To indicate the key minerals for the Polish economy according to the above mentioned definition, Galos et al. (Galos et al. 2021) have proposed a single criterion, i.e. the average annual value of consumption of a given mineral in Poland in the period 2009–2018 (according to the equation: value of consumption = value of domestic production + value of imports – value of exports). The key minerals have been distinguished from among 148 minerals (or mineral groups) analyzed as those for which this value exceeded PLN 40 million/year. This threshold was set at this level due to the fact that a clear gap appeared between the minerals with the value of domestic consumption above PLN 40 million/year and the remaining minerals analyzed, the consumption value of which did not exceed PLN 30 million/year. Also general tendencies in the consumption of a particular mineral in Poland (declining, stable, variable, increasing, strongly increasing) have been examined. Moreover, according to the calculated average share of imports on demand for the given mineral in the analyzed period, the following groups of minerals have been distinguished: domestic (share of imports <10%), mainly domestic (10–50%) and deficit (>50%).

Taking the criterion of the average annual consumption value into account, 42 key minerals have been indicated (Table 1). These were: 4 fossil fuels, 18 metals (or their groups) and 20 industrial minerals. Regarding the supply source, only 13 minerals have been of domestic origin (the share of imports on demand <10%), 7 minerals – mainly domestic (10–50%), while as many as 22 minerals have been deficit minerals (>50%), characterized by the highest risk of supply disruptions (Galos et al. 2021). The list of these 22 key deficit minerals includes 2 fossil fuels, 13 metallic minerals (or their groups), and 7 industrial minerals (Table 1). These minerals have become the subject of this work.

For each of the 22 key deficit minerals the domestic demand in the years 2009–2018, usually referred to the so-called apparent consumption (domestic production + imports – – exports), has been calculated on the basis of data from Statistics Poland (GUS). Data on real consumption has only been available in the case of fossil fuels. Taking the changes in consumption of a given mineral in 2000–2018, as well as the premises for future development of the industries that are its main users into account, the forecast of its demand by the years 2030, 2040 and 2050 has been made (Galos et al. 2020). In the cases where mineral groups have been analyzed (e.g. bauxite and alumina; manganese ores and concentrates, metal and dioxide), the forecasts have been performed separately for each mineral belonging to the group (Table 2).

Table 1. Key minerals for the Polish economy[1]

Tabela 1. Surowce mineralne kluczowe dla polskiej gospodarki

Mineral (mineral commodity)	Mean value of domestic consumption 2009–2018 (million PLN)	Net import reliance, mean value 2009–2018 (%)	The nature of minerals in context of their sources
Crude oil	44,916.8	97.4	scarce
Hard coal (steam and coking)	23,555.7	15.5	mainly domestic
Natural gas	>13,000.0	85.9	scarce
Copper (refined)	6,326.3	4.3	domestic
Aggregates, crushed	1,838.1	4.3	domestic
Iron ores and concentrates	1,746.6	100.0	scarce
Aggregates, sand and gravel	1,596.8	1.0	domestic
Limestone, industrial	1,382.5	0.3	domestic
Lignite	1,351.4	0.4	domestic
Aluminum, metal (non-alloyed)	955.7	100.0	scarce
Potash salts	938.2	96.0	scarce
Zinc, metal	876.5	<10.0	domestic
Stone, crushed and dimension	572.6	12.4	mainly domestic
Lead, metal	542.1	<10.0	domestic
Phosphate rock	434.4	100.0	scarce
Feldspars and related minerals	383.8	42.7	mainly domestic
Salt (rock salt and salt brine)	295.7	17.6	mainly domestic
Ferroalloys	274.1	100.0	scarce
Sulphur, elemental	222.5	5.3	domestic
Magnesite and magnesia (raw, calcined, dead-burned and fused)	209.1	100.0 (calcined, dead-burned, fused)/4.0 (raw)	scarce/domestic

Mineral (mineral commodity)	Mean value of domestic consumption 2009–2018 (million PLN)	Net import reliance, mean value 2009–2018 (%)	The nature of minerals in context of their sources
Silicon, metal	203.3	100.0	scarce
Bauxite and alumina	175.4	100.0	scarce
Dolomite, industrial (raw)	145.9	5.4	domestic
Kaolinite clays (ball clays, refractory clays)	138.1	70.9	scarce
Phosphorus, elemental	136.1	100.0	scarce
Corundum, synthetic and natural	133.9	98.7	scarce
Platinum group metals	130.9	100.0	scarce
Nickel, metal	100.1	100.0	scarce
Gold, metal	>100.0	lack of data	mainly domestic
Titanium, ores and concentrates	86.6	100.0	scarce
Kaolin	72.3	44.2	mainly domestic
Sand, glass	69.8	0.9	domestic
Sand, foundry	64.6	0.0	domestic
Magnesium, metal	61.6	100.0	scarce
Silver, metal	>60.0	<10.0	domestic
Tin, metal	52.6	83.5	scarce
Gypsum and anhydrite	49.6	1.7	domestic
Manganese minerals	46.7	100.0	scarce
Talc and steatite	42.8	100.0	scarce
Tungsten, metal	41.7	100.0	scarce
Amber	>40.0	>85.0	scarce

[1] The listing of minerals follows the decreasing mean value of their domestic consumption in 2009–2018.

Table 2. Demand for deficit key minerals important for the Polish economy in the years 2009–2018 with forecast[1]

Tabela 2. Zapotrzebowanie na deficytowe surowce mineralne kluczowe dla polskiej gospodarki w latach 2009–2018 wraz z prognozą

Mineral (mineral commodity)	Unit	Demand for mineral in the years 2009–2018: min.–max; average	Development trends of forecasted demand	Demand forecast 2030	Demand forecast 2040	Demand forecast 2050
Fossil fuels						
Crude oil	million Mg	20.6–27.8; 24.5	stable	27–28	27–28	27–28
Natural gas (high methane gas)	billion m^3	12.8–17.2; 14.9	slightly growing	20–20.5	21–22	22–23
Metallic minerals						
Alumina	‘000 Mg	50.7–93.2; 67.8	stable, then decreasing	80–90	75–80	65–70
Aluminum, metal (non-alloyed)	‘000 Mg	87.9–185.4; 133.8	growing	215–225	245–250	270–280
Bauxite	‘000 Mg	35.2–59.3; 47.2	decreasing	40–45	35–40	30–35
Ferroalloys	‘000 Mg	110.6–193.7; 144.9	slightly growing	150–160	180–200	180–200
Iron ores and concentrates	‘000 Mg	3777–7495; 6545	decreasing, then stable	4000	3500–4000	3500–4000
Magnesium, metal	‘000 Mg	3.3–9.1; 6.3	growing	14–15	15–20	25–30
Manganese minerals: Manganese ore and concentrates	‘000 Mg	0.0–137.8; 35.7	decreasing	50	40	30
Manganese, metal	‘000 Mg	0.3–1.9; 1.0	growing	1.5	2.0	2.5
Manganese, dioxide	‘000 Mg	1.4–4.8; 2.6	strongly growing	14–16	16–20	20–25
Nickel, metal	‘000 Mg	0.0–3.6; 2.0	growing	3–4	4–5	5–6
Platinum group metals	Mg	0.0–5.2; 0.8	stable	10	10–13	<10

