resources

Article

Safeguarding of Key Minerals Deposits as a Basis of Sustainable Development of Polish Economy

Alicja Kot-Niewiadomska *, Krzysztof Galos and Jarosław Kamyk

Mineral and Energy Economy Research Institute, Polish Academy of Sciences, Division of Mineral Policy, ul. Wybickiego 7A, 31-261 Kraków, Poland; kgalos@min-pan.krakow.pl (K.G.); kamyk@min-pan.krakow.pl (J.K.)
* Correspondence: a.kn@min-pan.krakow.pl

Abstract: Secure and sustainable supply of minerals is important for the stable development of a country's economy, as well as the global economy. Poland's economic performance—as a dynamically developing country—is also largely dependent on the availability of minerals and security of their supplies both from internal sources and form imports. In Poland, 42 key minerals—i.e., those of fundamental importance for the proper functioning of the economy and satisfying the living needs of the society—have been recently indicated. From among them, 19 key minerals have been recognized by authors as having a proven resource base in Poland and—on the other hand—having moderately- or strongly growing domestic consumption trends. An assessment of the mineral resource base for their production, a sufficiency of the resources of developed deposits, as well as possible means of undeveloped deposits safeguarding were analyzed and discussed. It was found that the long-term needs of the Polish industry can be satisfied only for some of them: coking coal, copper, and silver, as well as numerous industrial and construction minerals. Moreover, existence of a sufficient resource base and appropriate means of their safeguarding may potentially have a significant impact on Poland's and Europe's minerals security, in particular regarding several minerals for which Poland is an important supplier to the European market, i.e., coking coal, copper, silver, and elemental sulfur.

Keywords: key minerals; mineral deposits safeguarding; sustainable development; Poland

Citation: Kot-Niewiadomska, A.; Galos, K.; Kamyk, J. Safeguarding of Key Minerals Deposits as a Basis of Sustainable Development of Polish Economy. *Resources* **2021**, *10*, 48. https://doi.org/10.3390/resources10050048

Academic Editor: Xianlai Zeng

Received: 10 April 2021
Accepted: 8 May 2021
Published: 11 May 2021

1. Introduction

The paradigm of continuous economic growth, dominant until recently, is being replaced by a sustainable development policy, and balancing today's needs with the constraints of responsibility for future generations is its basic philosophy [1,2]. At the same time, a secure and sustainable supply of raw materials is important for the stable development of a country's economy and, through increasing interdependence in the global economy, also for the global economy [3]. Raw materials provide the necessary basis for further industrial production and are a prerequisite for growth and employment in industrial, emerging, and developing economies [4–6]. The World Trade Organization (WTO) highlighted this in one of its reports—the World Trade Report [7]. Poland's economic performance—as a dynamically developing country—is also largely dependent on the availability of raw materials. For this reason, securing their supply from imports must be backed by a committed foreign policy, including an economic one, as well as a sustainable policy of obtaining mineral raw materials from domestic sources, both from mineral deposits and secondary and waste sources [8–12].

Securing the access to the mineral deposits in the European Union (EU) is one of the key factors and actions enabling a decrease in the EU's dependency on external supplies. A growing concern about potential limitation of minerals supplies for the EU economy resulted in launching the Raw Materials Initiative (RMI) in 2008 [13] and the strategic implementation plan (SIP) of the European Innovation Partnership (EIP) on raw materials in 2013 [14], to better manage and coordinate responses to mineral raw materials through a three-pillar approach. Availability of minerals is important for the development of innovative and competitive industry of the EU, the integration of sustainable growth and the implementation of numerous objectives of the Europe 2020 strategy [15,16]. Recently, there are new strategies and policies resetting the scenery and raising the importance of minerals at the EU level, such as the European Green Deal [17], Industrial Strategy for Europe [6], EU Regulation on the establishment of a framework to facilitate sustainable investment [18], and the EU Recovery plan for Europe [19]. They are applied to minerals' management being an all-inclusive set of policy initiatives, e.g., addressing energy transition, circular economy, and resource efficiency, to enable climate neutrality by 2050. The European Union aspires to reducing the import dependency of raw materials that are critical for its industries also by, among other goals, improving access to and utilization of their existing primary resources and increasing recycling activities [8,9,20,21]. Simultaneously, a strong focus has been put on the key elements of sustainable development—environmental, economic, and societal ones [3,22].

Following the EC expert working group recommendations [23], RMI recommended the design of individual EU Member States' mineral policy strategies (National Mineral Strategies—NMS), though it was not obligatory. As a result, a dozen or so EU Member States have designed such NMSs to better accommodate the EU mineral policy framework objectives, taking into account their own minerals needs and the specific circumstances of their national economies [21]. However, the only country (so far) with such a complementary NMS in the Central and Eastern Europe is the Czech Republic [24], although work in this area is or was also carried out, inter alia, in Poland, Romania, Hungary, and Estonia [20,25]. There are numerous barriers related to the development and proper implementation of a mineral policy of a given country, related, e.g., to the need to ensure public acceptance of mining operations (Social Licence to Operate—SLO), coherence with other policy areas (e.g., environmental policy), as well as management of sustainable mining production [21,26–28]. There is no doubt that mining can bring important economic growth opportunities to the given country, also at regional and local level, but mining activities can also come at a cost to the environment, including biodiversity and conservation issues, as well as real environmental risks, if resources and operations are not managed properly and sustainably [26,27,29]. Conducting inclusive and continuing dialogue with local communities throughout the mining cycle is a precondition of creation of strong, transparent, trusting, collaborative, and lasting relationships [28]. The fundamental aim must be equitable distribution of the benefits of development and minimization of the negative impact on people and the environment, having essentially as a goal sustainable land use management [30].

The varied availability of mineral raw materials (minerals) from domestic sources, the possibility of obtaining them through imports and the varied importance of individual minerals in meeting the needs of the economy make it advisable to carry out work on the identification of minerals with a leading role in the economy of a given country [31,32]. Depending on the assumptions, criteria, and methodology of their designation adopted by the authors, the lists of such minerals, referred to as, e.g., critical, strategic, key, and pivotal, may differ significantly. Such assessments, especially in the last decade, have been conducted with the focus on various aspects, e.g., with regard to specific minerals or products, technologies, specific needs, and objectives (e.g., for military security and defense, for energy security, for "clean" energy), as well as to countries (especially highly industrialized, commonly dependent on imports of minerals), regions, organizations, and even the whole world [12,33–39]. No standard holistic methodology for selecting critical minerals has been developed so far, although the proposed solutions have many common elements. The most-used proposed methodologies are based on two groups of indicators. The first group is related to the economic importance of the mineral, the second one to the risk of supply chain disruption. The choice of factors results from, among others, different definitions of the "mineral criticality", "mineral importance", as well as different mineral policies in individual countries. Therefore, despite some common methodological premises, the assessments show significant differences in the number and types of components considered, as well as the weights assigned to them and methods of data aggregation [40–42].

In Poland, for several years intensive work related to the methodology of identification of key, strategic, and critical minerals for the Polish economy has been carried out (e.g., [12,43–45]). This is a result of the ongoing work on the development of the national mineral policy [46] as well as intensive work at the EU level to implement the EU mineral policy, including an update of the list of critical minerals for the EU every 3 years [5]. In the latter case, the solutions proposed in Poland draw important inspirations in terms of methodological approach.

However, work aimed at introducing an appropriate system of safeguarding of mineral deposits has been going on for much longer in Poland [47–50]. Various aspects of rational mineral deposit management and mineral resources safeguarding have been discussed in numerous publications [51–64]. An important proposed outcome of this work was a draft proposal of the law on mineral deposits safeguarding presented in 2011 [52], although it has never become the subject of a legislative process at the government level. Further solutions in this regard were proposed in 2015 [65], but they have ultimately not been implemented either.

The subject matter of this paper seeks to bring together issues related to both the country's development policy and its mineral policy. The development policy should be defined as a set of interrelated activities undertaken by the state to ensure a permanent, sustainable development of the country and its socio-economic and territorial cohesion. A properly implemented development policy is based, among other things, on rational management of the resources and means available in a given country [66,67]. These resources cover natural resources, including mineral deposits. These, in turn, should be the subject of a properly implemented mineral policy whose task is to establish an individual list of the most important minerals for the economic security of a given country. It is therefore necessary to properly categorize minerals, considering the current situation on the minerals market and short-term economic forecasts. At the same time, the domestic minerals market is characterized by a number of indicators, among which the following should be mentioned: the size of the resource base possessed and the degree of its utilization in covering the demand of the domestic industry, the size of exports and its share in the national income, the number of jobs generated, the amount or values of the average annual consumption of a given mineral in comparison with other minerals, and also the scale of necessary imports and the related degree of supply risk [68].

The purpose of this article is to indicate the key minerals for the Polish economy and the structure and trends in the use of these minerals, together with an indication of the most important industries for which they provide the basis for development. In this context, an assessment of the mineral resource base for their production and the sufficiency of the resources of developed deposits was carried out. Means of their safeguarding were also discussed. These factors may potentially have a significant impact on Poland's and Europe's mineral raw materials security, in particular regarding several minerals whose production leader in Europe is Poland.

This article is devoted to an important topic in the field of minerals security and sustainable development. This is the first work to focus in detail on all the key minerals identified for the Polish economy based on the latest methodology. Existing studies cover only selected strategic minerals focusing on the methodology of their determination. The added value of this article is a strong connection between resource issues and trends in the consumption of given minerals, along with the identification of the most important industries using these minerals. This is accompanied by the assumption that the role of a given mineral in the national economy is evidenced by its consumption and/or export in its raw form, but it can also be an important intermediate for many industries, for which Poland is one of the European leaders.

2. Materials and Methods

Key minerals for the Polish economy were determined by Galos et al. [12] based on a previously proposed methodology. According to the terminology adopted in this work, key minerals are those of fundamental importance for the proper functioning of the economy and satisfying the living needs of the society, i.e., such minerals whose sustainable supply must be ensured. These are both minerals with a large domestic resource base as well as those partially or fully imported.

Galos et al. [12] considered the average annual value of consumption of a given mineral, which should exceed PLN 40 million/year in an assumed period of at least 10 years (in the analyzed case it refers to the years 2009–2018) to be a decisive parameter when determining that a given mineral is one of key minerals, which allowed separation of 42 such key minerals. The trend in the consumption of each of these minerals in terms of quantity and value was also assessed for the time range thus adopted. The selected 42 key minerals showed a diverse trend of domestic consumption: stable, declining, increasing, strongly increasing, or fluctuating. Additionally, for minerals analyzed the share of imports in covering the demand for a mineral was determined (*Net Imports Reliance—NIR*), which allowed to indicate key minerals of domestic, mainly domestic or deficit nature (Tables 1 and 2).

Table 1. The main parameters characterizing key minerals for the Polish economy.

Threshold of the Average Annual Value of Mineral Consumption	General Tendency of Mineral Consumption	Nature of Mineral Expressed As Its Net Imports Reliance (NIR) *	Tendency of Mineral Primary Production (Mining Output)	Sufficiency of Mineral Reserves
Over 40 million PLN/y	Stable Decreasing Increasing Strongly increasing Variable **	Domestic mineral—NIR<10% Mainly domestic mineral—NIR 10–50% Scarce mineral—NIR >50%	Stable Decreasing Increasing Strongly increasing	Short (<15 years) Medium (15–30 years) Long (>30 years)

* With assumed total domestic production from primary sources (mineral deposits) and secondary sources, ** lack of general tendency.

Two groups of minerals were further analyzed and discussed in detail in terms of the need for safeguarding, considering the directions of consumption:

- Group 1—domestic and mainly domestic minerals characterized by a stable, growing, or strongly growing consumption trend,
- Group 2—scarce minerals characterized by a stable, growing, or strongly growing consumption trend, for which the proven resource base is known.

The need to analyze the second group of minerals (currently deficient) results from the fact that the share of domestic production is calculated for a specific period. However, it is probable that proper management of the documented resources may enable future increase of the share of domestic production in covering the Polish economy's demand for a given mineral. This assessment of available resources and the appropriateness of their future use was conducted in Section 3.1.3. Consequently, 19 minerals belonging to these two groups were assessed in terms of the domestic resource base and consumption trends (Table 2):

- Group 1—domestic or mainly domestic minerals: elemental sulfur, refined copper (due to the fact that silver is a co-occurring mineral in copper deposits, in many cases these resources must be analyzed together; this is why it appears in some of the analyses below), refined lead, metallic zinc, raw industrial dolomite, gypsum and anhydrite, raw magnesite, foundry sand, glass sand, coking coal, dimension stone, kaolin, and feldspar raw materials;
- Group 2—scarce minerals: titanium ores and concentrates, crude oil, nickel metal, potassium salts, natural gas, ball clays, and refractory clays.

For these selected 19 key minerals a detailed analysis of the domestic resource base was carried out and trends of mineral extraction for their production (stable, decreasing, increasing, strongly increasing, or variable) in the analyzed decade were determined (Table 1). Taking into account the average annual extraction of particular minerals and the size of industrial resources in currently developed deposits, static sufficiency of these resources was estimated for each group of mineral deposits and in this case groups of mineral deposits showing short (up to 15 years), medium (15–30 years), and long (more than 30 years) sufficiency were separated.

Table 2. Tendencies of mineral consumption vs. nature of mineral in the Polish conditions.

Tendency of Consumption/Nature of Mineral	Decreasing Consumption	Stable Consumption	Increasing Consumption	Strongly Increasing Consumption	Variable Consumption	TOTAL
Domestic mineral	Lignite	**Elemental sulfur; foundry sand**	**Copper; industrial dolomite; gypsum and anhydrite; glass sand**	**Lead; zinc; raw magnesite**	Silver; crushed aggregates; sand and gravel aggregates	13 **(9)**
Mainly domestic mineral	Steam coal	**Coking coal; Kaolin**	**Dimension stone; feldspars and related minerals**	-	Gold; salt	7 **(4)**
Scarce mineral	-	**Titanium ores and concentrates**	**Crude oil**; bauxite and alumina; silicon metal; magnesium; manganese minerals; nickel; ferroalloys; phosphorus; corundum (synthetic and natural); **potash salts;** calcined, dead-burned and fused magnesite; talc and steatite	**Natural gas**; aluminium; **ball clays and refractory clays**	Tin; platinum group metals; tungsten; iron ores and concentrates; amber; phosphate rock	22 **(6)**
TOTAL number of key minerals	2	5 **(5)**	18 **(9)**	6 **(5)**	11	42 **(19)**

In parentheses numbers of minerals of rising economic importance and resource potential for domestic production development. Minerals subject to detailed analysis are marked in bold. Single underline —Group 1 of analyzed minerals, Double underline —Group 2 of analyzed minerals.

For a few of the analyzed minerals—coking coal, copper, and silver as well as sulfur—due to the fact that they are important Polish export minerals, detailed analyses were carried out in respect of their present and future importance for the economy of Poland and the European Union, possibilities to develop or at least maintain their production in Poland, as well as identification of so far undeveloped deposits which may ensure continuation of this production on the condition that access to them is ensured in the future.