Mineral (mineral commodity)	Unit	Demand for mineral in the years 2009–2018: min.–max; average	Development trends of forecasted demand	Demand forecast 2030	Demand forecast 2040	Demand forecast 2050
Silicon, metal	‘ 000Mg	10.8–30.7; 20.3	growing	40	50	60
Tin	‘000 Mg	1.8–3.7; 2.6	growing	4.5–5.0	5.0–5.5	5.5–6.0
Titanium, ores and concentrates	‘000 Mg	81.0–105.4; 91.0	stable	80–100	70–110	70–110
Tungsten, metal	Mg	0–243; 90	stable	10–30	10–30	10–30
Industrial minerals						
Corundum, synthetic and natural	‘000 Mg	16.5–48.4; 36.3	stable, then decreasing	40–55	35–45	30–40
Kaolinite clays (ball clays, refractory clays)	‘000 Mg	366.7–693.2; 486.0	slightly growing	680–720	720–760	760–800
Magnesite and magnesia (calcined, dead-burned and fused)	‘000 Mg	81.2–144.1; 113.3	slightly growing, then decreasing	120–140	100–120	80–100
Phosphate rock	‘000 Mg	458.9–1437.4; 1159.4	slightly growing	1140–1170	1200–1250	1200–1250
Phosphorus, elemental	‘000 Mg	7.1–20.4; 15.1	growing	25–30	30–35	35–40
Potash salts	‘000 Mg	191.4–1117.6; 855.4	growing	1050–1100	1200–1250	1350–1400
Talc and steatite	‘000 Mg	17.6–38.6; 30.0	growing	50	65–70	70–75

[1] In alphabetical order.

2. Trends of domestic demand for deficit key fossil fuels

2.1. Natural gas

In the years 2009–2018 the domestic demand for high-methane natural gas grew continuously (Figure 1), from approximately 12.8 billion m^3 to approximately 17.2 billion m^3 (an average of 14.9 billion m^3 per year). The vast majority of high-methane natural gas has been imported to Poland from Russia (on the basis of the so-called Yamal Contract) and – in smaller quantities – from various Central Asian countries. Moreover, increasing amounts of LNG from Qatar, Norway and the US have been delivered to Poland by sea. The structure of natural gas consumption is dominated by industrial production (55%), households for heating and living purposes (23%), electricity and heat generation in central heating plants (8%) and other non-industrial applications (14%). The fertilizers industry remains its main industrial consumer (for the production of ammonia and – to a lesser extent – as a fuel).

Due to the current climate policy it is expected that in the near future natural gas will play an increasingly important role in the national energy mix, especially in the electricity sector. However, its consumption will be influenced by prices fluctuations, as well as other alternative solutions limiting its use in the industry and households. This may lead to a reduction of the use of natural gas after 2025, provided that more efficient energy storage systems from renewable energy sources are implemented. It should also be taken into account that the European Union declares to completely abandon fossil fuels use after 2040. Taking the aforementioned factors into account, it should be considered that in the most likely scenario the consumption of natural gas in Poland will increase to 20 billion m^3 by 2030, after that its growth rate will slow down and in 2040 it will range maximum of 21–22 billion m^3, while in 2050 – 22–23 billion m^3.

2.2. Crude oil

In the period 2009–2018 the demand for crude oil in Poland increased from ca. 20.6 to ca. 28.0 million Mg/year (averaging 24.5 million Mg/year) (Figure 1). In 96–97% this was met by imports, mainly from Russia. The remaining 2–3% constituted small production from two domestic suppliers: PGNiG S.A. (onshore production) and LOTOS Petrobaltic S.A. (offshore production). The demand has been followed by the needs of the whole economy. The domestic supplies are determined by processing capacities of Polish refineries (currently estimated at ca. 27.25 million Mg/year of crude oil) and the rate of these capacities utilization, which was 98.5% in 2018.

As there are no plans for the construction, expansion or even a thorough modernization of the technological lines of crude oil processing in refineries, it should be assumed that the domestic consumption of crude oil has already reached its maximum level, and probably

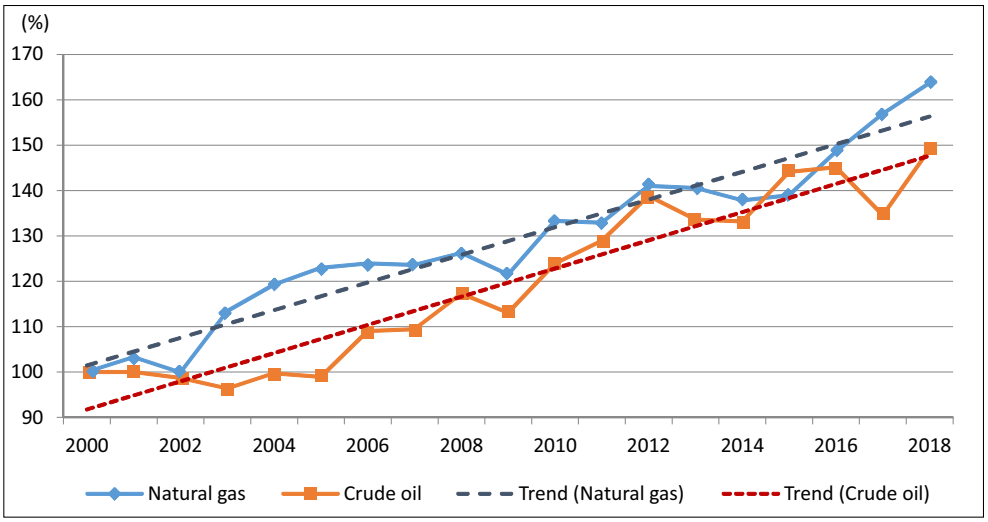

Fig. 1. The consumption of natural gas and crude oil in Poland in the years 2000–2018 with trend lines (2000 = 100)

Rys. 1. Zużycie gazu ziemnego i ropy naftowej w Polsce w latach 2000–2018 wraz z liniami trendu (2000 = 100)

the still growing demand for fuels and petroleum products will have to be covered to an increasing extent by imports. Therefore, the domestic demand for crude oil may only slightly increase to 28 million Mg/year in 2030 and will probably remain at this level in the following years. In the case of implementing other sources of propulsion of transportation means (e.g. electric or hydrogen engines), the importance of traditional hydrocarbon fuels, and thus crude oil, will systematically decrease. However, this is unlikely before 2040.

3. Trends of domestic demand for deficit key metallic minerals

3.1. Iron ores and concentrates

The domestic demand for iron ores and concentrates, utilized only for the production of pig iron, depends mainly on the prosperity of the iron and steel industry in Poland. In the period 2009–2018 their consumption in Poland doubled, increasing from almost 3.8 million Mg/year to ca. 7.5 million Mg/year (6.5 million Mg/year on average). However, over the past 20 years the consumption tended to decline (Figure 2). In the absence of domestic sources, the demand for iron ores and concentrates is met by imports, mainly from Ukraine (about 70%) and Russia (15%).

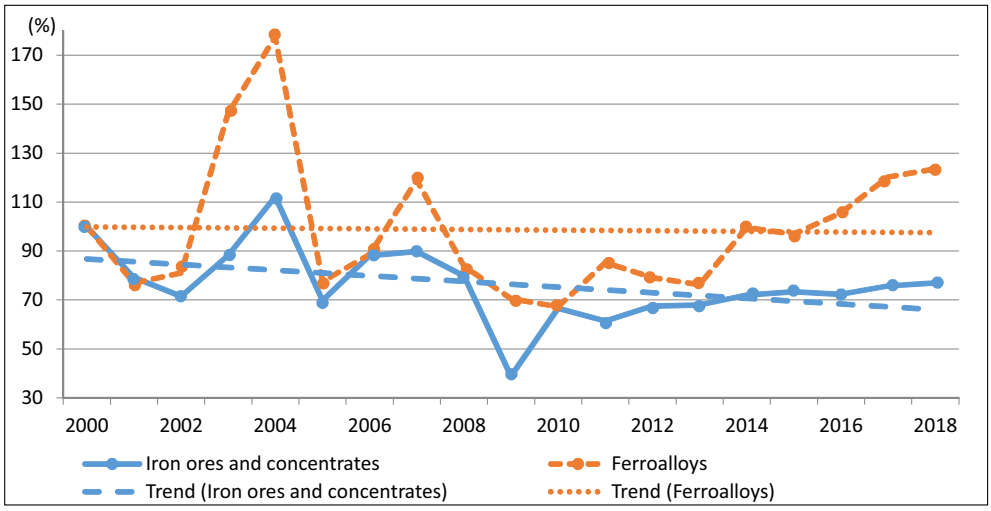

Fig. 2. The consumption of iron ores and concentrates and ferroalloys in Poland in the years 2000–2018 with trend lines (2000 = 100)

Rys. 2. Zużycie rud i koncentratów żelaza oraz żelazostopów w Polsce w latach 2000–2018 wraz z liniami trendu (2000 = 100)

By 2030 the domestic demand for iron ores and concentrates will probably be significantly reduced due to the implementation of the principles of climate neutrality in the EU (increase in prices of EU ETS emission allowances and tightening of industrial emissions standards), as well as a reduced financing of infrastructure projects from the EU funds. Recently, one of the consequences of the EU climate policy was the shutdown of the blast furnace at the ArcellorMittal steelworks in Krakow in 2020, which resulted in a decrease in the production of pig iron, and thus – the demand for iron ores and concentrates. As a result ArcellorMittal steelworks in Dąbrowa Górnicza remained the only producer of pig iron and consumer of iron ores and concentrates in Poland. Therefore, it should be assumed that the future domestic demand for these commodities will be reduced to ca. 4.0 Mg/year in 2030 and 3.5–4.0 million Mg/year by 2040 and 2050.

3.2. Ferroalloys

In the years 2009–2018 the domestic demand for ferroalloys varied in the range of 105,300–193,700 tons per year, averaging around 145,000 tons per year. It showed large fluctuations over the past 20 years (Figure 2) due to changes in steel production in Poland. Ferroalloys are used in 100% in the steelmaking as alloying additives for stainless, acid-resistant and heat-resistant steel as well as deoxidizers and reducers. Domestic production provides approx. 50% of the demand for some ferroalloys, namely ferrosilicon, ferrosili-

comanganese and ferrochromium. The remaining ferroalloys are imported from numerous countries.

In the coming years, due to the expected further decline in the production of pig iron, a reduction in the production of crude steel at the ArcellorMittal plants in Dąbrowa Górnicza and Kraków is also very probable. The problems of the European steel industry exacerbated by the Covid-19 pandemic that have been coupled with the increase in the production costs (including energy costs) and the continuous inflow of imported steel products to the EU market make forecasting the demand for ferroalloys in the steel industry difficult. The implementation of the strategy for the sustainable development of the European Union economy puts a particular emphasis on climate-neutral solutions, which means the need for costly investments in the decarbonization of the steel industry. Nevertheless, in the optimistic scenario it can be assumed that in 2030 the domestic demand for ferroalloys will amount to ca. 160,000 Mg/year, in 2040 it may slightly increase to 180,000–200,000 Mg/year, and in 2050 it will probably remain at a similar level of below 200,000 Mg per year.

3.3. Bauxite

In the period 2009–2018 the consumption of bauxite in Poland fluctuated between 35,200 tons in 2010 and 59,300 tons in 2018 (avg. 47,200 tons per year) (Figure 3). This fol-

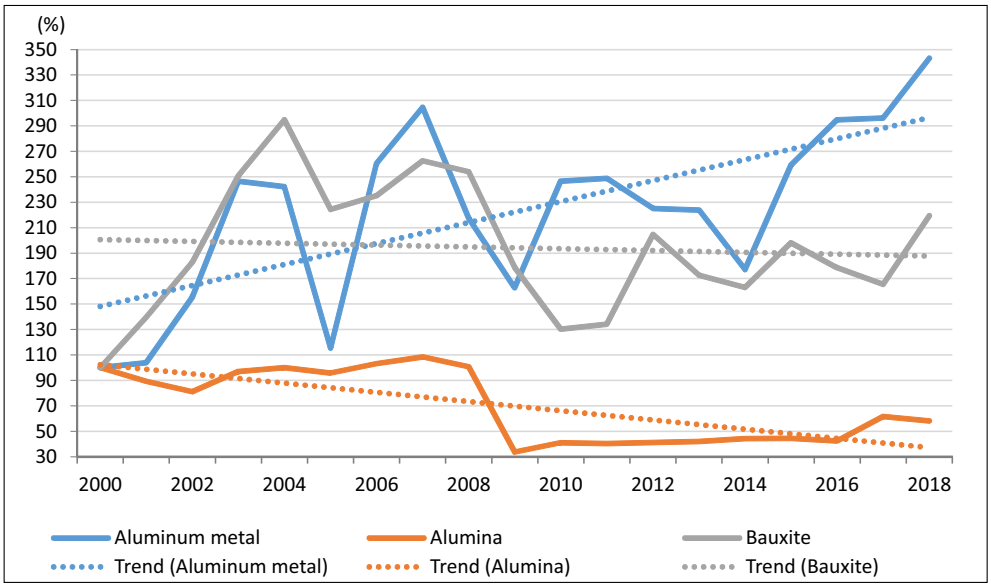

Fig. 3. The consumption of bauxite, alumina and aluminum metal in Poland in the years 2000–2018 with trend lines (2000 = 100)

Rys. 3. Zużycie boksytów, aluminy i aluminium metalicznego w Polsce w latach 2000–2018 wraz z liniami trendu (2000 = 100)

lowed volatile demand in the so-called non-metallurgical applications, i.e. the production of aluminous cement (55–60%), high-alumina refractories (30–35%), and Al chemicals. Raw bauxites are imported mainly from Greece, Montenegro, Turkey and Bosnia and Herzegovina, while calcined bauxites from China and Guyana.