The source materials for the analyses indicated above are relatively extensive. As regards production and trade (import, export) of minerals in terms of value and volume, these are the data of the Central Statistical Office (CSO) [69]. CSO presents data related to domestic production and trade of minerals and related products in Poland, in accordance with the Polish Classification of Goods and Services (PKWiU) (production) and Polish Combined Nomenclature (PCN) (international trade). Official data sometimes are supplemented with data coming directly from mining enterprises, including their stock exchange reports, industry reports, as well as companies' development policies (e.g., for Jastrzębska Spółka Węglowa S.A. (JSW) and KGHM Polska Miedź S.A). Mentioned documents are basic sources of information regarding production, trade, and development plans. As regards the size of the resource base and mining of minerals from deposits, these are the data from the yearbooks in the Balance of Mineral Resources Deposits in Poland (editions

2011–2019) [70]. In these yearbooks the Polish Geological Institute—National Research Institute (PGI-NRI) presents data on almost 14,000 mineral deposits recognized in Poland.

To illustrate the position of Poland on the international (European) arena in the case of selected minerals (coking coal, copper, silver, and sulfur), the data of Eurostat PRODCOM [71], World Mineral Production [72] and World Mining Data [73] were used.

3. Results

3.1. Key Minerals for the Polish Economy

3.1.1. General Remarks on Key Minerals for the Polish Economy

The methodology used to determine the key minerals for the Polish economy allowed for the selection of 42 key minerals (Tables 2 and 3), of which 5 are fossil fuels, 17 are metallic raw materials, and the remaining 20 are industrial minerals (rock and chemical). The value of their average annual consumption varies within a very wide range: from ca. PLN 40 million in the case of amber, talc, and tungsten to nearly PLN 45 billion in the case of crude oil. The share of imports in covering domestic demand for particular minerals also varies widely, from 0% for foundry sands to 100% for many metallic and some industrial minerals (Table 3).

Key fossil fuels can be divided into hydrocarbon fuels (natural gas and oil) and solid fuels (steam and coking coal and lignite). The former show a growing or strongly growing trend in consumption over the period analyzed. Additionally, they are strongly deficient, as domestic production satisfies only 2–3% of domestic demand in the case of oil and about 15% in the case of natural gas [74–76]. Crude oil is also characterized by the highest average consumption value among all key minerals. Its value determines the negative balance of trade in all minerals in Poland [77,78]. The group of fossil fuels also includes coking coal, which de facto is used primarily in metallurgy: 82% of coking coal in the EU is used to produce coke for use in steel production [79]. Consequently, in some countries it is referred to as a metallurgical raw material (metallurgical coal) (e.g., [80]). It is worth mentioning that in 2020 the European Commission confirmed the status of coking coal as a critical raw material on the list of 30 critical raw materials for which the risk of supply shortage and its effects on the economy are higher than in the case of other raw materials [79]. In Poland, coking coal shows a growing volume and value of consumption, which is mainly characterized by its domestic nature (Table 3).

A numerous group of metallic raw materials of key importance to the Polish economy consists of scarce minerals which are not available in Poland either from primary or—usually—from secondary sources and therefore they must be imported. This is due to the lack of documented mineral deposits from which these minerals could be extracted, although in some cases recycling is being developed. At the same time there are some of them which have shown in recent years a strong upward trend in consumption in Poland, e.g., metallic aluminum, bauxite and alumina, silicon, magnesium, manganese raw materials, titanium ores and concentrates, and ferroalloys. In the discussed group there are also domestic minerals for which increasing (zinc and lead) or stable (copper) consumption is observed. It should be mentioned that the domestic nature of refined lead is mostly related to its extraction from secondary sources [81,82], despite the existence of a domestic resource base. This thread will be developed in the next section. Among the key metallic raw materials in the analyzed decade, the highest average annual consumption value was recorded for refined copper. Iron ores and concentrates came second, but with a value several times lower (Table 3).

The last and the most numerous groups of key raw materials are industrial minerals, mainly rock materials, but also chemical raw materials such as elementary phosphorus, phosphate rock, sulfur, rock salt and potash salts. Almost all the key rock minerals (except for amber, ball clays and refractory clays, alumina, magnesite—calcined, dead-burned, and fused) are domestic or mainly domestic in nature. In the vast majority, they are obtained from domestic mineral deposits, although most of the domestic gypsum supply is synthetic gypsum obtained during flue gas desulfurization in conventional power plants [82,83].

Two chemical key minerals—rock salt and sulfur—are also obtained from domestic sources, the latter of which, apart from domestic sulfur deposits, has been documented and is obtained incidentally from oil and natural gas deposits [10,84,85]. Among non-metallic key minerals, crushed aggregates, sand and gravel aggregates, and dimension stone are traditionally characterized by the highest average annual consumption value (Table 3).

3.1.2. Consumption Trends of Selected Key Minerals for Polish Economy

Among the 19 key minerals for the Polish economy, which show a growing (or at least stable) trend of consumption, fossil fuels—crude oil and natural gas, as well as coking coal—are and will be consumed in the near future, definitely in the largest amounts exceeding 10 million tonnes/year. In the case of numerous rock minerals, the volume of such consumption also reaches several million t/y. For example, this applies to gypsum and anhydrite, dimension stone, industrial dolomite, glass sand and potash salts, and more recently to feldspars. The use of metallic raw materials analyzed here is at least an order of magnitude lower (Table 4).

For a many of the 19 analyzed minerals, a significant increase in demand of the Polish economy was recorded in the last decade, reaching 5% annually, and in several cases (lead, ball clays and refractory clays, raw magnesite) even 8–10% annually. It related to a significant development of many branches of domestic metal and machine industry, chemical industry (including fertilizers), and building materials industry, where these minerals are used (Table 4). However, in the analyzed group there were also minerals whose consumption did not show any growth trends, being stable with only slight fluctuations. This applied in particular to coking coal, titanium ores and concentrates, foundry sand, kaolin, and sulfur (Table 4).

Forecasts made last year concerning the development of demand for particular raw materials in the Polish economy [85] indicated that for some of these minerals, general demand growth trends may be maintained, although the rate of growth may be lower than in the last decade. This includes oil and natural gas, ball clays and refractory clays, feldspars, glass sand, gypsum and anhydrite, crude magnesite, and potassium salts. Maintaining or increasing the demand growth rate in this group of minerals may concern only few metals, in particular copper, zinc, and lead (Table 4), which is related to the expected further development of the metal industry, also in the context of the needs of the developing renewable energy sector. In turn, the energy transformation initiated towards a reduction in the use of fossil fuels, apart from a rapid fall in the use of thermal coal and lignite, will probably cause a slowdown or even a decline in the use of crude oil after 2030. In the case of natural gas, the continuation of the upward trend can be expected until about 2040, as in this period it will be a source of energy ensuring the preservation of flexibility of the national power system with a rapidly growing share of renewable energy sources, probably also with its growing use in the municipal and household sector. However, this is assumed to be a transitional energy source whose importance will begin to decline after 2040 [86].

3.1.3. Resources and Extraction of Minerals for Production of Selected Key Minerals in Poland

Of the 42 selected key minerals for the Polish economy (see Table 3), for 27 of them domestic documented deposits for their production are known, including 21 minerals currently being exploited in Poland. Table 5 provides detailed information on the size of the resource base and extraction, but limited to 19 groups of minerals with stable, growing, or strongly growing consumption trends as shown in Table 2.

Table 3. Minerals recognized as key for the Polish economy ([12,82,85], supplemented).

No.	Mineral	Average Value of Domestic Consumption 2009–2018 (Million PLN)	Consumption Tendency	Net Imports Reliance 2009–2018 (%)	Nature of Mineral	Recognized Resource Base	Production from Primary Sources (Mineral Deposits)	Production from Secondary Sources
				Fuels				
1	Coking coal	6393.9	Stable	21.1	Mainly domestic	Y	Y	-
2	Crude oil	44,916.8	Increasing	97.4	Scarce	Y	Y	-
3	Lignite	1351.4	Decreasing	0.4	Domestic	Y	Y	-
4	Natural gas	>13,000	Strongly increasing	85.9	Scarce	Y	Y	-
5	Steam coal	16,486.3	Decreasing	14.5	Mainly domestic	Y	Y	-
				Metallic minerals				
1	Aluminium (non-alloyed)	955.7	Strongly increasing	100	Scarce	N	N	Y
2	Bauxite and alumina	175.4	Increasing	100	Scarce	N	N	N
3	Copper	6,326.3	Increasing	4.3	Domestic	Y	Y	Y
4	Ferroalloys	274.1	Increasing	100	Scarce	N	N	N
5	Gold	>100	Variable	<30	Mainly domestic	Y [1]	Y	Y
6	Iron ores and concentrates	1746.6	Variable	100	Scarce	Y [2]	N	Y
7	Lead	542.1	Strongly increasing	<10	Domestic	Y	Y	Y
8	Magnesium	61.6	Increasing	100	Scarce	N	N	N
9	Manganese minerals	46.7	Increasing	100	Scarce	N	N	N
10	Nickel	100.1	Increasing	100	Scarce	Y	N	Y
11	Platinium group metals	130.9	Variable	>90	Scarce	Y [1]	Y	Y
12	Silicon metal	203.3	Increasing	100	Scarce	Y [3]	N	N
13	Silver	>60	Variable	<10	Domestic	Y	Y	Y
14	Tin	52.6	Variable	83.5	Scarce	Y	N	Y
15	Titanium ores and concentrates	86.6	Stable	100	Scarce	Y [2]	N	N
16	Tungsten	41.7	Variable	100	Scarce	Y	N	N
17	Zinc	876.5	Strongly increasing	<10	Domestic	Y	Y	Y

Table 3. *Cont.*

No.	Mineral	Average Value of Domestic Consumption 2009–2018 (Million PLN)	Consumption Tendency	Net Imports Reliance 2009–2018 (%)	Nature of Mineral	Recognized Resource Base	Production from Primary Sources (Mineral Deposits)	Production from Secondary Sources
				Industrial minerals				
1	Amber	>40	Variable	>85	Scarce	Y	Y	-
2	Ball clays and refractory clays	138.1	Increasing	70.9	Scarce	Y	Y	-
3	Corundum (synthetic and natural)	133.9	Increasing	98.7	Scarce	N	N	-
4	Crushed aggregates	1838.1	Variable	4.3	Domestic	Y	Y	Y [4]
5	Dimension stone	572.6	Increasing	12.4	Mainly domestic	Y	Y	-
6	Dolomite industrial	145.9	Increasing	5.4	Domestic	Y	Y	-
7	Feldspars and related minerals	383.8	Increasing	42.7	Mainly domestic	Y	Y	-
8	Foundry sand	64.6	Stable	0	Domestic	Y	Y	-
9	Glass sand	69.8	Increasing	0.9	Domestic	Y	Y	-
10	Gypsum and anhydrite	49.6	Increasing	1.7	Domestic	Y	Y	Y [5]
11	Kaolin	72.3	Stable	44.2	Mainly domestic	Y	Y	-
12	Magnesite, raw	<10	Strongly increasing	4.0	Domestic	Y	Y	-
13	Magnesite, calcined, dead-burned and fused	>200	Increasing	100	Scarce	N	N	-
14	Phosphorus	136.1	Increasing	100	Scarce	N	N	-
15	Phosphate rock	434.4	Variable	100	Scarce	N	N	-
16	Potash salts	938.2	Increasing	96.0	Scarce	Y	Y	-
17	Salt (rock salt and brine)	295.7	Variable	17.6	Mainly domestic	Y	Y	-
18	Sand and gravel aggregates	1596.8	Variable	1.0	Domestic	Y	Y	-

Table 3. *Cont.*

No.	Mineral	Average Value of Domestic Consumption 2009–2018 (Million PLN)	Consumption Tendency	Net Imports Reliance 2009–2018 (%)	Nature of Mineral	Recognized Resource Base	Production from Primary Sources (Mineral Deposits)	Production from Secondary Sources
19	Sulfur, elemental	222.5	Stable	5.3	Domestic	Y [6]	Y	-
20	Talc and steatite	42.8	Increasing	100	Scarce	N	N	-

[1] accompanying metal in Cu-Ag ores deposits without estimated resources; [2] currently uneconomic resources; [3] some highest quality deposits of quartz and glass sand; [4] from constructions demolition and on the basis of some industrial wastes, [5] synthetic gypsum from flue gas desulfurization in power plants; [6] native sulfur and sulfur as accompanying element in hydrocarbon deposits; Y—yes, N—no, - not applicable.

Table 4. Level of consumption and main users of the selected 19 key minerals with increasing consumption trends and existing or potential domestic sources in Poland (based on [85]).

No.	Mineral	Level of Consumption 2009–2018	Trend 2009–2018	Expected Future Trend until 2040	Main Users
			Fuels		
1	Coking coal	9.9–13.5 Mtpy	Stable consumption	Stable consumption (after 2040 possible decline)	Production of coke for steelworks and for households
2	Crude oil	20.6–27.8 Mtpy	Increase >5%/y	Some increase 2–3%/y until 2030, then stable or decrease	Oil products, petrochemical products
3	Natural gas	12.8–17.2 billion m^3py	Increase >5%/y	Further increase 3–5%/y (after 2040 stable or decrease)	Nitrogen fertilizers, electricity and heat generation, glassworks, cement plants, households heating
			Metallic minerals		
4	Copper	203–296 ktpy	Increase ca. 2%/y	Increase up to 4–5%/y	Copper wires, sheets, strips, pipes, rods, Cu alloys
5	Lead	75–193 ktpy	Increase >10%/y	Increase 5–8%/y	Acid-lead batteries, Pb oxide
6	Nickel	0.7–3.6 ktpy	Very variable, increasing in general	Some further increase	Stainless steel, Ni alloys
7	Titanium ores and concentrates	81–105 ktpy	Stable, slightly variable	Stable, slightly variable	Titanium white
8	Zinc	47–145 ktpy	Increase >5%/y, but variable	Increase >5%/y	Steel galvanization, Zn alloys, Zn compounds

Table 4. *Cont.*

No.	Mineral	Level of Consumption 2009–2018	Trend 2009–2018	Expected Future Trend until 2040	Main Users
			Industrial minerals		
9	Ball clays and refractory clays	367–693 ktpy	Increase >8%/y	Increase 2–4%/y	Ceramic tiles, refractories, ceramic sanitaryware
10	Dimension stone	1549–2772 ktpy	Very variable, increasing in general	Some further increase	Dimension stone for buildings and tombstones, road stone
11	Dolomite, industrial	1824–3373 ktpy	Very variable, increasing in general	Some further increase	Glass, ceramics, refractories, steelworks, fillers, fertilizers
12	Feldspars and related minerals[2]	745–1,095 ktpy	Increase 4–5%/y	Increase 2–3%/y	Ceramic tiles, glass, ceramic sanitaryware
13	Foundry sand	720–920 ktpy	Stable	Stable or small increase	Foundries, dry mortars
14	Glass sand	1646–2213 ktpy	Increase 4–5%/y	Increase 2–3%/y	Glass
15	Gypsum and anhydrite	3511–4362 ktpy	Increase 2–3%/y	Increase 1–2%/y	Gypsum plasterboards, gypsum binders, cement
16	Kaolin	214–287 ktpy	Stable, slightly variable	Stable, slightly variable	Ceramic tiles, ceramic sanitaryware, paper, rubber, paints
17	Magnesite	52–133 ktpy	Increase >8%/y	Increase 2–4%/y	Fertilizers, Mg compounds
18	Potash salts (K-Mg salts)	192–1118 ktpy	Increase >5%/y, but variable	Increase 1–2%/y	Fertilizers, K compounds
19	Sulfur	322–569 ktpy	Stable, slightly variable	Stable, slightly variable	Sulfuric acid for fertilizers production, (rubber, paper, food)

Number 1,4-5, 8, 10-17 and 19 —Group 1 of analyzed minerals—domestic or mainly domestic minerals, Number 2-3, 6-7, 9 and 18 —Group 2 of analyzed minerals—scarce minerals (see Table 2).