The future domestic demand for bauxite will depend on the needs of the only domestic producer of aluminous cement as well as industries using high-alumina refractory products, such as steelworks, non-ferrous metals smelters, glass and ceramics plants. The above industries, with the exception of iron and steel industry, have fairly good growth prospects and their demand for bauxite-based products is likely to remain steady or even increase. On the other hand, technological changes and reduced production capacities of the iron and steel industry in Europe may, in a short term, result in a decrease of high-alumina refractories consumption. As a consequence, in the coming years there may be a systematic decline in the domestic demand for bauxite, to 40,000–45,000 tons in 2030, 35,000–40,000 tons in 2040 and 30,000–35,000 tons in the perspective of 2050.

3.4. Alumina

In 2009–2018 the consumption of alumina in Poland increased from 50,700 tons to 87,800 tons (avg. 67,800 tons per year). However, in the past 20 years it showed a clear declining tendency. Due to the end of the production of primary aluminum in Konin smelter in 2008 all imported alumina is currently utilized for non-metallurgical purposes, i.e. the production of high-alumina refractories (65–70%), aluminous cement (up to 30%), while minor amounts – for aluminous chemicals, glass and ceramics, or cleaning agents. The domestic demand for calcined and hydrated alumina is covered by their imports: calcined alumina mainly from Germany, Bosnia and Herzegovina, Hungary and France, and hydrated alumina from Germany.

Similarly to bauxite, the future domestic demand for calcined and hydrated alumina will depend on the growth prospects of industries using high-alumina refractories, notably the iron and steel industry. The demand for hydrated alumina will be dictated mainly by producers of aluminous chemicals, glass and cleaning agents. Nevertheless, the gradual decommissioning of the steel industry in Europe and Poland will entail a significant reduction in the consumption of high-alumina refractories, and consequently a decrease in the domestic demand for alumina to 80,000–90,000 tons per year in 2030 that will not be compensated by other industries. In the longer term it is expected that alumina consumption will not exceed 80,000 tons in 2040 and 70,000 tons in 2050.

3.5. Aluminum metal

In 2009–2018 the consumption of metallic aluminum in Poland increased from ca. 87,900 tons to ca. 185,400 tons (avg. around 133,800 tons per year). This was due to growth of

the domestic production of aluminum alloys and products. Over 90% of the total aluminum consumption in Poland is attributable to the non-ferrous metal industry, where aluminum alloys and products from aluminum and its alloys are produced in several large processing plants both from primary (imported) and secondary (domestic waste and scrap) unalloyed aluminum. Demand, covered mostly by supplies from abroad (81–95%, mainly from Russia), has been supplemented by a small-scale recovery from secondary sources (waste, scrap).

Aluminum, mainly as alloys, due to its specific properties (especially lightness) as well as well-developed and profitable recycling may become one of metals of the future. Aluminum-based products are utilized basically in the transportation, packaging and the construction sector. In the automotive industry the expected further increase of aluminum percentage in the unit weight of vehicles, especially electric ones, will result in the growth of its consumption also beyond 2030. The demand for aluminum should also increase in the construction (building facades, windows and doors), as well as in the production of photovoltaic panels and windmills. Hence, it is expected that the consumption of unalloyed aluminum in Poland will reach at least 215,000 tons in 2030, 245,000–250,000 tons in 2040 and minimum 270,000 tons in 2050.

3.6. Magnesium metal

During the decade 2009–2018 the domestic demand for magnesium showed a growing tendency, from 3,300 tons in 2009 to 9,100 tons in 2018 (avg. 6,300 tons per year). It is primarily used in the production of magnesium-based and aluminum-magnesium alloys. These alloys are increasingly utilized in the production of lightweight durable die castings for the automotive industry and other means of transportation. The demand for magnesium is entirely met by imports, mainly from China, Austria, Germany and Hungary.

In the next decades, a further increase in magnesium consumption in Poland is expected, even up to ca. 14,000 Mg in 2030 and 25,000–30,000 Mg in 2050. Especially in the coming years, magnesium consumption will systematically grow at a rate of even 15–20% per year. This will be determined by the still growing demand of the automotive industry for light and durable construction materials such as castings made of Mg and Al-Mg alloys in order to reduce the weight of vehicles. The needs will be still satisfied by imports, though in the longer term is it possible that recycling of Mg and Al-Mg alloys will develop in Poland. Domestic primary magnesium production would be also possible (e.g. on the basis of high purity dolomite), but it is unprofitable due to high energy costs.

3.7. Silicon metal

The demand for metallic silicon (mainly grades with purity below 99.99% Si) in Poland ranged from 10,800 tons in 2009 to 30,700 tons in 2018 (avg. 20,300 tons per year). This has

been met by imports, mainly from Brazil, France, the Netherlands, and Norway. The vast majority of imported metallic silicon is utilized in the manufacturing of alloys (with Al, Cu, and Ni) by the non-ferrous metal industry. Only small amounts (up to 1%) of the purest metallic silicon are used to produce semiconductor silicon.

Future growth of the domestic demand for metallic silicon may be associated with the development of metallurgy (Al, Cu, Ni alloys), as well as of digital and telecommunications technologies. As a result the consumption may reach around 40,000 tons in 2030, 50,000 tons in 2040 and possibly even up to 60,000 tons in the perspective of 2050. However, the entire needs will be still met by foreign deliveries (primary metallic silicon production in the country would be possible on the basis of pure quartz or silica sand, but it is unprofitable due to high energy costs).

3.8. Nickel

The demand for metallic nickel in Poland ranged between 700 and 2,500 Mg/year until 2015, while in the following years it increased markedly to 3,600 Mg/year (averaging ca. 2,000 Mg/year in the analyzed decade). Nickel has been used for stainless and alloy steels (70%) as well as non-ferrous metal alloys (15%) manufacturing as well as for nickel plating (approx. 10%). All domestic demand has been met by imports, mainly from Russia.

Economic fluctuations in the steel industry have caused rapid changes in the demand for nickel. However, nickel-based alloys and stainless steel have played a key role in renewable energy technologies (e.g. photovoltaic, geothermal, hydropower). Nickel consumption has also been increasing in the batteries industry. The fast development of the demand for lithium-ion batteries in the automotive industry and ongoing technological progress in electricity storage systems are key premises for further growth in nickel consumption, even up to 3,000–4,000 Mg/year in 2030, 4,000–5,000 Mg/year in 2040 and 5,000–6,000 Mg/year in 2050.

3.9. Tin

In 2009–2018 the demand for tin in Poland increased from ca. 1,800 Mg/year to 3,500––3,700 Mg/year. Supplies from domestic sources have developed to ca. 70% owing to progress in tin recycling (mainly by the Fenix Metals Co. in Chmielów). Tin has been utilized basically in the production of binders and solders, tinning of steel products/packaging, and manufacturing of tin alloys with copper – brass and bronze. In recent decades other important uses of tin have also been: in a liquid state in the production of float flat glass, and in a form of organic compounds as stabilizing additives for polymers (especially PVC). The domestic demand for tin has been supplemented by decreasing importation from numerous countries.