Table 5. Mineral resources and mining output for the production of selected key minerals for the Polish economy (as of the end of 2018). Based on [70], own calculations.

No.	Minerals		Recognized Resources	Recognized Resources of Active Mines	Recognized Reserves of Active Mines	Average Mining Output 2009–2018	Sufficiency of Reserves of Active Mines (years)	Tendencies of Mining Output
				Fuels				
1	Coking coal	kt	21,056,540	11,009,640	1,286,540	11,849.5	108.6 (long)	Stable
2	Crude oil	kt	23,957	22,154	13,017	817.2	15.9	Stable
3	Natural gas	mln m^3	142,160	90,556	42,269	5356.9	7.9	Decreasing
				Metallic minerals				
4	Copper	kt Cu	48,722	30,400	23,741	473.4	50.1	Decreasing
5	Lead	kt Pb	4074	1749	75	70.4	[1]	Variable
6	Nickel	kt Ni	209	-	-	-	-	-
7	Titanium ores	kt TiO_2	97,700	-	-	-	-	-
8	Zinc	kt Zn	6222	1062	196	70.1	[1]	Decreasing
				Industrial minerals				
9	Ball clays and refractory clays	kt	222,479	2294	2220	236.9	9.4	Increasing
10	Crushed and dimension stone—for the production of crushed aggregates and dimension stone	kt	11,935,411	6,276,450	3,495,790	66,530.5	52.5	Increasing
11	Dolomite, industrial	kt	508,947	214,298	131,193	3,034.5	43.2	Increasing
12	Fedspars and related minerals [2]	kt	152,320	16,256	5254	62.6	83.9	Decreasing
13	Foundry sand	kt	307,877	50,028	18,600	1172.5	15.9	Decreasing
14	Glass sand	kt	776,512	193,840	67,422	2,259.4	29.8	Strongly increasing
15	Gypsum and anhydrite	kt	255,230	83,329	67,686	1125.8	60.1	Decreasing
16	Kaolin	kt	272,241	54,015	45,976	276.1	166.5	Increasing
17	Magnesite	kt	15,904	3693	3693	83.6	44.2	Strongly increasing
18	Potash salts (K-Mg salts)	kt	704,998	-	-	-	-	-
19	Sulfur	kt	538,711	18,248	17,420	601.7	29.0	Variable

[1] Extraction from Zn-Pb deposits was stopped in December 2020 and future extraction of Zn-Pb ores in Poland is unlikely, [2] over 90% of production comes from granite crushed and dimension stone deposits. Number 1,4-5, 8, 10-17 and 19 —Group 1 of analyzed minerals—domestic or mainly domestic minerals, Number 2-3, 6-7, 9 and 18 —Group 2 of analyzed minerals—scarce minerals (see Table 2).

Among the key fossil fuels, coking coal is domestic, with a documented resource base of 21 billion tonnes in deposits located in Southern Poland—within the Upper Silesian Coal Basin. It is estimated that coking coal constitutes about 27–28% of the hard coal resources documented in Poland [87]. The average annual output of coking coal amounted to almost 12 million tonnes in the analyzed decade, showing a clear upward trend. Considering average annual output of this raw material and its industrial reserves in currently developed deposits, sufficiency of reserves should be assessed (Table 5). Two other analyzed key fossil fuels—crude oil and natural gas—are in deficit; in the case of natural gas the domestic production has been decreasing in the recent years, with a very short period of sufficiency of developed resources (only 7 years). Stable oil production in recent years—at the level of only about 0.8 million t/y—and relatively small reserves in developed deposits is the basis for defining the sufficiency of its reserves for about 15 years (Table 5). At the same time, it should be stressed that a vast majority of Polish oil deposits are currently under exploitation [65,70,77], and the perspectives of discovery of new rich deposits are small.

Among the analyzed metallic minerals the largest resources, but also the largest (although slightly decreasing in recent years) average annual output exceeding 470,000 tonnes Cu/y, are recorded for copper ore. The silver extracted from these ores is also noteworthy. Its content in mined ore showed an upward trend, averaging over 1400 tonnes per year for the years 2009–2018. For both raw materials, copper and silver, the large resource base of the active mines guarantees long reserves sufficiency, estimated at around 50 years. On the other hand, mining of Zn-Pb ores in the Silesian–Cracow region is in decline in Poland. Despite the still relatively large resource base for these metals, the last Zn-Pb ore mine in Poland was finally closed in December 2020. However, that recovery has remained an important source of lead for years—in recent years about 70% of the domestic production of refined lead came from secondary sources [10,85]. The total production of refined lead in Poland is about 130,000 tonnes per year [88] and, according to the Economic Chamber of Nonferrous Metals and Recycling [89], the processing rate of lead-bearing battery scrap is over 95%. Among the analyzed metallic raw materials, lead is the one for which extraction from secondary sources has the highest share, significantly exceeding the production from mineral deposits. Small nickel deposits and large but poor deposits of vanadium-bearing titanomagnetite ores are also documented in Poland (Table 5). However, there are no prospects for their development in the near future.

The analyzed key rock minerals are documented in Poland in over a thousand deposits [70] located mainly in the southern part of the country. The largest resource base (exceeding 6 billion tonnes) among the analyzed raw materials is represented by crushed and dimension stone for production of crushed aggregates and dimension stone. This group also records the highest average annual output—65 million t/y (Table 5). The systematic increase in the extraction of these minerals is based on significant reserves documented in active mines. Consequently, their sufficiency is estimated at over 50 years. Long (more than 30 years) reserves sufficiency with growing or strongly growing extraction is characteristic also of industrial dolomite, kaolin, magnesite, and glass sand. Long period of sufficiency of developed reserves also concerns minerals with variable or decreasing consumption, such as gypsum and anhydrite or sulfur (Table 5).

In the group of key industrial minerals there are also two minerals of scarce character. These are ball clays and refractory clays, exploited in Poland on a small scale, with the reserves availability not exceeding 10 years, as well as yet undeveloped deposits of potassium sulphate salts.

3.2. Indications on the Safeguarding of Deposits for the Production of Selected Key Minerals

In Poland there is no commonly accepted and legally sanctioned definition of the term "safeguarding of mineral deposits" [90]. All views on this subject are descriptive and postulative. In this paper, the safeguarding of mineral deposits is considered in the context of undeveloped deposits and is defined as the necessity to ensure future access to resources through appropriate development and use of the area above the documented deposit. Each time, the starting point for safeguarding understood in such a way is a proper multi-criteria evaluation of deposits completed with their ranking. In Poland it is particularly important due to a huge—exceeding 14 thousand—number of documented deposits, mostly of rock, but also of energy, metallic, and chemical minerals. Providing equivalent protection for all of them, with relatively extensive environmental, land use, and social conditions, may give rise to many conflicts. It is therefore justified to designate those most valuable mineral deposits which would be subject to legal obligation of safeguarding.

In Poland, the methodology of ranking and assessment of deposits has been repeatedly applied to various types of minerals (e.g., [91–101]). As a result of such extensive work, deposits were selected which—based on various criteria, but basically in view of the size of resources and quality of the minerals—seem to be the most attractive and valuable.

The results of the evaluation of mineral deposits for selected key minerals for the Polish economy presented below assume that these deposits will be classified in at least two categories:

- National—deposits of the greatest economic importance for the country, for which decisions on their safeguarding and development should be taken at the level of national administration;
- Regional—deposits of significant economic importance for the region, which should be decided at the level of regional (provincial) administration.

Such a division is directly connected with the hierarchy of the land use planning system in Poland, which is widely recognized as the most important instrument in the safeguarding of mineral deposits [64]. In such a context, deposits of national importance should be considered in planning documents of the national level, i.e., first of all in the national development concept. This in turn—according to the act on planning and spatial development [102]—is to ensure that they are considered in regional documents (province spatial development plan) and local documents (the study of conditions and directions of spatial development in the municipality and the local spatial development plan). They should also be the subject of other strategic documents of the state, such as mineral policy or energy policy. In the case of these deposits, the priority is to establish a mining direction over the deposit, which would ensure unrestricted access to its resources in the future. On the other hand, the safeguarding of deposits from the second category (regional) should be considered on the regional level, taking into account economic needs of the region. A method of utilizing the area of the deposits included in this category other than for commercial purposes should require a decision of the province marshal, based on detailed geo-environmental, planning, social, and economic analyses.

The starting point for further considerations is the assumption that deposits of energy and chemical minerals and metal ores are minerals of important economic importance on a national scale, because, in accordance with the Geological and Mining Law of Poland, they are owned by the State Treasury [103]. Therefore, they should be protected as a whole, and the assessment of the assets of individual deposits in terms of the safeguarding of their resources, by applying detailed criteria, is—in most cases—unnecessary [104].

Due to the critical nature of coking coal and the limited possibilities of its supply from other primary sources in Europe, safeguarding should be extended to all hard coal deposits in which a significant amount, or the majority, of the resources is coking coal. Currently, it is 21 deposits.

From among analyzed mineral deposits for obtaining key fuels for the Polish economy, most crude oil deposits are currently exploited [77]. Admittedly, there is still a group of undeveloped deposits (27 deposits) [70], but these are mostly very small deposits whose potential economically justified exploitation can only take place in a situation of joint exploitation with adjacent deposits, or abandoned deposits of only historical significance. The White Book of Mineral Deposits indicated the necessity of safeguarding only four oil deposits [65]. Updating this list relative to the end of 2018 [70] would authorize leaving only one deposit. Several dozen undeveloped natural gas deposits are also discussed—these are mostly undeveloped deposits, but also a large group of abandoned deposits. The

White Book of Mineral Deposits mentioned above—after updating to the state as of the end of 2018—would make it possible to select 10 deposits intended for such safeguarding. Should be mentioned that during last 10 years of Polish gas deposits reserves (despite exploitation), have increased by 10 billion m^3. Moreover, deposits that were not designated for safeguarding (based on White Book), are currently being prepared for exploitation or even exploited. These facts confirm that deposits of strategic minerals should be protected comprehensively (without categorization).

In Poland about 40 deposits remain undeveloped, from which theoretically it is possible to obtain metallic key raw materials listed in Tables 4 and 5: copper, zinc, lead, nickel, and titanium ores. A significant role in this group is occupied by Polish deposits of copper ores (or more precisely: deposits of copper and silver ores). Out of the 12 deposits documented in South-Western Poland, four are currently undeveloped and two deposits have been abandoned. Over 87% of the documented resources of this mineral are contained in currently developed deposits. In terms of resource potential, undeveloped deposits are therefore of lesser importance, but this does not disqualify them from the highest protection [65]. The situation is different for Zn-Pb ore deposits. Of the 21 proven deposits, three were formally closed in December 2020, mainly due to resource depletion. As a result, all resources from which there is a possibility of obtaining zinc and lead ores in the future lie only in undeveloped deposits. Among them only three, with total resources of almost 50 million tonnes of Zn-Pb ore (about 3 million tonnes of Zn and about 1 million ton of Pb), can be described as sufficiently known [105] and requiring special considerations for their safeguarding. However, in accordance with the strategic nature of ore deposits for the country's economy, other deposits with much smaller resources should also be subject to appropriate safeguarding.

Single deposits of other metals ores have been evaluated in Poland mainly using an expert method. This is the case, among others, of the few documented nickel ore deposits in Lower Silesia. The resource base of this metal is contained in 4 deposits with resources of about 125,000 tonnes Ni [70]. Three of them were in operation by 1983 [106].

Titanium ore deposits in Poland have been documented in NE Poland in Suwałki vicinity in three large, poor deposits with total resources exceeding 1.34 billion tonnes of titanomagnetite ore with vanadium [107,108], including 97 million tonnes of titanium oxide [53]. It should be emphasized that over 80% of these resources are connected with one deposit—Krzemianka. However, at present it seems that in the area of this deposit the issues of environmental protection are dominating (the area of so called "green lungs of Poland"), and the plans considered in the past for development of a mining district here are of only historical significance only [109]. This is also confirmed by the fact that in 1996, the resources of Fe-Ti-V ore deposits, among others, were considered uneconomical, due to the high depth of occurrence (more than 1000 m) and the lack of fulfilment of requirements regarding the ore quality [108,110]. The small size of the resource that could be considered economic and the form of its occurrence in the form of small, isolated ore bodies do not justify further documentation work here. In view of the aforementioned reasons the priority of environmental protection requirements in the Suwałki region in relation to economic use of these deposits seems to be non-threatened [107].

The most numerous resource base for the production of key minerals in Poland is represented by deposits of rock minerals. Their common occurrence and relatively large resource base mean that their safeguarding should be considered (with a few exceptions) mainly at the regional level. At the same time, it was this group that was most often subjected to evaluation aimed at identification of the most valuable deposits in order to protect them. The last, and at the same time their most comprehensive, evaluation was developed by Nieć and Radwanek-Bąk [99]. This was the basis for multi-criteria evaluation of all rock mineral deposits documented in Poland. In accordance with the concept proposed by these authors, several deposits were selected into three categories with different scope of safeguarding: (1) highest; (2) high, and (3) ordinary. According to the minerals' values (understood in this methodology as the number of resources and the quality of the mineral), the management of deposits and their safeguarding should be considered within the framework of land use management planning at the national scale (deposits of category 1), regional scale (deposits of category 2), and local scale (deposits of category 3) [111].

With reference to the analyzed mineral deposits from which the selected key minerals may be obtained, the largest number, 119 deposits (out of 247 undeveloped deposits) requiring the highest or high level of protection were selected in the crushed and dimension stone group. These are deposits with significant resources and characterized by high quality minerals for specific uses, including unique decorative values for the revaluation of monuments. The same evaluation identified 11 industrial dolomite deposits, of which three deposits should become of national interest [99]. High economic value was also determined for 12 documented and presently undeveloped deposits of glass sand and six deposits of foundry sand in Poland [111]. The group of valued deposits also includes gypsum and anhydrite deposits, four of which require the highest level of safeguarding and another five require a regional decision. This result was also confirmed in other assessments carried out in Poland [100].

In 2017, the evaluation proposed by Nieć and Radwanek-Bąk became the starting point for a multi-criteria analysis developed and tested within the international MINATURA2020 project [112,113]. The methodology was intended to delineate mineral deposits of public interest at the national and regional levels. This division would be reflected in the safeguarding of those deposits. Testing of the evaluation for selected rock mineral deposits in Poland made it possible to indicate six rock mineral deposits which should be subject to safeguarding, including five for which the safeguarding should be considered at the national level. For kaolin two such deposits were selected and the remaining eight would be considered for safeguarding at the regional level [101].

Deposits of chemical minerals were evaluated relatively least often in Poland and the evaluation was carried out only for deposits of native sulfur [95]. Nevertheless, as mentioned above, chemical minerals are of great importance for the national economy and especially in the case of native sulfur and potassium salts they should be entirely subject to the highest safeguarding. According to the above assumption, there would be seven deposits of native sulfur and five deposits of potassium salts, so far undeveloped.

3.3. Key Polish Minerals against the Background of the Minerals Market in Europe

Polish mining industry in several aspects stands out against the background of the European Union. Recently, on the international forum there has been a discussion mainly about the reasons and consequences of the decreasing significance of the Polish hard coal mining in the context of its gradual liquidation (e.g., [114–117]). In some cases, the minerals obtained by the Polish mining industry have played and may continue to play an important role in ensuring the Community's minerals security. This applies in particular to coking coal, copper and silver, and sulfur discussed below.

3.3.1. Coking Coal

For years, Poland has remained the largest producer of high-quality coking coal in the European Union [79,85] and one of the leading producers of coke (based on domestic coking coal) used in steel melting. Apart from Poland, coking coal is only exploited in the Czech Republic (Figure 1), and among European countries outside the EU—in Russia and Ukraine [73]. Its exploitation in Germany was completed in 2018 [118]. According to World Mining Data [73], annual coking coal output in the EU has seen a steady decline from 25 million tonnes to 15 million tonnes between 2010 and 2018. In Poland, throughout the analyzed period it remained at a similar level of about 12 million tonnes annually, constituting in recent years almost 80% of total output in the EU countries (Figure 1). At the same time, it is estimated that community demand for coking coal in the analyzed period averaged 50 million t/y [119], and Poland satisfied $\frac{1}{4}$ of that demand. The deficit in coking coal on the EU market was met by imports mainly from Australia, USA, Canada, and Russia, and in recent years from Mozambique [79,120]. The level of these imports is likely to increase due to the eventual phasing out of Czech coal mines.

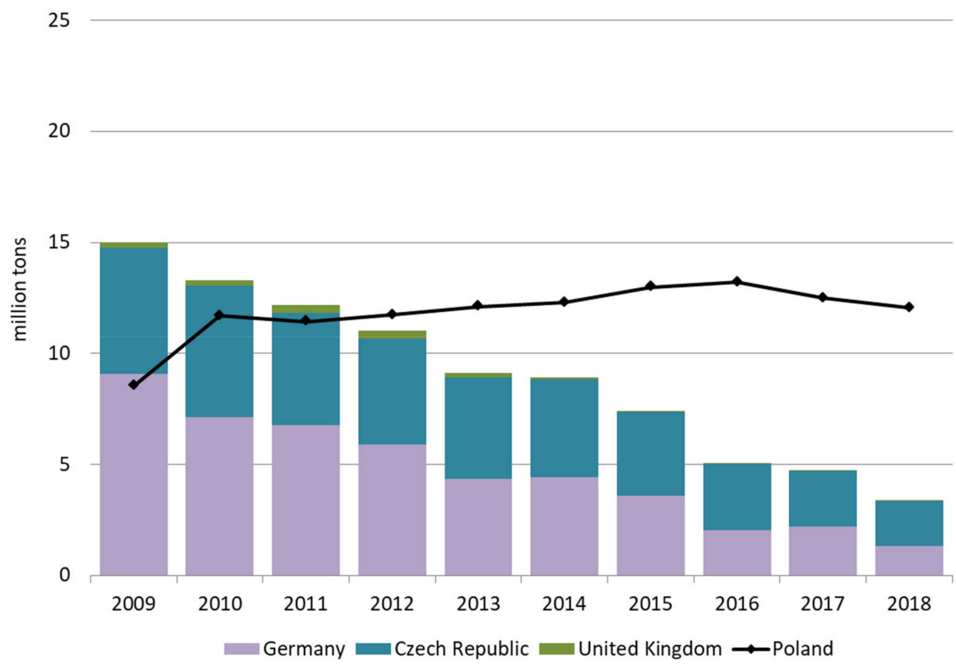

Figure 1. Production of coking coal in Europe and European Union. Based on [69,73].

In Poland, the main producers of coking coal are the underground mines of Jastrzębska Spółka Węglowa S.A. (JSW). About 86% of the domestic production of this raw material comes from them [120,121]. It is used in Central Europe, mainly for the production of coke consumed by local mills belonging to international steel producers. The high-quality coke produced by the JSW Group is also sold on the domestic and international markets. The strategic products in the Group's offer include blast furnace and foundry coke (75% of coke production in the Group). The main recipients of the JSW Group's products (coking coal and coke) are customers from Poland, Germany, Austria, the Czech Republic, Slovakia, and Italy as well as France, Serbia, and Hungary [122]. The JSW Group processes approximately 45% of the coking coal produced by the group at its own coking plants, with the remaining portion destined mostly for the domestic market (coking plants not related to the company—approximately 80% of what remains) and export (20%), primarily to EU countries [120].

The JSW S.A. company's mines have total coal resources of approximately 6.7 billion tonnes, including 1 billion tonnes of reserves [121]. The group intends to expand the base of its reserves to enable it to maintain its strong position on the international markets for coking coal and coke for the next several decades if the demand for this raw material is maintained in this time horizon [122].

3.3.2. Copper and Silver

Among the key metallic raw materials manufactured in Poland, copper is of major importance in the context of securing the needs of the European Union. To date the KGHM Polska Miedź S.A. concern has been the sole user of the largest in Europe and one of the largest in the world deposits of polymetallic Cu-Ag ores located in South-Western Poland [123]. The deposits for which KGHM holds mining licenses, as well as exploration licenses, or is in the process of obtaining them [124], are among the largest and most promising deposits of copper ore, silver, and other metals in Europe, providing the basis for the Company's operations for at least the next 35 years (with respect to deposits currently in operation and those planned for subsequent years).

According to CRU International estimates [125], KGHM ranked eighth largest of the world's copper mining producers in 2018; however, this was influenced by the mining carried out by the company also in other (outside Poland) mines located in Chile and Canada. In Europe, KGHM is by far the largest mining copper producer and refined copper producer, with production many times greater than other major producers such as Spain, Bulgaria, Sweden, Portugal, and Finland [72,73] (Figure 2). Although in this respect Poland's share is steadily declining from 63% in 2009 to 44% in 2018, it is still dominant among European countries. All the copper ore concentrates produced by the Polish mines of KGHM are sent for the production of refined copper in adjacent (domestic) smelters, for which imported copper ore concentrates are also used, currently accounting for 10–15% of total input. The company's strategy assumes maintaining refined copper production at the current level of over 500,000 tonnes annually, at which it has remained for almost 20 years (Figure 3). Currently, production in Poland accounts for nearly 20% of total refined copper supply in the EU [126]. At the same time, Poland is the leading exporter of refined copper to European markets, mainly to Germany, followed by Italy, France, and Turkey [69,127].

The outlook for copper mining and smelter production in Poland is also optimistic. Cu-Ag ore resources located in the area of Głogów Głęboki-Przemysłowy (the most important mining investment project currently carried out by KGHM in Poland) constitute about one fourth of copper reserves and about one third of silver reserves in all licensed areas of KGHM Polska Miedź S.A. in Poland [128]. According to the investment plan, between 2028 and 2035, the production from this new area will be 10–11 million t/y of ore, from which 200,000–220,000 t/y of refined copper can be obtained. This will allow KGHM to maintain its planned level of ore extraction from domestic deposits at over 400,000 tonnes Cu/year for at least the next 30 years [129]. Development of further, deeper Cu-Ag ore deposits by Miedzi Copper Corp. belonging to the Canadian Lumina Group, in particular the Nowa Sól deposit, cannot be ruled out [130].

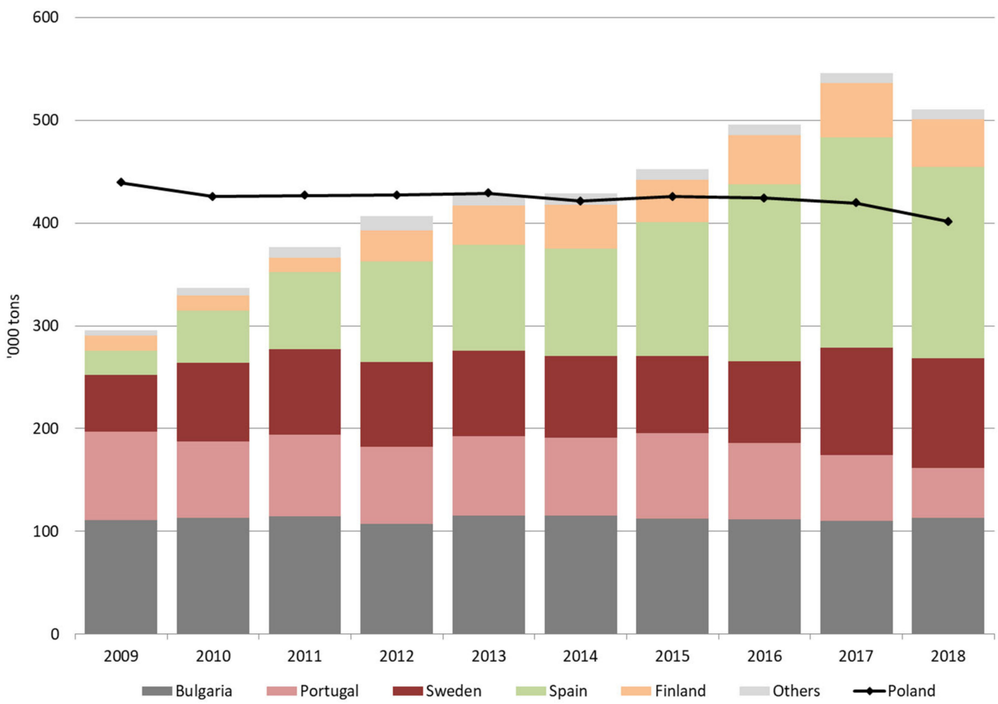

Figure 2. Mine production of copper in European Union countries. Based on [73].

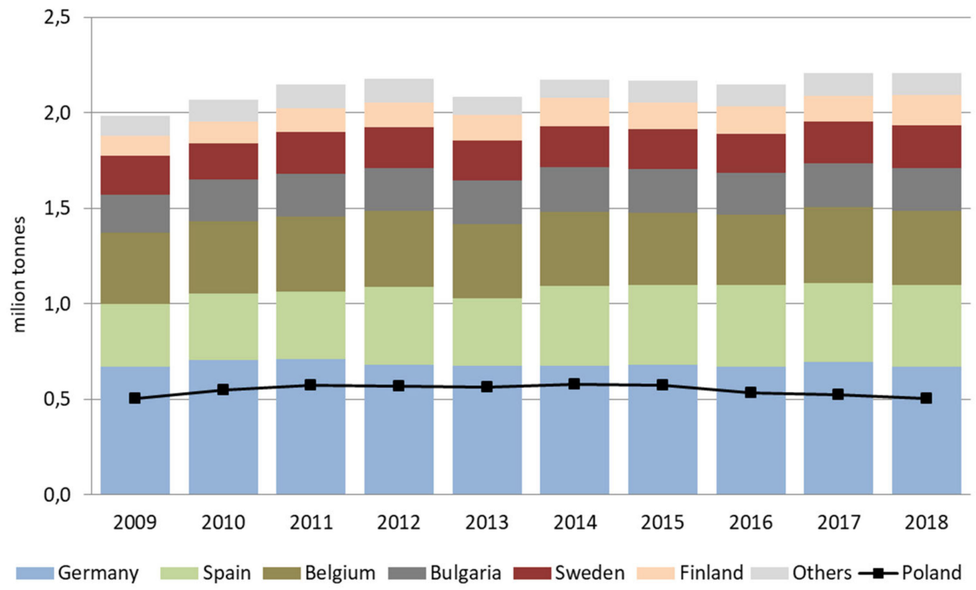

Figure 3. Production of refined copper in EU countries. Based on [55].

Polymetallic deposits located in south-western Poland, for which KGHM holds mining concessions, and KGHM and Miedzi Copper hold exploration concessions [131] are also the richest and largest sources of silver in Europe and one of the largest in the world. Within the EU, KGHM is the clear leader in terms of refined silver production [132] with significant production also recorded in Sweden (Figure 4). According to the World Silver Survey, Poland ranks seventh in the world in terms of silver production, and among mining companies KGHM ranks third in the world in this respect.

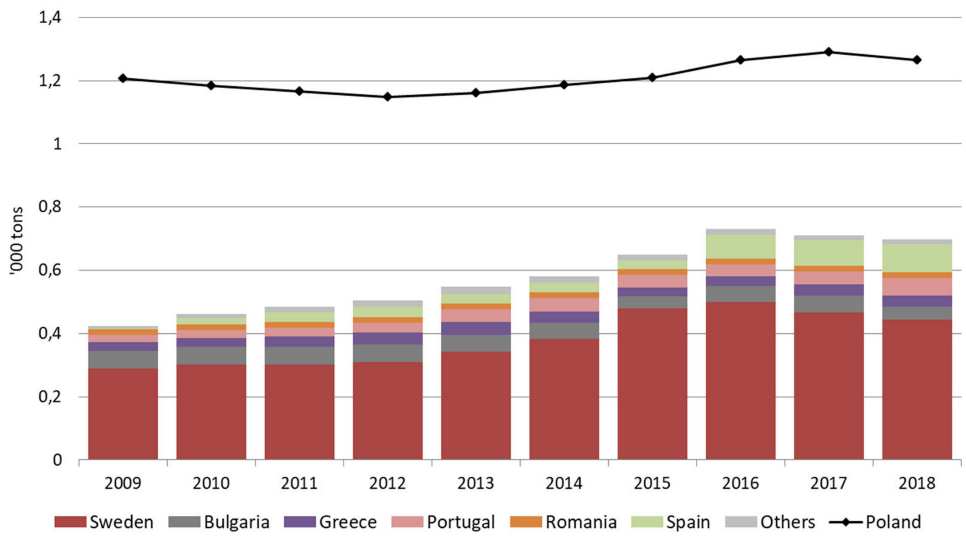

Figure 4. Silver production in European Union countries [52,56,107].

Refined silver produced in Poland is almost entirely exported, with exports level of 1,2–1,4 milion tonnes per year from 2009 to 2018. It is directed almost exclusively to other European countries [69,82,85].

Silver production in Poland is inextricably linked to the exploitation of copper and silver ore deposits. The prospects for developing or at least maintaining its production are therefore closely linked to the prospects for the operation of mines exploiting these deposits, which currently reach at least 35 years.