The development of domestic use of tin has resulted from the increasing use of electronic devices with tin in the form of binders and solders, as well as from the growth in demand for lithium-ion batteries containing tin (1.6–2.0%). However, its future consumption will depend on whether the components with tin are manufactured in Poland or the semi-finished products are imported from outside Europe. In the longer term, the increase of demand for tin may also be associated with solid electrolytes for the next-generation lithium-ion batteries. Taking the above premises into account it is expected that the domestic demand for tin may reach 4,500–5,000 tons in 2030, 5,000–5,500 tons in 2040, and 5,500–6,000 tons by 2050.

3.10. Manganese minerals

In the years 2009–2018 domestic consumption of manganese ores and concentrates fluctuated from almost zero to ca. 140,000 tons (in 2015), averaging 35,700 tons per year. This was associated with a volatile situation in the iron and steel industry, utilizing these minerals mainly in the production of ferro-manganese and ferrosilicomanganese in electric furnaces. Manganese-rich ferroalloys are used in various alloy steels manufacturing. The domestic demand for manganese ores and concentrates is met by imports, currently mainly from South Africa and Gabon.

Due to the difficulties faced by the iron and steel industry in Poland, influenced also by the climate policy of the European Union, an increase in the consumption of manganese

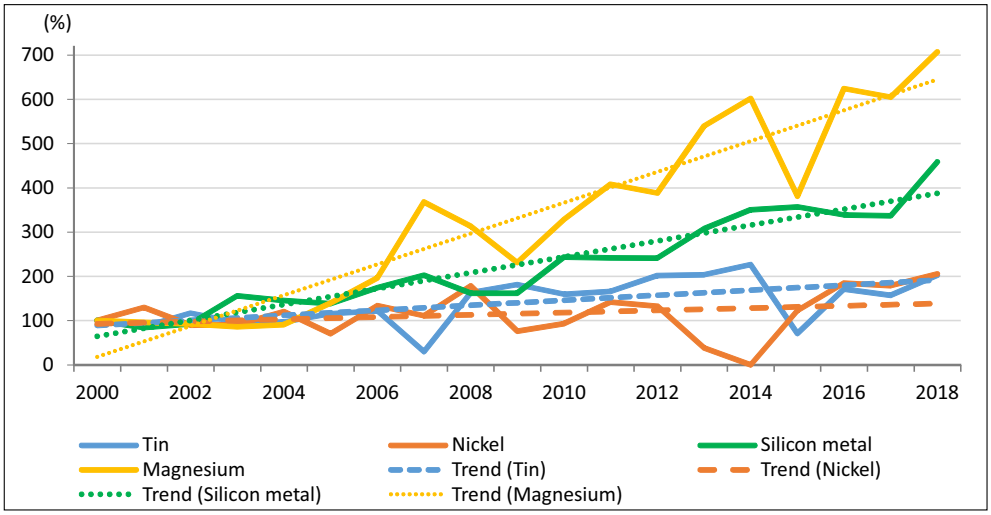

Fig. 4. The consumption of magnesium, nickel, silicon metal and tin in Poland in the years 2000–2018 with trend lines (2000 = 100)

Rys. 4. Zużycie magnezu, niklu, krzemu metalicznego i cyny w Polsce w latach 2000–2018 wraz z liniami trendu (2000 = 100)

ores and concentrates is not expected in the coming decades. At best their consumption may range 30,000–40,000 tons per year.

The domestic demand for metallic manganese changed in a wide range of 400––1,800 Mg/year, showing a clear upward trend (avg. ca. 1,000 Mg/year in the analyzed decade). This metal is mainly used in the metallurgy of iron, steel, cast iron and non-ferrous metals (especially aluminum). The entire domestic demand is covered by imports, mainly from China, the Netherlands, Ukraine, and South Africa.

The future demand for metallic manganese in aluminum alloys, where it improves corrosion resistance and is therefore irreplaceable in the production of beverage cans and other packaging, is particularly promising. Hence, it is assumed that manganese consumption may reach about 1,500 Mg/year in 2030, and 2,500–3,000 Mg/year in the perspective of 2050.

The domestic demand for manganese dioxide that varied between 1,200 and 1,800 Mg/year until 2015, exceeded 4,800 Mg/year in the following years (ca. 2,600 Mg/year on average in the analyzed decade). This was a result of the development of the production of alkaline and non-alkaline dry cell batteries, as well as LiMn and LiNiMn batteries. In addition, manganese dioxide is utilized in the chemical industry (pigments, reagents) and as a feed additive. The supply of this compound in Poland has come from third countries, mainly Spain, Greece, Colombia, and China.

The future demand for manganese dioxide is closely related to the development of electromobility and the market of batteries. It seems certain that its consumption in the horizon of 2050 will be increasing. By 2030, this demand may even triple – to 14,000–16,000 Mg/year, in 2040 it may reach 16,000–20,000 Mg/year, and in 2050 – 20,000–25,000 Mg/year.

3.11. Platinum group metals

Only ca. 20% of the demand for platinum group metals (PGM) in Poland has been covered by domestic production (recycling). The remaining 80% has come from imports, mainly from European countries. The consumption is determined mostly by the demand for platinum and palladium; rhodium is of subordinate importance, while iridium, osmium and ruthenium – of marginal importance. In the years 2009–2018 the consumption of platinum group metals varied widely between around 1 ton per year and a record 5.2 tons in 2018. This was due to the development of the domestic production of platinum- or palladium-based automotive catalysts (BASF plant in Środa Śląska and Umicore in Ruda Śląska), for which 70–80% of the total supplies of platinum metals is currently used.

The production of automotive catalysts will further influence the domestic demand for platinum group metals in the future. At the turn of 2021/2022 another automotive catalysts plant is expected to be launched – the Johnson Matthey Group factory in Gliwice. It is estimated that in 2030 the consumption of platinum group metals may reach 10–13 tons per year. The global development of electromobility, which will probably enter a crucial phase after 2040, may inhibit the growth rate of the production of automotive catalysts for internal

combustion engines; hence a decrease in the consumption of PGM to ca. 10 tons per year after 2040 may be expected.

3.12. Titanium ores and concentrates

The demand for titanium ores and concentrates in Poland depends on the production of titanium white pigment, which is utilized mainly in the manufacturing of paints and varnishes, paper and plastics. The only domestic supplier of titanium white is the Police Chemical Plant. In the period 2009–2018 the domestic consumption of titanium ores and concentrates ranged 81,000–105,400 tons per year (avg. 91,000 tons per year). The demand for these raw materials has been met by imports, mainly from Norway, and to a lesser extent from Canada.

Based on the structure of consumption of titanium ores and concentrates by their main user, i.e. the Police Chemical Plant, it can be assumed that the demand for these minerals will remain at the current level of 80,000–100,000 tons per year in the perspective of 2030 or even 2050.