3.3.3. Sulfur

Poland is currently the only country in the world producing native sulfur with underground smelting method (the so-called Frasch process) [133] from native sulfur deposits [84,126,134]. In Europe, sulfur from deposits, but pyrite deposits, is still carried out by Finland. This production is complemented by the recovery of sulfur from sulfurized hydrocarbon deposits (usually in the form of elemental sulfur) and in the processing of metal ores (in the form of sulfuric acid) carried out in many EU countries [126,135,136] including Poland. Poland supplied on average in the analyzed decade about 880,000 t/y of sulfur with over 60% of production coming from the exploited deposits of native sulfur. In total, considering sulfur production in all forms (including recovered sulfuric acid), Poland's share in total EU production amounted to about 15% in recent years, which allowed it to remain among the European leaders of producers (Figure 5).

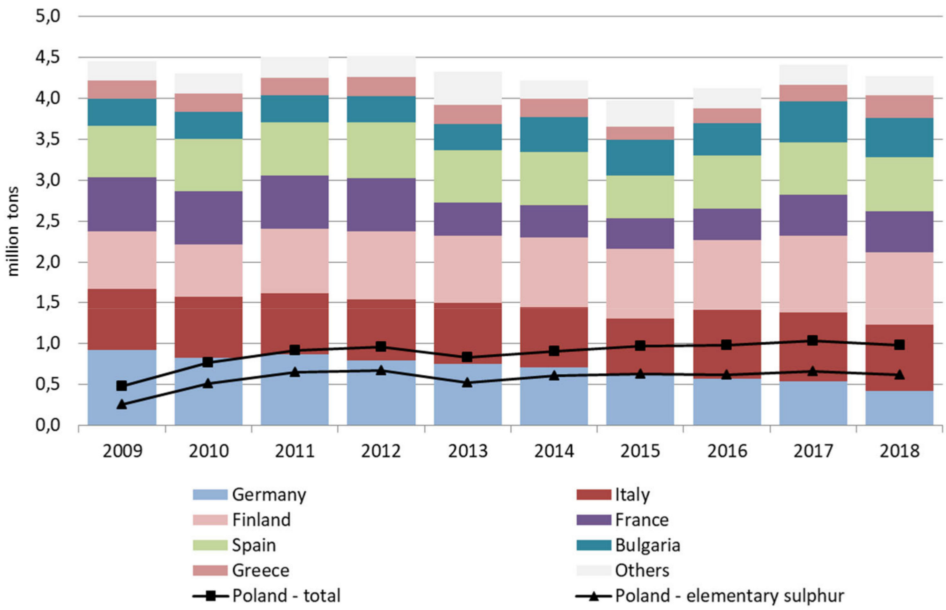

Figure 5. Sulfur production in European Union countries [51,52,73].

In the analyzed decade Polish sulfur export remained in the range of 400,000–580,000 t/y, being directed to many recipients in the world, with the biggest share to Morocco—one of the biggest sulfur consumers in the world (57–83% of sales), but also Brazil, the Czech Republic, Germany, Finland, and Slovakia [51,127]. The total volume of sulfur exported to EU countries was relatively low in the analyzed period and amounted on average to 67,000 t/y, but it is worth mentioning that it has been clearly increasing in recent years.

4. Discussion

Among the industries which seriously contribute to the GDP in Poland, mining occupies fourth place. In 2018, the mining and quarrying industry generated 5.1% of national GDP. At the same time, more than 134,000 people worked in the mining industry in 2018. It is estimated that 540,000 people more are employed in supply companies in this industry [137]. The Polish mining industry is often mistakenly identified with hard coal and lignite mining. It is still dominant in the employment structure (together with copper ore mines), but in reality, the Polish mining industry consists of more than 2600 economic entities (state and private) of various sizes. This number has doubled over the past several years [138]. According to Eurostat, they account for over 15% of enterprises operating in the EU in the "mining and quarrying" sector, which puts Poland in the first place in terms of the number of entities [139]. In Poland, most of this number are opencast mines supplying over 40 different rock minerals necessary for the proper functioning of the economy. To this number another few thousand business entities from the industrial processing section should be added [138] operating based on domestic mineral resources. Moreover, among the 20 largest enterprises in Poland, eight of them, or parts of their groups, directly operate in the mining sector, which includes hard coal, lignite, ore, and hydrocarbon extraction. Analyses of the Mining Chamber of Industry and Commerce [140] indicate that 33% of revenues of mining companies in Poland are transferred to the central and local budgets. This influences the fact that Poland has the highest in the European Union and one of the highest in Europe, as almost 60%, MCI (Mining Contribution Index) which determines what part of revenues of mining companies returns to social budgets in the form of taxes and other fees [141].

At the same time, in recent years the Polish mining industry has been undergoing dynamic changes dictated by macroeconomic, technological, social, and legislative challenges. Access to minerals as factors of production still is (and will remain for a long time) the condition for dynamic industrial development of Poland. Securing their supply from imports must be backed by a committed foreign policy, including an economic one, as well as a sustainable policy of obtaining minerals from domestic sources, both from mineral deposits and secondary and waste sources. This is why it is so important to draw up a minerals security strategy which, in addition to making an inventory of deposits and their legal protection, should contain clear rules to safeguard the common interest. Ultimately, it will contribute to reducing the investment risks associated with exploration and exploitation of deposits [46]. Though the European Commission recommended the design of individual EU Member States' mineral policy strategies a decade ago [15] and numerous "old" European Union members have designed such strategies, in the Central and Eastern Europe such complementary mineral strategy has been introduced only in the Czech Republic [24,142], although work in this area is or was also carried out, inter alia, in Romania, Hungary, and Estonia [20,25]. In the last cases, the different scope of minerals for the proposed actions in the field of mineral policy have been noticeable, but in all cases the emphasis has been on the sustainable use of domestic available mineral sources, especially minerals deposits, also with recycling actions, sometimes also paying attention to the needs in the scope of liquidation of the previous mining activity. The Czech mineral policy is more comprehensive, with appropriate "mineral diplomacy" to provide imported minerals being its important pillar [25]. The work on the mineral policy of Poland to date has also aimed at such a comprehensive approach, highly consistent with the general indications of the EU Raw Materials Initiative [46], but considering its own current and future minerals needs and specific circumstances of the Polish economy, as well as the need to be coherent with other state policies such as environmental policy, energy policy, and land use policy.

Poland's crude oil and natural gas resource potential necessitates continual imports, which in the perspective of at least the next several years will be compounded by their growing consumption, including in important sectors of the domestic economy such as the petrochemical industry, production of mineral fertilizers, and electricity. Crude oil is the main industrial raw material and natural gas is the main industrial and energy raw material for the Polish chemical industry, which is the second largest industrial sector in Poland in terms of value of production sold and the third largest in terms of employment [143]. Obviously, ensuring access to domestic oil and gas deposits is important, also in view of the need to diversify supplies of these raw materials—in accordance with Poland's energy policy [86]. In the context of ensuring energy security, however, domestic resources are not significant, and this situation is unlikely to improve significantly.

However, coking coal deposits occurring in Poland deserve special attention. The quality of these coals is high enough [144] that Poland can produce coke for demanding international markets with virtually no competition in this part of Europe. JSW Group, which is a near monopolist in the domestic market for coking coal mining [120], additionally has its own coking plants. As a result, it supplies both coking coal and coke to its customers. Poland was, in 2018, the second largest exporter of coke in the world after China [120]. In 2019, it already ranked first with nearly 24% share of global exports [145]. JSW Group's strong position results from the resources it possesses as well as from its favorable location in relation to key European steelworks which are the Group's main customers for coking coal and coke. As both the coking coal and coke markets have a global dimension, this strengthens Poland's position in the international arena, particularly in Europe. This is supported by the fact that coking coal has been identified as critical for the EU for many years [79]. At the same time, it is important for the European steel industry (as the final link in the coking coal—coke—steel supply chain) to guarantee a stable supply of basic raw materials at competitive conditions. In this respect, high prices of Chinese raw materials in recent years have encouraged some steelworks to increase purchases from alternative sources, including Poland [146]. Hence, the importance of Poland as a producer of coking coal, given the current state of resources and their reserves sufficiency (Table 5), will certainly be very relevant for years to come. The long sufficiency of reserves in currently developed deposits does not release from the necessity to consider the safeguarding of resources of this raw material in undeveloped deposits, but also in selected prognostic areas [147]. This is particularly important in view of the growing demand from the metallurgical industry and, at the same time, depletion of deposits with the highest quality coal (hard type) most preferred in coke production processes [148].

The production of copper (and related silver) from domestic Cu-Ag ore deposits should be considered in a similar context. Despite significant sufficiency of reserves in the deposits currently exploited (Table 5), the necessity to safeguard also undeveloped resources in selected deposits should be considered in the future. However, raw material consumption trends, domestic, European, and global [149,150], indicate the growing importance of this metal in the perspective of at least the next 20–30 years. These trends include the increased use of electronic products, the increase in the number of electric vehicles, increased renewable energy generation, and the continued drive to improve energy efficiency [85,126,151]. It is particularly important because Poland has been a significant exporter of the raw material for years. Since most of the domestic copper resources are in deposits which have already been developed, in the case of this raw material the protection of prognostic areas should be equally important [130]. At present, most of these areas are covered by concessions for prospecting [131] which will make it possible in the future to determine their resources, assess the content of other metals (not always studied in the past) and geological and mining conditions, mainly connected with exploitation from deeper and deeper levels [152].

On the other hand, the end of exploitation of Zn-Pb ore deposits in Poland should be a basis for clarification of the state mineral policy concerning future coverage of domestic demand for zinc and lead raw materials and future use of the domestic resource base, which is still considerable. In this paper, both zinc and lead are defined as domestic minerals (see Table 3). While a significant share of recycling will maintain this status for lead in the coming years, it is likely that zinc will become a scarce mineral. For years, domestic Zn-Pb steelworks have been forced to use—in the process of zinc production—imported Zn ore concentrates as well as secondary and waste materials, with a strategic assumption to base the production of electrolytic zinc in at least 50% on raw materials classified today as waste [153]. However, the abandonment of the use of primary sources should not release the national decision-makers from a proper policy of protection of several documented, relatively rich Zn-Pb ore deposits in Poland. Currently, their potential exploitation arouses objections of both local communities and self-governments [154].

At present, nickel and titanium ore deposits documented in Poland are not of economic significance mainly due to too low content of metals, and additionally—in the case of titanium ore deposits—high depth and environmental constraints. Although the prospects for consumption of both nickel and titanium indicate a growing demand in the domestic economy, at this point in time, these facilities should not be considered as a source of these key minerals in the foreseeable future. Thus, their deficit nature will be maintained in the following years.

Significant resources of key rock minerals in Poland allow to conclude that in spite of the growing trend of consumption, their predominantly domestic nature remains unthreatened, provided access to the potential resource base is ensured over at least the next several years. Large resources and significant extraction of rock minerals allow the Polish economy to remain independent (or minimally dependent) on their imports. These raw materials are usually not exported, or only marginally. Nevertheless, it should be clearly emphasized that many of them are semi-finished products, the production of which places Poland in the forefront of European manufacturers.

Poland is currently the third largest producer in Europe of ball clays and refractory clays, feldspar raw materials, and kaolin, which are the basic components in the production of ceramic tiles [155]. Due to the limited absorptive capacity of the domestic market, exports (also to EU countries), which account for over 40% of production, represent an opportunity for greater utilization of production capacity [156]. Thus, Poland participates in the building and development of the ceramics industry which is one of the EU's strategic ones [157].

Similarly, the importance of magnesite (used in their raw form or as magnesium compounds) for the production of complex mineral fertilizers, as well as of sulfur used indirectly for the production of phosphate and complex fertilizers should be considered. The production of mineral fertilizers is, in terms of quantity and value, a very important part of the Polish chemical industry [158]. Additionally, links between the fertilizer sector and the agricultural economy make it a guarantor of widely understood national security, mainly food security [159]. The Azoty Group, a leader on the Polish mineral fertilizers industry, is at the same time the second largest producer of these fertilizers in the European Union [160]. In the scope of magnesite and sulfur supplies for the production of mineral fertilizers and other industries listed in Table 4, Poland remains self-sufficient, using the national resource base whose sufficiency is estimated for the next several dozen years. However, considering the bad practices observed in the case of native sulfur deposits, consisting in the development of areas above the deposits limiting the possibilities of their exploitation [84,134], the issue of their protection should receive special attention. Potassium salts are also one of the basic minerals in the production of mineral fertilizers in Poland [143]. As mentioned in the previous chapters—for the country it is a deficit raw material (similarly as another fertilizer raw material—phosphate rock), imported in total, mainly from Belarus and Russia (import to the European Union from these countries is covered with high customs duties, which influences the increase of production costs). However, Poland possesses considerable resources of potassium sulphate salts in Puck Bay in Northern Poland, which in recent years have become the subject of exploration and prospecting works of domestic and foreign companies [161].

The importance of key minerals used in glass production, including glass sand and, to a lesser extent, industrial dolomite (see Table 4), can also be regarded as supranational. Glass production in Poland has been growing for at least 30 years and new investments in this sector create optimistic perspectives for further development of the industry, the total annual production capacity of which is expected to exceed 4 million tons in the coming years. This will account for approximately 10% of glass production in Europe [162]. Additionally, Polish glassworks of artistic and household glass have an excellent brand in the world and most of their production is sold abroad [163]. Prosperity in the group of end customers of the products causes a continuous growth of demand for basic glassmaking raw materials, especially high-quality quartz sand [164]. At present, it comes almost entirely from domestic sources, and proper management of undeveloped deposits will enable this trend to continue in the future.

A thriving part of the Polish mining industry is the extraction of crushed and dimension stone, for which the main driver is the development of domestic housing as well as rail and road infrastructure. These industries are almost entirely based on domestic resources. Exceptions may be made for imported dimension stone with exceptional decorative quality [82]. The domestic nature of these minerals is ensured by a well-recognized and documented resource base in several hundred deposits located throughout the country. On the one hand, the multiplicity of deposits is an advantage, but on the other hand it encourages their reliable evaluation and assessment to select the most valuable deposits that require protection. Although the sufficiency of reserves in exploited deposits is estimated for about 50 years [165] it is with concern that we should look at the recently growing reluctance of local communities to exploitation of such deposits [166,167], often argued by the environmental assets of the region [168]. The lack of formal and legal solutions for counteracting such social conflicts may quickly result in serious limitations of the possibility to exploit many of these deposits.

5. Conclusions

As it results from the data and analyses quoted in the article, the currently developed deposits will make it possible to satisfy the long-term needs of the Polish industry for the following raw materials deemed crucial for the Polish economy:

- Fossil fuels: coking coal;
- Metallic raw materials: copper (including silver);
- Construction minerals (crushed and dimension stone);
- Other minerals for various industries (kaolin, feldspar raw materials, glass sand, magnesite, industrial dolomite, foundry sand, elemental sulfur, gypsum and anhydrite).