3.13. Tungsten metal

In the years 2009–2018 the domestic consumption of tungsten metal varied from zero (even with a sale of stocks) to almost 40 tons per year. This was due to the changes in the production of tungsten carbides or their sinters utilized in the production of cutting materials for tools exposed to rapid wear. Other uses of tungsten – for welding electrodes, tungsten wires for the lighting, electronics and electrical industries, etc. are of marginal importance. The demand for metallic tungsten in Poland is met by imports, mainly from European countries.

The future demand for tungsten metal in Poland will follow the production of tungsten carbides and welding electrodes. In the perspective of 2030 and even by 2050 this will probably range between 10 and 30 tons per year.

4. Trends of domestic demand for deficit key industrial minerals

4.1. Phosphorus, elemental

In recent years the demand for elemental phosphorus in Poland has fluctuated in the range of 11,300–20,400 tons per year (avg. 15,100 tons per year). Its volume has been determined by the chemical industry. Supplies of elemental phosphorus have come from third countries, mainly Kazakhstan, and recently also Vietnam. More than 90% of imported phosphorus has been used at the Alventa plant in Alwernia for the manufacturing of high-quality

phosphoric acid, utilized in the production of sodium tripolyphosphate and other phosphates (components of phosphorus fertilizers). Small amounts of phosphorus have been used in the production of red phosphorus and other phosphorus compounds.

The current domestic demand for elemental phosphorus and phosphorus chemical compounds seems stable and there are no reasons for its change. In the future a slight increase in the consumption of high-quality phosphorus fertilizers in horticulture is possible, as well as the implementation of innovative technology for the use of phosphorus compounds in electronics. Therefore it can be expected that the domestic demand for elemental phosphorus may reach 25,000 tons in 2030, 30,000 tons in 2040 and 35,000 tons by 2050.

4.2. Phosphate rock

The domestic consumption of phosphate rock after a sharp reduction to only ca. 460,000 Mg in 2009, ranged 950,000–1,450,000 Mg/year in the following years (avg. 1,160,000 Mg/year), showing a downward trend. The demand for this mineral depends mainly on the needs of domestic agriculture as it is used almost entirely in the production of mineral fertilizers – phosphorus and multi-component fertilizers. Deliveries of phosphate rock to Poland have

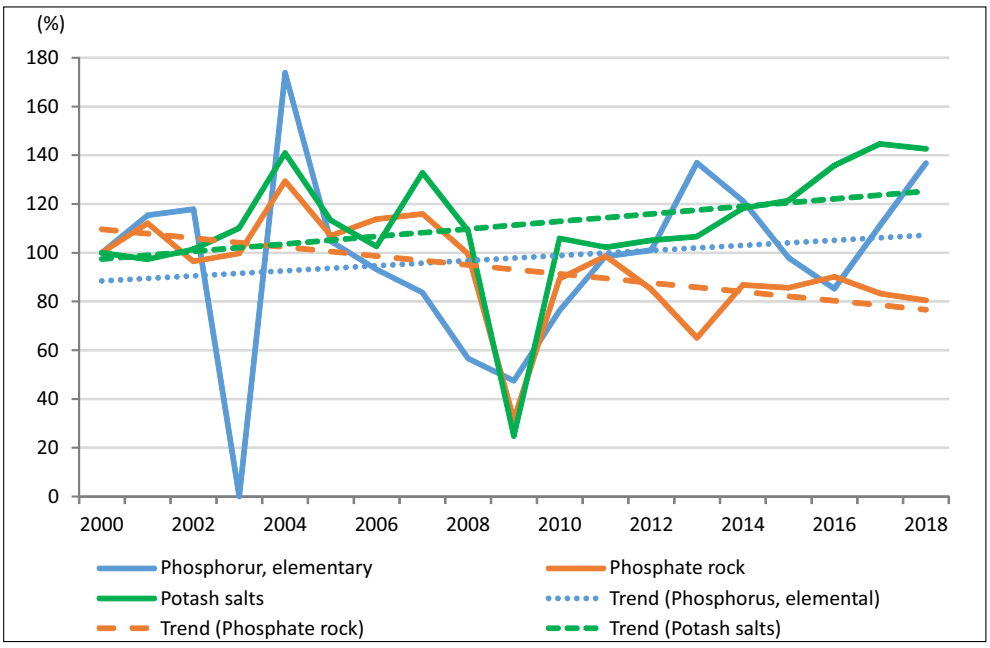

Fig. 5. The consumption of elemental phosphorus, phosphate rock and potash salts in Poland in the years 2000–2018 with trend lines (2000 = 100)

Rys. 5. Zużycie fosforu elementarnego, fosforytów i soli potasowych w Polsce w latach 2000–2018 wraz z liniami trendu (2000 = 100)

come from imports, mainly from Morocco and Algeria, and recently also from Senegal and Egypt.

The future demand for phosphate rock may be influenced by the development of technology for phosphorus recovery from wastewater to be utilized in the production of phosphorus fertilizers. This may result in reduced demand for imported phosphate rock. On the other hand, the development of the production of oilseeds, cereal or vegetables and fruits, which require intensive fertilization, may stimulate the increase in demand for phosphate rock. Taking these factors into account, it is estimated that the demand for phosphate rock may stabilize at the level of 1,200,000–1,250,000 tons per year in the long term, with possible large cyclical fluctuations.

4.3. Potassium salts

Domestic demand for potassium salts, after a reduction to ca. 191,000 tons in 2009, showed a growing tendency in the following years, approaching ca. 1,102,000 tons in 2018 (avg. 855,400 tons per year). The entire supply of potassium salts has been used for the production of mineral fertilizers, mainly multi-component fertilizers. In addition, a dynamic increase in the production of one-component fertilizers containing mainly potassium chloride, less often potassium sulfate, or mixtures of fertilizers with an addition of potassium salts have been recorded. The entire domestic demand for natural potassium salts has been met by imports. Potassium chloride has been imported in 95%, mostly from Russia, Belarus and Germany, while small amounts of potassium sulfate – mainly from Germany.

Future domestic demand for potassium salts will be associated with a further increase in the production of mineral fertilizers. Recently it has showed an upward trend, mainly related to the dynamic growth of supplies of one-component fertilizers consisting mainly of potassium chloride. Depending on the demand from plant producers requiring intensive fertilization, e.g. oilseeds purposed for the manufacturing of ethanol and other biofuels, wheat and corn, or vegetables and fruit, in the longer term the consumption of potassium salts may increase to 1,050,000–1,100,000 tons in 2030, to 1,200,000–1,250,000 tons in 2040 and even up to 1,350,000 tons by 2050. The prices of the offered fertilizers, which follow the prices of potassium salts and energy, will be of great importance.