Among the minerals currently in deficit, crude oil and natural gas will remain in deficit, and the share of domestic sources in the coverage of domestic demand for them will gradually fall. However, among the scarce minerals ball clays, refractory clays, and as potassium salts deserve special attention. At present, use is of their domestic sources is small (clays) or non-existent (salts), but the potential of the documented resource base makes it possible to conclude that in the future share of domestic production in meeting the domestic demand could significantly increase, especially that the industries using them are developing dynamically in Poland, basing on imported minerals. An appropriate policy for their protection should respond to the changing economic conditions in the country and the directions of development of the sectors of the economy which directly benefit from the mining industry. Moreover, Poland's strong international position in terms of mining and processing of coking coal, copper and silver, and sulfur obliges it to react to changes on European and even global markets. The article also points out the key minerals exploited in Poland, which are an important component in the production of many products intended for export to European markets (e.g., glass sand, kaolin, feldspar raw materials, magnesite). Finally, the list of key minerals for the country is finalized by crushed and dimension stone, as well as gypsum and anhydrite, which are used mainly in the domestic building industry and are the basis for meeting the population's living needs.

Despite the existence of an available resource base, there are concerns on the industry side that competing land uses and environmental and social issues will lead to supply problems for some minerals when mining needs to be expanded. This may be particularly true of rock mineral deposits. Avoidance of such a scenario requires complex regulations concerning protection of deposits, which currently in Poland—despite the existence of relevant legal provisions—do not guarantee protection of the most valuable mineral deposits in the country [46]. On the other hand, the demand for protection of all undeveloped mineral deposits in Poland, even if they are potential sources of the analyzed key minerals for the country's economy, seems to be unjustified, especially with respect to very numerous rock minerals deposits. However, the methodologies developed in Poland for evaluating deposits give grounds for creating an appropriate ranking and selecting those which should be subject to absolute protection. At the same time, the postulate that these deposits should be divided into deposits of national and regional importance seems right [82,84] which would be reflected in planning documents. Obviously, the changing conditions, including environmental, spatial, and legal ones, but also those related to the development of mining technologies and trends in the economy development, force the necessity to update assumptions of these methodologies and, consequently, their results. Periodical updating of resource potential and possibilities of its utilization for industries should be included in the national deposit protection strategy as an element of the postulated, but still not implemented mineral policy of Poland [28].

The concept of strategic minerals is commonly used in many government documents (e.g., [28,69]), also in the context of their proper protection. None of these documents provides a complete definition of strategic minerals, but they indirectly indicate that in Poland this concept should refer exclusively to mineral deposits owned by the State Treasury. According to the Polish Geological and Mining Law [86] these are all deposits of fuels, and metallic and chemical minerals. This assumption is generally correct and, as mentioned above, all deposits which are potential sources of the mentioned minerals should be subject to protection without additional evaluation. Even in this respect it is necessary to take a critical approach to the whole known resource base and eliminate, e.g., deposits with minimal resources or extremely conflictive from the environmental point of view (e.g., located within the boundaries of national parks). However, the analysis carried out in this paper shows that many of the industries that make a significant contribution to Poland's economic development and show optimistic growth prospects are based on many other key minerals, such as key rock minerals. Their acquisition is one of the pillars of Poland's stable development. In view of the above, it is necessary that not only the obvious strategic raw materials, but also key rock minerals are included in the national mineral policy, which has been in place for several years, and in other government documents.

Despite an in-depth discussion, supported by references, the issues raised in article require supplementing and continuation in several aspects. At the same time, it can make a significant contribution to the implementation of the country's mineral policy. Firstly, it should be underlined that the list of key minerals should be periodically updated based on production and consumptions trends. Moreover, the detailed analysis is required for assessment of availability of the resource base of domestic or mainly domestic key minerals. Such assessment should include environmental and spatial conditions and—if possible—social ones. Together with quality and quantity analysis it would be a base for updated valorization process of recognized deposits. A significant drawback of the national mineral policy emerging in Poland is the lack of an up-to-date list of deposits which could be a source of selected key minerals for Polish economy and which should be protected (the latest analyses in this area come from 2015–2016). This is of particular importance in terms of dynamically changing spatial and social conditions.

As for limitations of the study, it should be noted that the number of key minerals for the Polish economy is quite extensive and they represent several mineral groups. Because of the volume, it was not possible to carry out in-depth analyzes for all these minerals. In the future, therefore, it might be worthwhile for individual mineral groups to make in-depth analyses of the issues discussed, and to compare to the situation in this respect in other Central and Eastern Europe countries.

Author Contributions: Conceptualization, A.K.-N. and K.G.; methodology, A.K.-N.; software, not applicable; validation, K.G., J.K.; formal analysis, A.K.-N., K.G., and J.K.; investigation, not applicable; resources A.K.-N., J.K.; data curation, J.K.; writing—original draft preparation, A.K.-N. and K.G.; writing—review and editing, K.G. and J.K.; visualization, A.K.-N., J.K.; supervision, K.G.; project administration, A.K.-N.; funding acquisition, A.K.-N. All authors have read and agreed to the published version of the manuscript.

Funding: This article has been supported by the Polish National Agency for Academic Exchange under Grant No PPI/APM/2019/1/00079/U/001.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: This research was written as part of research in projects by the Polish National Agency for Academic Exchange under Grant No PPI/APM/2019/1/00079/U/001.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. The 2030 Agenda for Sustainable Development. Report of the World Commission on Environment and Development: Our Common Future. Available online: https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf (accessed on 10 February 2021).
2. Organization for Economic Cooperation and Development. *Policies to Enhance Sustainable Development*; Meating of the OECD Council at Ministerial Level; OECD Publishing: Paris, France, 2001; Available online: https://www.oecd.org/greengrowth/1869800.pdf (accessed on 10 February 2021).
3. Mancini, L.; Vidal Legaz, B.; Vizzarri, M.; Wittmer, D.; Grassi, G.; Pennington, D. *Mapping the Role of Raw Materials in Sustainable Development Goals. A Preliminary Analysis of Links, Monitoring Indicators and Related Policy Initiatives*; Publications Office of the European Union: Luxembourg, 2019. [CrossRef]
4. Ericsson, M.; Löf, O. Mining's contribution to national economies between 1996 and 2016. *Miner. Econ.* **2019**, *32*, 223–250. [CrossRef]
5. European Commission. *Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability*; Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2020) 474 Final; European Commission: Brussels, Belgium, 2020.
6. European Commission. *A New Industrial Strategy for Europe*; Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2020) 102 Final; European Commission: Brussels, Belgium, 2020.
7. World Trade Organization. *Trade and Development: Recent Trends and the Role of the WTO*; World Trade Report; WTO: Geneva, Switzerland, 2014; Available online: https://www.wto.org/english/res_e/booksp_e/world_trade_report14_e.pdf (accessed on 10 February 2021).
8. Nieć, M.; Galos, K.; Szamałek, K. Main challenges of mineral resources policy of Poland. *Resour. Policy* **2014**, *42*, 93–103. [CrossRef]
9. Galos, K.; Tiess, G.; Kot-Niewiadomska, A.; Murguia, D.; Wertichova, B. Mineral Deposits of Public Importance (MDoPI) in relation to the Project of National Mineral Policy of Poland. *Gospod. Surowcami Miner. Miner. Resour. Manag.* **2018**, *34*, 5–24. [CrossRef]
10. Lewicka, E.; Burkowicz, A. Ocena obecnego stanu pokrycia potrzeb surowcowych gospodarki krajowej (Assessment of the current state of coverage of the domestic economy's demand for mineral raw materials). *Przegląd Geol.* **2018**, *66*, 144–152. (In Polish with English Abstract)
11. Lewicka, E. Rational use of selected mining by-products in the ceramic industry in Poland. *Gospod. Surowcami Miner. Miner. Resour. Manag.* **2020**, *36*, 59–76. [CrossRef]
12. Galos, K.; Lewicka, E.; Burkowicz, A.; Guzik, K.; Kot-Niewiadomska, A.; Kamyk, J.; Szlugaj, J. Approach to identification and classification of the key, strategic and critical minerals important for the mineral security of Poland. *Resour. Policy* **2021**, *70*, 101900. [CrossRef]
13. European Commission. *The Raw Materials Initiative: Meeting our Critical Needs for Growth and Jobs in Europe*; Communication from the Commission to the European Parliament and the Council, COM (2008) 699 Final; European Commission: Brussels, Belgium, 2008.
14. SIP 2013. Strategic Implementation Plan (SIP) of the European Innovation Partnership (EIP) on Raw Materials. Part II. Priority Areas, Action Areas and Actions. Final Version-18/09/2013. Available online: https://ec.europa.eu/growth/sectors/raw-materials/eip/strategic-implementation-plan_en (accessed on 30 April 2021).
15. European Commission. *EUROPE 2020. A Strategy for Smart, Sustainable and Inclusive Growth*; Communication from the Commission, COM(2010) 2020 Final; European Commission: Brussels, Belgium, 2010.
16. European Commission. *Roadmap to a Resource Efficient Europe*; Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2011) 571 Final; European Commission: Brussels, Belgium, 2011.
17. European Commission. *The European Green Deal*; Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2019) 640 Final; European Commission: Brussels, Belgium, 2019.
18. European Commission. *Regulation of the European Parliament and of the Council of 18 June 2020 on the Establishment of a Framework to Facilitate Sustainable Investment, and Amending Regulation*; (EU) 2019/2088. O.J.E.U. L 198/13; European Commission: Brussels, Belgium, 2020.
19. European Commission. *Proposal for a Regulation of the European Parliament and of the Council Establishing a Recovery and Resilience Facility*; COM(2020) 408 Final; European Commission: Brussels, Belgium, 2020.
20. Tiess, G.; Majumder, T.; Cameron, P. (Eds.) *Encyclopedia of Mineral and Energy Policy*; Springer: Berlin/Heidelberg, Germany, 2016.
21. Endl, A. Addressing "wicked problems" through governance for sustainable development—a comparative analysis of national mineral policy approaches in the European Union. *Sustainability* **2017**, *9*, 1830. [CrossRef]
22. Lewicka, E.; Lewicka, E.; Guzik, K.; Galos, K. On the Possibilities of the Critical Raw Materials Production from the EU's Primary Sources. *Resources* **2021**, under review.

23. European Commission. *Improving Framework Conditions for Extracting Minerals for the EU. Report of the RMSG Ad-Hoc Working Group on Exchanging Best Practices on Land Use Planning, Permitting and Geological Knowledge Sharing*; European Commission: Brussels, Belgium, 2010.
24. Sivek, M.; Kavina, P.; Jirásek, J. New mineral policy of the Czech Republic of June 2017. *Resour. Policy* **2019**, *60*, 246–254. [CrossRef]
25. Tiess, G.; Murguía, D. Report on Policy Reommendations and Stakeholder Feedback. SCRREEN Project, Deliverable 7.4. 2019. Available online: SCRREEN-D7.4-Report-on-policy-recommendations-and-stakeholder-feedback.pdf (accessed on 30 April 2021).
26. Ruokonen, E. Preconditions for successful implementation of the Finnish standard for sustainable mining. *Extr. Ind. Soc.* **2020**, *7*, 611–620.
27. Haikola, S.; Anshelm, J. Mineral policy at a crossroads? Critical reflections on the challenges with expanding Sweden's mining sector. *Extr. Ind. Soc.* **2016**, *3*, 508–516. [CrossRef]
28. Lesser, P.; Gugerell, K.; Poelzer, G.; Hitch, M.; Tost, M. European mining and the social licence to operate. *Extr. Ind. Soc.* **2020**. [CrossRef]
29. Vesalon, L.; Cretan, R. Cyanide kills! Environmental movements and the construction of environmental risk at Rosia Montana, Romania. *Area* **2013**, *45*, 443–451. [CrossRef]
30. Guzik, K.; Galos, K.; Kot-Niewiadomska, A.; Eerola, T.; Eilu, P.; Carvalho, J.; Fernandez-Naranjo, F.J.; Arvidsson, R.; Arvanitidis, N. A look at the potential benefits and constraints of development of CRMs production in the EU—Analysis of selected case studies. *Resources* **2021**, under review.
31. Radwanek-Bąk, B.; Galos, K.; Nieć, M. Surowce kluczowe, strategiczne i krytyczne dla polskiej gospodarki (Key, strategic and critical raw materials for the Polish economy). *Przegląd Geol.* **2018**, *66*, 153–159. (In Polish with English Abstract)
32. Erdmann, L.; Graedel, T.E. Criticality of non-fuel minerals: A review of major approaches and analyses. *Environ. Sci. Technol.* **2011**, *45*, 7620–7630. [CrossRef] [PubMed]
33. Graedel, T.E.; Barr, R.; Chandler, C.; Chase, T.; Choi, J.; Christoffersen, L.; Friedlander, E.; Henly, C.; Jun, C.; Nassar, N. Methodology of metal criticality determination. *Environ. Sci. Technol.* **2012**, *46*, 1063–1070. [CrossRef] [PubMed]
34. Hounari, Y.; Speirs, J.; Gross, R. *Materials Availability: Comparison of Material Criticality Studies—Methodologies and Results Working Paper III*; UK Energy Research Centre: London, UK, 2013; Available online: https://d2e1qxpsswcpgz.cloudfront.net/uploads/2020/03/materials-availability-working-paper-iii.pdf (accessed on 25 March 2021).
35. Bedder, J.C.M. Classifying critical materials: A review of European approaches. *Appl. Earth Sci.* **2015**, *124*, 207–212. [CrossRef]
36. Dewulf, J.; Blengini, G.A.; Pennington, D.; Nuss, P.; Nasaar, N.T. Criticality on the international scene: Quo vadis? *Resour. Policy* **2016**, *50*, 169–176. [CrossRef]
37. Jin, Y.; Kim, J.; Guillaume, B. Review of critical materials studies. *Resour. Conserv. Recycl.* **2016**, *113*, 77–87. [CrossRef]
38. Blengini, G.A.; Nuss, P.; Dewulf, J.; Nita, V.; Peiro, L.T.; Vidal-Legaz, B.; Latunussa, C.; Mancini, L.; Blagoeva, D.; Pennington, D.; et al. EU methodology for critical raw materials assessment: Policy needs and proposed solutions for incremental improvements. *Resour. Policy* **2017**, *53*, 12–19. [CrossRef]
39. Graedel, T.; Harper, E.M.; Nassar, N.T.; Nuss, P.; Reck, B.K. Criticality of metals and metalloids. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 4257–4262. [CrossRef] [PubMed]
40. Schrijvers, D.; Hool, A.; Blengini, G.A.; Chen, W.Q.; Dewulf, J.; Eggert, R.; Ellen, L.; Gauss, R.; Gossin, J.; Habib, K.; et al. A review of methods and data to determine raw material criticality. *Resour. Conserv. Recycl.* **2020**, *155*, 104617. [CrossRef]
41. Yu, Y. Assessing the criticality of minerals used in emerging technologies in China. *Gospod. Surowcami Miner. Miner. Resour. Manag.* **2020**, *36*, 5–20. [CrossRef]
42. Galos, K.; Smakowski, T. Wstępna propozycja metodyki identyfikacji surowców kluczowych dla polskiej gospodarki (The initial proposal of methodology for identification of raw materials key for Polish economy). *Bull. Miner. Energy Econ. Res. Inst. Pol. Acad. Sci.* **2014**, *88*, 59–79. (In Polish with English Abstract)
43. Radwanek-Bąk, B. Zasoby kopalin w Polsce w aspekcie oceny surowców krytycznych dla Unii Europejskiej (Mineral resources in Poland in the view of the assessment of raw materials critical for the European Union). *Gospod. Surowcami Miner. Miner. Resour. Manag.* **2014**, *27*, 5–19. (In Polish with English Abstract)
44. Radwanek-Bąk, B. Określenie surowców kluczowych dla polskiej gospodarki (Determining raw materials key for Polish economy). *Bull. Miner. Energy Econ. Res. Inst. Pol. Acad. Sci.* **2016**, *96*, 241–254. (In Polish with English Abstract)
45. Kulczycka, J.; Pietrzyk-Sokulska, E.; Koneczna, R.; Galos, K.; Lewicka, E. *Surowce Kluczowe dla Polskiej Gospodarki (Key Raw Materials for the Polish Economy)*, 1st ed.; Publishing House of MEERI PAS: Kraków, Poland, 2016. (In Polish with English Abstract)
46. National Mineral Policy (Draft). Ministry of Environmental. Poland. 2019. Available online: http://psp.mos.gov.pl/images/pdf/PSP_projekt.pdf (accessed on 10 September 2020).
47. Nieć, M. Stulecie idei ochrony złóż kopalin (Century of the idea of mineral deposits safeguarding). *Gospod. Surowcami Miner. Miner. Resour. Manag.* **2008**, *24*, 47–50. (In Polish with English Abstract)
48. Paulo, A. Kierunki ochrony zasobów kopalin (Direction of mineral deposit safeguarding). In *Geologiczne Aspekty Ochrony Środowiska Naturalnego (Geological Aspects of Environmental Protection)*, 1st ed.; Wydawnictwo AGH: Poland, Kraków, 1991. (In Polish)