4.4. Kaolinite clays (ball clays, refractory clays)

The demand for kaolinite clays (ball clays and refractory clays) in Poland in the last 10 years increased from 366,700 tons in 2009 to 693,200 tons in 2018 (ca. 486,000 tons per year on average). This resulted from the development of the ceramic tiles industry consuming more than 60% of kaolinite clays and – to a lesser extent – aluminosilicate refractories industry (ca. 20% of consumption) and ceramic sanitary ware production (ca. 10%). Less

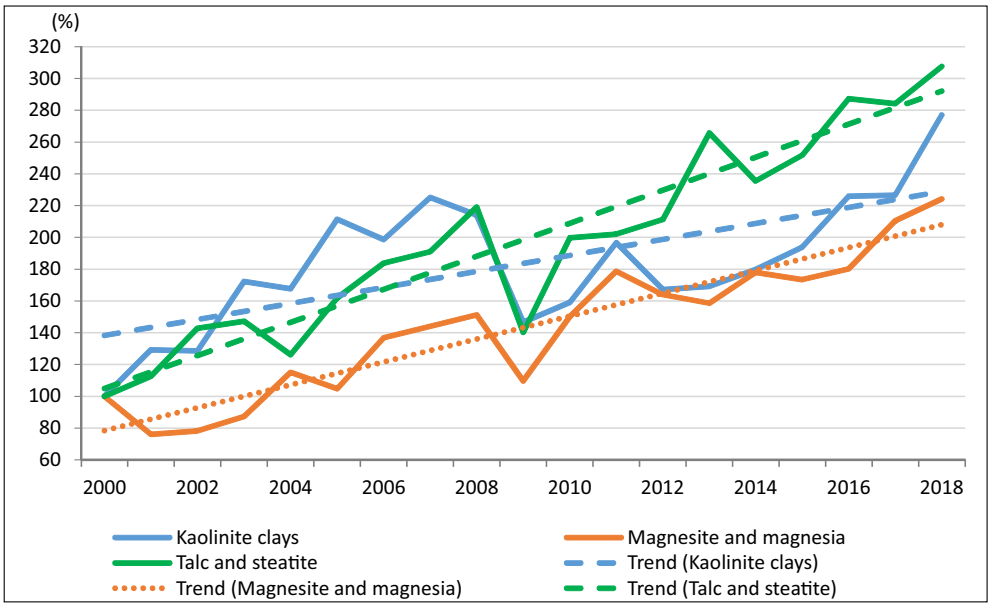

Fig. 6. The consumption of kaolinite clays, magnesite and magnesia (calcined, dead-burned and fused), and talc and steatite in Poland in the years 2000–2018 with trend lines (2000 = 100)

Rys. 6. Zużycie iłów kaolinitowych, magnezytów i magnezji (kalcynowanych, prażonych i topionych) w Polsce w latach 2000–2018 wraz z liniami trendu (2000 = 100)

than 30% of the domestic demand for kaolinite clays has been satisfied from domestic sources, while over 70% has come from third countries, mainly Ukraine, as well as Germany, the United Kingdom and others.

The future domestic demand for kaolinite clays will be associated with further expected growth of their use in the production of ceramic tiles. A slight (up to 10%) increase in the domestic supply of these goods can be expected in the perspective of 2030. After 2030 their production is expected to stabilize due to both the probable weakening of the demand and the limited opportunities for the further increase of their foreign sales. Based on the current trends and the existing premises of the use of kaolinite clays in the ceramic industry, it can be assumed that the demand for these minerals may increase to 680,000–720,000 tons in 2030, 720,000–760,000 tons in 2040 and 760,000–800,000 tons per year by 2050.

4.5. Magnesite and magnesia (calcined, dead-burned and fused)

In the years 2009–2018 the demand for calcined, dead-burned and fused magnesites and magnesia in Poland showed significant fluctuations in the range of 81,200–144,100 tons per year (113,300 tons per year on average). This reflected the state and economic situation of

the domestic iron and steel industry, and – to a lesser extent – the cement industry and other industries using high-temperature processes (non-ferrous metallurgy, glass, ceramics, lime industries, etc.). These industries are the main recipients of magnesia, magnesia-graphite, magnesia-chromite and relative refractories, for the production of which all dead-burned and fused magnesites and magnesia are used (small amounts of calcined magnesites are, in turn, used for the production of magnesium compounds). The demand for all these magnesites and magnesia is met by imports. The main suppliers of dead-burned and fused magnesites and magnesia to Poland have been China, Slovakia, and Brazil, while small amounts of calcined magnesites and magnesia have come from Greece, Germany, and Spain.

The development of the domestic demand for calcined, dead-burned and fused magnesites and magnesia strictly depends on the future consumption of basic refractories (magnesite-graphite, magnesite-chromite, magnesite-spinel, magnesite, etc.) in the iron and steel industry. Other important users of basic refractories have relatively stable prospects for development, hence their demand for these goods and thus – for dead-burned and fused magnesites and magnesia – should remain at the current level or even increase. In the domestic iron and steel industry – on the contrary – a gradual but significant reduction in demand for basic refractories is expected. As a consequence, it is probable that the total demand for magnesite and magnesia will amount to 120,000–140,000 tons per year in 2030, while in the following decades it will be noticeably reduced, to 100,000–120,000 tons per year in 2040 and 80,000–100,000 tons per year by 2050.

4.6. Talc and steatite

The demand for talc and steatite in Poland that varied between 17,600 tons in 2009 and 38,600 tons in 2018 (30,000 tons per year on average) showed a clear upward trend. These minerals have been primarily used in the production of plastics (mainly for the automotive industry), and in much smaller quantities in cosmetics, pharmaceuticals, rubber, paper, ceramics and other industries. The domestic needs for talc and related raw materials, mostly of powdered talc and ground steatite, are met by imports mainly from Finland, Austria, and Italy.

The expected growth of the automotive production (with increasing importance of plastics), as well as probable development of paper and paints and varnishes industries in Poland indicate that in the long term a further increase in the domestic demand for talc and steatite may be forecasted, even up to 50,000 tons per year in 2030, 65,000–70,000 tons per year in 2040, and perhaps 70,000–75,000 tons per year by 2050.

4.7. Corundum (natural and synthetic)

In the years 2009–2018 the demand for natural corundum, corundum-rich emery and synthetic corundum in Poland increased threefold, from ca. 16,500 tons to ca. 48,400 tons.

Natural corundum and emery constituted only about 1% of the corundum raw materials consumed at that time, while synthetic corundum – over 99%. Corundum is utilized mainly in the production of abrasive materials (70–90%), and – to a lesser extent – of corundum refractories (10–20%), although its use in abrasive blasting is also developing. The demand for all these types of corundum has been met by imports. Synthetic corundum is imported mainly from China and from many European countries.

The demand for corundum in the coming years will depend directly on the condition of the abrasive materials industry, as well as abrasive blasting, which will be influenced by the economic situation in the construction industry and the general economic situation. The strong development of housing and infrastructure construction, which has currently been reported, is likely to slow down in the long term and therefore the consumption of corundum will probably decline. It is expected that the domestic demand for corundum may reach even 40,000–55,000 tons by 2030, and after that it will drop to 35,000–45,000 tons in 2040 and to 30,000–40,000 tons per year in 2050.