49. Ney, R. Ochrona złóż i zasobów kopalin (Safeguarding of mineral deposits and resources). In *Przemiany Środowiska Naturalnego a Ekorozwój (Changes in the Natural Environment and Eco-Development)*, 1st ed.; Wydawnictwo GEOSFERA: Kraków, Poland, 2001. (In Polish)
50. Nieć, M. Problemy Ochrony Złóż Kopalin (The problems of mineral deposits safeguarding). *Przegląd Geol.* **2003**, *51*, 870–875. (In Polish with English Abstract)
51. Kasztelewicz, Z.; Ptak, M. Wybrane problemy zabezpieczania złóż węgla brunatnego w Polsce dla odkrywkowej działalności górniczej (Chosen problems of securing brown coal deposits in Poland for opencast mining activity). *Polityka Energetyczna* **2009**, *12*, 263–276. (In Polish with English Abstract)
52. Nieć, M.; Radwanek-Bąk, B. Propozycja ustawowej ochrony niezagospodarowanych złóż kopalin (The proposition of statutory protection of undeveloped mineral deposits). *Bezpieczeństwo Pr. Ochr. Sr. Górnictwie* **2011**, *7*, 12–17. (In Polish)
53. Szamałek, K. Ochrona niezagospodarowanych złóż kopalin (Safeguarding of undeveloped mineral deposits). *Stud. Kom. Przestrz. Zagospod. Kraj.* **2011**, *141*, 39–45. (In Polish with English Abstract)
54. Gałaś, S.; Gałaś, A. Protection of mineral resources as a part of spatial planning in Poland and in Slovakia. *Pol. J. Environ. Stud.* **2012**, *21*, 73–77.
55. Kasztelewicz, Z.; Ptak, M. Zabezpieczenie niezagospodarowanych złóż kopalin jako najważniejszy gwarant istnienia i rozwoju polskiego górnictwa odkrywkowego (Protection of non-developed mineral deposits as the most important guarantor of existence and development of the Polish surface mining). *Przegląd Górniczy* **2012**, *8*, 20–26. (In Polish with English Abstract)
56. Nieć, M.; Radwanek-Bąk, B. Ochrona złóż kopalin jako element planowania i zagospodarowania przestrzennego—Problem prawne i mentalne (Protection of mineral deposits as an element of planning and land development—Formal and mental problems). *Przegląd Górniczy* **2012**, *8*, 3–6. (In Polish with English Abstract)
57. Kostka, E.A. Ochrona złóż kopalin w planach zagospodarowania przestrzennego w świetle prawa geologicznego i górniczego—Uwagi de lege lata i de legi ferenda (Mineral deposits protection in area development plan, under the geological and mining law—Comments de lege lata and de lege ferenda). *Gór. Odkryw.* **2014**, *56*, 25–31. (In Polish with English Abstract)
58. Lipiński, A. Niektóre problemy ochrony złóż kopalin w planowaniu przestrzennym (Selected problems of mineral deposits protection in spatial planning). *Zesz. Nauk. IGSMiE PAN* **2015**, *91*, 135–148. (In Polish with English Abstract)
59. Wiland, M. Złoża kopalin i ich wydobywanie a planowanie i zagospodarowanie przestrzenne (Mineral deposits and their extraction with respect to planning and spatial development). *Zesz. Nauk. IGSMiE PAN* **2015**, *91*, 227–245. (In Polish with English Abstract)
60. Gałaś, S.; Gałaś, A. Mineral deposits protection in terms of spatial conflicts with road construction projects. In *Ecology, Economics, Education and Legislation. Vol. 3 Environmental Economics, Education and Accreditation in Geosciences. Book 5 Vol. 3, Proceedings of the 16th International Multidisciplinary Scientific Geoconference, Albena, Bulgaria, 30 June–6 July 2016*; Stef92 Technology Ltd.: Sofia, Bulgaria, 2016.
61. Gałaś, S. Assessment of implementation of protection of mineral deposits in spatial planning in Poland. *Land Use Policy* **2017**, *67*, 584–596. [CrossRef]
62. Kasztelewicz, Z.; Ptak, M. Zabezpieczenie złóż kopalin a Polityka Surowcowa Państwa (The issue of resources protection in the context of the National Mineral Policy). *Zesz. Nauk. IGSMiE PAN* **2018**, *106*, 53–60. (In Polish with English Abstract)
63. Stefanowicz, J. Polityka surowcowa—Ochrona obszarów prognostycznych i perspektywicznych złóż kopalin dla rozwoju kraju w świetle regulacji zintegrowanego zarządzania przestrzenią (Mineral policy—Protection of prognostic and perspective mineral deposits for national development in the light of integrated space management regulations). *Zesz. Nauk. IGSMiE PAN* **2018**, *106*, 163–180. (In Polish with English Abstract)
64. Gałaś, S.; Kot-Niewiadomska, A.; Gałaś, A.; Kondela, J.; Wertichová, B. Instruments of Mineral Deposit Safeguarding in Poland, Slovakia and Czechia—Comparative Analysis. *Resources* **2021**, *10*, 16. [CrossRef]
65. Biała Księga Ochrony Złóż Kopalin (White Book of Mineral Deposit Safeguarding). Ministerstwo Środowiska. Warszawa. 2015. Available online: https://infolupki.pgi.gov.pl/sites/default/files/czytelnia_pliki/1/biala_ksiega_zloz_kopalin.pdf (accessed on 20 January 2021).
66. Better Policies for 2030. An OECD Action Plan on the Sustainable Development Goals. OECD. 2016. Available online: https://www.oecd.org/dac/Better%20Policies%20for%202030.pdf (accessed on 19 March 2021).
67. Espey, J.; Lafortune, G.; Schmidt-Traub, G. Delivering the Sustainable Development Goals for all: Policy priorities for leaving no one behind. In *Development Cooperation Report 2018. Joining Forces to Leave No One Behind*; OECD Publishing: Paris, France, 2018; Available online: https://www.oecd-ilibrary.org/docserver/dcr-2018-9-en.pdf?expires=1616157384&id=id&accname=guest&checksum=0A95C3CD57CF93082C2A8D025490D251 (accessed on 20 January 2021).
68. European Commission. *Raw Materials Scoreboard 2018*; European Innovation Partnership on Raw Materials; European Commission: Brussels, Belgium, 2018.
69. Production-Imports-Exports. In *Statistical Data for the Years 2000–2018*; The Central Statistical Office: Warsaw, Poland, 2018.
70. Szuflicki, M.; Malon, A.; Tymiński, M. *The Balance of Mineral Resources Deposits in Poland, Editions 2011–2019*; The Polish Geological Institute—National Research Institute: Warsaw, Poland, 2019. (In Polish with English Online Version). Available online: http://geoportal.pgi.gov.pl/surowce (accessed on 10 January 2021).
71. PRODCOM Database. Available online: https://ec.europa.eu/eurostat/web/prodcom/data/database (accessed on 20 January 2021).

72. World Mineral Production. Years 2010–2018. British Geological Survey: Nottingham, UK. Available online: https://www2.bgs.ac.uk/mineralsUK/statistics/worldStatistics.html (accessed on 20 January 2021).
73. World Mining Data. Available online: https://www.world-mining-data.info/ (accessed on 20 January 2021).
74. Pepłowska, M.; Gawlik, L. Gaz ziemny w zrównoważonym rozwoju krajowej gospodarki (Natural gas in the sustainable development of the domestic economy). *Zesz. Nauk. IGSMiE PAN* **2017**, *98*, 39–50. (In Polish with English Abstract)
75. National Report of the President of The Energy Regulatory Office. Energy Regulator Office: Warszawa, Poland, 2019. Available online: https://www.ure.gov.pl/en/about-us/reports/67,Reports.html (accessed on 15 March 2021).
76. Rybak, A.; Manowska, A. The future of crude oil and hard coal in the aspect of Poland's energy security. *Polityka Energetyczna-Energy Policy J.* **2018**, *21*, 141–154. [CrossRef]
77. Kamyk, J.; Kot-Niewiadomska, A.; Galos, K. The criticality of crude oil for energy security: A case of Poland. *Energy* **2021**, *220*. [CrossRef]
78. Kamyk, J.; Kot-Niewiadomska, A. Obroty międzynarodowe ropą naftową w Polsce w latach 1990–2017 (International crude oil trade in Poland in 1990–2017). In Proceedings of the XXIII National Conference The Issues of Energy Resources and Energy in the National Economy, Kościelisko, Poland, 13–16 October 2019. (In Polish).
79. European Commission. *Study on the EU's List of Critical Raw Materials (2020). Critical Raw Materials Factsheets*; Final; European Commission: Brussels, Belgium, 2020.
80. Metallurgical Coal. Resources and Energy Quarterly. 2019. Available online: https://publications.industry.gov.au/publications/resourcesandenergyquarterlymarch2019/documents/Resources-and-Energy-Quarterly-March-2019-Met-Coal.pdf (accessed on 3 April 2021).
81. Galos, K.; Lewicka, E. Ocena znaczenia surowców mineralnych nieenergetycznych dla gospodarki krajowej (Assessment of importance of non-energy mineral raw materials for the domestic economy). *Zesz. Nauk. IGSMiE PAN* **2016**, *92*, 7–36.
82. *Mineral Yearbook of Poland 2013*; Mineral and Energy Economy Research Institute Polish Academy of Science, Polis Geological Institute-National Research Institute: Warszawa, Poland, 2014. Available online: http://geoportal.pgi.gov.pl/css/surowce/images/2013/Minerals_Yearbook_of_Poland_2013.pdf (accessed on 10 February 2021).
83. Szlugaj, J.; Naworyta, W. Analiza zmian podaży gipsu w Polsce w świetle rozwoju odsiarczania spalin w elektrowniach konwencjonalnych (Analysis of the changes in Polish gypsum resources in the context of flue gas desulfuruzation in conventional power plants). *Gospod. Surowcami Miner. Miner. Resour. Manag.* **2015**, *31*, 93–108. [CrossRef]
84. Kamyk, J.; Kot-Niewiadomska, A. Ocena dostępności polskich złóż siarki rodzimej w kontekście zapotrzebowania na surowiec (Assessment of availability of Polish native sulfur deposits in the context of raw material demand). *Gór. Odkryw.* **2018**, *3*, 47–56. (In Polish with English Abstract) Available online: https://www.igo.wroc.pl/wp-content/uploads/2018/12/GO_03_2018_07_47_56.pdf (accessed on 15 February 2020).
85. Galos, K.; Burkowicz, A.; Czerw, H.; Figarska-Warchoł, B.; Gałaś, A.; Guzik, K.; Kamyk, J.; Kot-Niewiadomska, A.; Lewicka, E.; Szlugaj, J. *Ocena Obecnego Oraz Przyszłego Zapotrzebowania Gospodarki Krajowej na Surowce w Perspektywie 2025, 2030, 2040 i 2050 Roku (Assessment of the Current and Future Demand of the National Economy for Raw Materials in the Perspective of 2025, 2030, 2040 and 2050)*; Mineral and Energy Economy Research Institute PAS: Kraków, Poland, 2020; Unpublished.
86. Energy Policy of Poland until 2040. Ministry of Climate and Environment. Poland. 2021. Available online: https://www.gov.pl/web/klimat/polityka-energetyczna-polski (accessed on 10 March 2021).
87. EUROCOAL. Country Profiles—Poland. Available online: https://euracoal.eu/info/country-profiles/poland/ (accessed on 10 February 2021).
88. Błachowicz, K. Życie po życiu akumulator (Life after life of battery). *Recykling* **2017**, *1*, 48–55. (In Polish)
89. Izba Gospodarcza Metali Nieżelaznych i Recyklingu (Economic Chamber of Non-Ferrous Metals and Recycling). Available online: http://www.igmnir.pl/zlom-odpady-metali-niezelaznych/olowiu (accessed on 10 March 2021).
90. Szamałek, K. Rational mineral deposit management in the light of mineral resources theory. *Gospod. Surowcami Miner. Miner. Resour. Manag.* **2011**, *27*, 5–15.
91. Piwocki, M.; Kasiński, J. Metoda ekonomiczno-sozologicznej waloryzacji złóż węgla brunatnego. *Przegląd Geol.* **1993**, *35*, 346–359.
92. Bromowicz, J.; Figarska-Warchoł, B.; Karwacki, A.; Kolasa, A.; Magiera, J.; Rembiś, M.; Smoleńska, A.; Stańczyk, G. *Waloryzacja Polskich Złóż Kamieni Budowlanych i Drogowych na tle Przepisów Unii Europejskiej (Valorization of Polish Deposits of Crushed and Dimension Stones in Comparison with European Union Regulations)*, 1st ed.; Uczelniane Wydawnictwo Naukowo-Dydaktyczne AGH: Kraków, Poland, 2005. (In Polish)
93. Nieć, M. Waloryzacja złóż i obszarów perspektywicznych. In *Programowanie Eksploatacji i Zagospodarowania Terenów Pogórniczych Złóż Kruszywa Naturalnego w Dolinach Rzek Karpackich na Przykładzie Karpat Zachodnich (PO ANG)*, 1st ed.; Stryszewski, M., Ed.; Uczelniane Wydawnictwo Naukowo-Dydaktyczne AGH: Kraków, Poland, 2006. (In Polish)
94. Kasiński, J.R.; Piwocki, A.H.; Mazurek, S. Waloryzacja i ranking złóż węgla brunatnego w Polsce (Valorization and ranking list of lignite deposits in Poland). *Prace Państwowego Inst. Geol.* **2006**, *187*, 1–79.
95. Nieć, M.; Ślizowski, K.; Kawulak, M.; Lankof, L.; Salamon, E. *Kryteria Ochrony Złóż Pozostawionych Przez Likwidowane Kopalnie w Warunkach Zrównoważonego Rozwoju na Przykładzie Modelowym Złóż Siarki Rodzimej (PO ANG)*, 1st ed.; Publishing House of MEERI PAS: Kraków, Poland, 2007. (In Polish)