Conclusions

Ensuring the security of supply of numerous important minerals is vital for the economic growth of the country. Monitoring changes and trends of the demand for minerals is of fundamental importance in the strategic and long-term assessment of the country development prospects. In the last 20 years, in the case of some minerals, persistent downward trends in demand were observed, resulting mostly from technological advancements and to some extent also from climate policy issues. The most striking examples in this regard are: hard coal, iron ores and concentrates, phosphate rock, alumina, and mercury. For others in turn recent years brought an increase in consumption related to the development of modern industries that are their main users. The most important examples in this regard are: natural gas, crude oil, aluminum, lead, silicon metal, magnesium metal, tin, gypsum and anhydrite, glass sand, feldspars and related minerals, kaolinite clays, talc and steatite, corundum, natural graphite, mineral aggregates (Galos et al. 2020).

From among 148 minerals analyzed, 42 minerals has been indicated as key minerals for the Polish economy according to the definition given by Radwanek-Bąk et al. (Radwanek-Bąk et al. 2018) and methodology proposed by Galos et al. (Galos et al. 2021). These are 4 fossil fuels, 18 metallic minerals (or their groups) and 20 industrial minerals. This group includes both minerals for which the national resource base is large and which are extensively utilized in the industry, and 22 important deficit minerals used on a large scale and vital for the country energy security as well as for the industry and agriculture (Galos et al. 2021). These deficit minerals (share of imports on demand >50%) are: 2 fossil fuels, 13 metallic minerals (or their groups) and 7 industrial minerals. They have been the subject of this work.

The forecasts of demand in the horizon 2030, 2040 and 2050 have been made for these deficit key minerals. These forecasts have considered the demand for a given mineral in the

past two decades as well as premises for future development of industries that are its main users. The most promising prospects for growth of domestic demand have been found for manganese dioxide (even a five-fold increase by 2050), magnesium metal (at least three-fold increase), nickel metal, silicon metal, talc and steatite (at least doubling), aluminum metal, tin, manganese metal, elemental phosphorus (by at least 50%). In the case of natural gas and crude oil the growing tendencies have been also predicted, but only by 2030. The most probable decline in domestic demand by 2050 should be assumed for: iron ores and concentrates, bauxite, tungsten metal (up to 40% decrease), magnesite and magnesia (at least 20% decrease), as well as crude oil and natural gas (especially after 2040).

Taking the above into account it seems inevitable that the deficit in foreign trade in minerals will continue to deepen in Poland. Until 2030 this phenomenon will result mainly from the growing imports of crude oil and natural gas, but later on – by 2050 – further deepening of the trade deficit will result from the growth in volume and the value of importation of many metals, in particular aluminum, silicon, nickel, and magnesium, as well as some industrial minerals, e.g. elemental phosphorus, potash salts. This may be mitigated by a possible decrease in the imports of hydrocarbons and iron ores and concentrates, especially after 2040.

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FORECAST TRENDS IN THE DEMAND FOR DEFICIT KEY MINERALS FOR THE POLISH ECONOMY

Keywords

key minerals, deficit minerals, mineral security, consumption trends, demand forecasts

Abstract

The observation of trends in the demand for minerals is of fundamental importance in the long-term assessment of prospects for economic development in Poland.

From among 148 minerals analyzed, 42 minerals are indicated as key minerals for the country's economy, of which 22 were recognized as deficit minerals. These minerals have been the subject of this paper.

For each of these minerals the forecasts of demand by the years 2030, 2040 and 2050 have been made taking the current trends in domestic economy and premises for the development of industries that are main users of these minerals into account. The most promising prospects for growth of domestic demand – with at least a two-fold increase by 2050 – have been determined for manganese dioxide, metallic: magnesium, nickel, silicon, as well as talc and steatite, while an increase by at least 50% have been anticipated for metallic aluminum, tin, metallic manganese, and elemental phosphorus. For natural gas and crude oil growing tendencies have also been predicted, but only by 2030. On the other hand, the most probable decline in domestic demand by 2050 may be foreseen for iron ores and concentrates, bauxite, metallic tungsten, magnesite and magnesia, as well as for crude oil and natural gas, especially after 2040.

It seems inevitable that the deficit in the foreign trade of minerals will continue to deepen in the coming years. By 2030 this will mainly result from the growing importation of crude oil and natural gas, but beyond – by 2050 – further deepening in the trade deficit will be related to the growing importation of many metals as well as of some industrial minerals. After 2040, the negative trade balance can be mitigated by a possible decrease in foreign deliveries of hydrocarbons and iron ores and concentrates.

TRENDY ROZWOJU ZAPOTRZEBOWANIA NA DEFICYTOWE SUROWCE MINERALNE, KLUCZOWE DLA POLSKIEJ GOSPODARKI

Słowa kluczowe

surowce kluczowe, surowce deficytowe, bezpieczeństwo surowcowe,
trendy zużycia, prognozy zapotrzebowania

Streszczenie

Obserwacja trendów zapotrzebowania na surowce mineralne ma fundamentalne znaczenie w długoterminowej ocenie perspektyw rozwoju gospodarczego Polski.

Spośród 148 surowców mineralnych poddanych analizie, 42 zostały wskazane jako kluczowe dla polskiej gospodarki. Spośród nich 22 zostały uznane zarazem za surowce deficytowe. Te ostatnie stały się przedmiotem niniejszej pracy.

Na podstawie dotychczasowych trendów krajowego zapotrzebowania na te surowce oraz przesłanek rozwoju branż będących ich głównymi użytkownikami, wykonano prognozy rozwoju popytu do 2030, 2040 i 2050 r. Najbardziej obiecujące perspektywy – przy min. dwukrotnym wzroście zapotrzebowania do 2050 r. – stwierdzono dla dwutlenku manganu, magnezu metalicznego, niklu, krzemu oraz talku i steatytu, a zwyżkę o co najmniej 50% – także w przypadku aluminium, cyny, manganu oraz fosforu pierwiastkowego. Dla gazu ziemnego i ropy naftowej wzrost jest oczekiwany, ale tylko do 2030 r. Największe prawdopodobieństwo spadku popytu do 2050 r. dotyczy rud i koncentratów żelaza, boksytów, wolframu oraz magnezytów i magnezji, a także gazu ziemnego i ropy naftowej, w szczególności po roku 2040.

W rezultacie, w najbliższych latach deficyt Polski w handlu zagranicznym surowcami mineralnymi będzie się pogłębiał. Do 2030 r. będzie to wynikać głównie z wciąż rosnącego importu ropy naftowej i gazu ziemnego, ale później – do 2050 r. – dalsze pogłębianie się deficytu w obrotach surowcami mineralnymi będzie związane z rosnącym importem wielu surowców metalicznych, w szczególności aluminium, krzemu metalicznego, niklu metalicznego i magnezu metalicznego, a także niektórych surowców niemetalicznych. Po 2040 r. to niekorzystne zjawisko może być złagodzone poprzez możliwy spadek importu węglowodorów oraz rud i koncentratów żelaza.