96. Sermet, E.; Górecki, J. Ocena geologiczno-górniczej atrakcyjności złóż kamieni łamanych i blocznych (Assessment of geological and mining attractiveness of crushed and dimension stones). *Kruszywa* **2007**, *5*, 8–12. (In Polish). Available online: https://www.kieruneksurowce.pl/Resources/art/827/bmp_4790ad438f5ff.pdf (accessed on 3 March 2021).
97. Jureczka, J.; Galos, K. Propozycja kryteriów waloryzacji złóż oraz obszarów prognostycznych i perspektywicznych złóż węgla kamiennego pod kątem ich ochrony (Proposals of criteria for valorization of deposits and prognostic/perspective areas of hard coal for their protection). *Zesz. Nauk. IGSMiE PAN* **2010**, *79*, 289–297.
98. Uliasz-Misiak, B.; Winid, B. Criteria for the Valorization of Hydrocarbon Deposits in Terms of Their Protection. *Rocz. Ochr. Srodowiska* **2013**, *15*, 2204–2217.
99. Radwanek-Bąk, B.; Nieć, M. Valorization of undeveloped industrial rock deposits in Poland. *Resour. Policy* **2014**, *45*, 290–298. [CrossRef]
100. Wołkowicz, S.; Olimpia, K.; Andrzejewska-Kubrak, K.; Brzeziński, D. Ochrona złóż kopalin—Koncepcja waloryzacji i selekcji złóż o znaczeniu publicznym (Safeguarding of mineral raw materials deposits—A concept of valorization and selection of mineral deposits of public importance). *Biul. PIG* **2018**, *472*, 171–184. [CrossRef]
101. Kot-Niewiadomska, A.; Galos, K.; Lewicka, E.; Burkowicz, A.; Kamyk, J.; Szlugaj, J. Methodology of assignment of Mineral Deposits of Public Importance proposed by MINATURA2020 Project and results of its pilot testing in the Dolnośląskie Province (SW Poland). *Gospod. Surowcami Miner. Miner. Resour. Manag.* **2017**, *33*, 71–94. [CrossRef]
102. The Act of 27 March 2003 on Spatial Planning and Development (Journal of Laws 2003 No 80, Item 717) as Amended (Poland). Available online: https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20030800717/U/D20030717Lj.pdf (accessed on 10 January 2021).
103. The Act of 9 June 2011 Geological and Mining Law (Journal of Laws of 2011, No. 163, item 981) as Amended. Available online: https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20111630981/U/D20110981Lj.pdf (accessed on 10 March 2021).
104. Nieć, M.; Radwanek-Bąk, B. *Ochrona i Racjonalne Wykorzystywanie Złóż Kopalin (Protection and Rational Use of Mineral Deposits)*, 1st ed.; Publishing House of MEERI PAS: Kraków, Poland, 2014. (In Polish)
105. Nieć, E.; Salamon, E.; Auguścik, J. Zmiany i zużycie zasobów złóż rud cynku i ołowiu w Polsce (Variation and utilization of zinc-lead ore resources in Poland). *Zesz. Nauk. IGSMiE PAN* **2018**, *102*, 129–152. Available online: https://journals.pan.pl/dlibra/publication/123733/edition/107940/content (accessed on 10 March 2021).
106. Mikulski, S.Z. Występowanie i zasoby perspektywiczne rud niklu w Polsce (The occurrence and prospective resources of nickel ores in Poland). *Biul. PIG* **2012**, *448*, 287–296. Available online: https://geojournals.pgi.gov.pl/bp/article/view/29461/21117 (accessed on 10 March 2021).
107. Nieć, M. Ocena geologiczno-gospodarcza złóż wanadonośnych rud tytanomagnetytowych masywu suwalskiego (Geo-economic evaluation of vanadiferous titanomagnetite deposits in Suwałki massif in Poland). *Gospod. surowcami Miner. Miner. Resour. Manag.* **2003**, *19*, 5–28. Available online: https://gsm.min-pan.krakow.pl/Geo-economic-evaluation-of-vanadiferous-titanomagnetite-deposits-in-Suwalki-massif,96372,0,2.html (accessed on 15 March 2021).
108. Wiszniewska, J.; Petecki, Z. Mezoproterozoiczne złoże rud tytanomagnetytowych w suwalskim masywie anortozytowym i jego środowisko geologiczne (A Mesoproterozoic titanomagnetite ore deposit in Suwalki Anorthosite Massif and its geological environment). *Górnictwo Odkryw.* **2014**, *2–3*, 44–50. Available online: https://www.igo.wroc.pl/wp-content/uploads/2015/09/GO_2-3_7.pdf (accessed on 15 March 2021).
109. Siemiątkowski, J. The ilmenite-magnetite ore deposit Krzemianka in northeastern Poland: Brief history of discovery and exploration. *Geol. Q.* **1998**, *42*, 443–450.
110. Świerubska, T. Historia powoływania pierwszego parku krajobrazowego w Polsce a projekt wydobycia rud tytanomagnetytowych masywu suwalskiego (History of the first landscape park established in Poland in regards to a project of titano-magnetite ores in Suwalki Massif). *Górnictwo Odkryw.* **2014**, *2–3*, 40–43. Available online: https://www.igo.wroc.pl/wp-content/uploads/2015/09/GO_2-3_6.pdf (accessed on 15 March 2021).
111. Nieć, M. (Ed.) *Waloryzacja Niezagospodarowanych Złóż Kopalin Skalnych w Polsce (Valorisation of Undeveloped Rock Mineral Deposits in Poland)*, 1st ed.; Poltegor Institute: Wrocław, Poland, 2013. (In Polish)
112. MINATURA Project. Available online: https://minatura2020.eu/ (accessed on 10 January 2021).
113. Galos, K.; Nieć, M. Europejska koncepcja złóż kopalin o znaczeniu publicznym (projekt MINATURA2020 (European concept of mineral deposits of public importance (MINATURA2020 project). *Zesz. Nauk. IGSMiE* **2015**, *91*, 35–43. Available online: https://min-pan.krakow.pl/wp-content/uploads/sites/4/2017/12/03-galos-niec.pdf (accessed on 10 March 2021).
114. Manowska, A.; Osadnik, K.; Wyganowska, M. Economic and social aspects of restructuring Polish coal mining: Focusing on Poland and the EU 2017. *Resour. Policy* **2017**, *52*, 192–200. [CrossRef]
115. *Climate and Energy Policies in Poland*; European Parliament: Brussels, Belgium, 2017. Available online: https://www.europarl.europa.eu/RegData/etudes/BRIE/2017/607335/IPOL_BRI(2017)607335_EN.pdf (accessed on 10 March 2021).
116. Alves Dias, P.; Kanellopoulos, K.; Medarac, H.; Kapetaki, Z.; Miranda Barbosa, E.; Shortall, R.; Czako, V.; Telsnig, T.; Vazquez Hernandez, C.; Lacal Arantegui, R.; et al. *EU Coal Regions: Opportunities and Challenges Ahead*; Publications Office of the European Union: Luxembourg, 2018.
117. Brauers, H.; Oei, P.-U. The political economy of coal in Poland: Drivers and barriers for a shift away from fossil fuels. *Energy Policy* **2020**, 140. [CrossRef]

118. EUROCOAL. Country Profiles—Germany. Available online: https://euracoal.eu/info/country-profiles/germany/ (accessed on 10 February 2021).
119. Coal Production and Consumption Statistics. Eurostat. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php/Coal_production_and_consumption_statistics#Consumption_and_production_of_hard_coal (accessed on 20 January 2021).
120. Jastrzębska Spółka Węglowa, S.A. Consolidated Annual Report for 2018. Available online: https://www.jsw.pl/raportroczny-2018/en/download-center/ (accessed on 9 March 2021).
121. Wardell Armstrong International; Jastrzębska Spółka Węglowa SA. Mineral Expert's Report. 2013. Available online: https://www.jsw.pl/fileadmin/user_files_ri/raporty_ds_zloz/Mineral_Experts_Report__2013.pdf (accessed on 12 March 2021).
122. Strategia JSW, SA. z Uwzględnieniem Spółek Zależnych Grupy Kapitałowej JSW na Lata 2020–2030. Jastrzębska Spółka Węglowa. *Jastrzębie Zdrówj.* 2020. Available online: https://www.jsw.pl/fileadmin/user_files_ri/strategia/2020/prezentacja_-_strategia_gk_jsw_2020-2030_final_2020_03_19.pdf (accessed on 9 March 2021).
123. Oszczepalski, S.; Speczik, S.; Zieliński, K.; Chmielewski, A. The Kupferschiefer Deposits and Prospects in SW Poland: Past, Present and Future. *Minerals* **2019**, *9*, 592. [CrossRef]
124. Kombinat Górniczo-Hutniczy Miedzi SA. Consolidated Annual Report for 2018. Available online: https://kghm.com/en/investors/results-center/financial-reports (accessed on 20 January 2021).
125. CRU Group. Available online: https://www.crugroup.com/ (accessed on 5 January 2021).
126. European Commission. *Study on the EU's list of the Critical Raw Materials 2020. Non-Critical Raw Materials Factsheet*; Final; European Commission: Brussels, Belgium, 2020.
127. Galos, K.; Burkowicz, A.; Czerw, H.; Figarska-Warchoł, B.; Gałaś, A.; Guzik, K.; Kamyk, J.; Kot-Niewiadomska, A.; Lewicka, E.; Szlugaj, J. *Określenie Przepływów Handlowych Surowców Kluczowych i Strategicznych dla Polskiej Gospodarki (Determining the Trade Flows of Key and Strategic Raw Materials for the Polish Economy)*; Mineral and Energy Economy Research Institute PAS: Poland, Kraków, 2020; Unpublished.
128. Zieliński, K.; Speczik, S. Deep copper and silver deposits—A chance for Polish metal mining industry. *Biul. Państw. Inst. Geol.* **2017**, *468*, 153–164. [CrossRef]
129. Projekty Rozwojowe—Głogów Głęboki. KGHM S.A. Available online: https://kghm.com/pl/biznes/projekty-rozwojowe/glogow-gleboki (accessed on 10 March 2021).
130. Zieliński, K.; Speczik, S.; Bieńko, T.; Pietrzela, A. Land management recommendations for protecting potential copper and silver mining areas in Lubuskie Province, western Poland. *Gospod. Surowcami Miner. Miner. Resour. Manag.* **2021**, *37*, 99–116. [CrossRef]
131. Geological Concessions. Information Bulletin of the Ministry of Climate and Environment. Available online: https://bip.mos.gov.pl/koncesje-geologiczne/mapy-koncesji-na-poszukiwanie-rozpoznawanie-i-wydobywanie-kopalin-ze-zloz-pliki-jpeg-i-shapefile/rok-2021/szczegoly/news/luty-2021/ (accessed on 5 March 2021).
132. Metal Ore Mining in Europe. AT Mineral Processing. 2018. Available online: https://www.at-minerals.com/en/artikel/at_Metal_ore_mining_in_Europe_3257608.html (accessed on 10 March 2021).
133. Ober, J.A. *Materials Flow of Sulfur*; Open File Report; U.S. Geological Survey: Reston, VA, USA, 2012. Available online: https://pubs.usgs.gov/of/2002/of02-298/of02-298.pdf (accessed on 8 March 2021).
134. Sermet, E.; Nieć, M. Not Mining Sterilization of Explored Mineral Resources. The Example of Native Sulfur Deposits in Poland Case History. *Resources* **2021**, *10*, 30. [CrossRef]
135. European Mineral Statistics 2010–2014. British Geological Survey. 2016. Available online: https://www2.bgs.ac.uk/mineralsuk/download/ems/EMS20102014.pdf (accessed on 10 January 2021).
136. Raw Materials Information System (RMIS). Sulphur. Available online: https://rmis.jrc.ec.europa.eu/uploads/rmprofiles/Sulphur.pdf (accessed on 1 March 2021).
137. *Statistical Yearbook of the Republic of Poland 2018*; Statistics Poland: Warszawa, Poland, 2018. Available online: https://stat.gov.pl/en/topics/statistical-yearbooks/statistical-yearbooks/statistical-yearbook-of-the-republic-of-poland-2018,2,19.html (accessed on 1 April 2021).
138. *Statistical Yearbook of Industry—Poland 2020*; Statistics Poland: Warszawa, Poland, 2020. Available online: https://stat.gov.pl/en/topics/statistical-yearbooks/statistical-yearbooks/statistical-yearbook-of-industry-poland-2020,5,14.html (accessed on 1 April 2021).
139. Structural Business Statistics—Overview. Eurostat. Available online: https://ec.europa.eu/eurostat/web/structural-business-statistics (accessed on 1 April 2021).
140. Górnicza Izba Przemysłowo-Handlowa (Mining Chamber of Industry and Commerce). Available online: http://www.giph.com.pl/ (accessed on 1 April 2021).
141. *Role of Mining in National Economies. Mining Contribution Index (MCI)*, 5th ed.; International Council on Mining & Metals (ICMM): London, UK, 2020; Available online: https://www.icmm.com/website/publications/pdfs/social-performance/2020/research_mci-5.pdf (accessed on 1 April 2021).
142. Raw Material Policy of the Czech Republic in the Field of Mineral Resources and their Resources, Ministry of Industry and Trade. Czech Republic. 2017. Available online: https://www.mpo.cz/en/construction-and-raw-materials/raw-material-policy/rawmaterial-policy-minerals-in-the-cr/new-raw-material-policy-for-minerals-and-their-resources---mpo-2017--233052/ (accessed on 10 September 2020).

143. Przemysł Chemiczny w Polsce—Pozycja, Wyzwania, Perspektywy (Chemical Industry in Poland—Position, Challenges and Perspectives). Polska Izba Przemysłu Chemicznego. 2017. Available online: http://www.pipc.org.pl/files/794915256/file/Raport_Final.pdf (accessed on 1 April 2021).
144. Jelonek, I.; Jelonek, Z. Wpływ parametrów petrograficznych węgli kamiennych na jakość koksu metalurgicznego (The influence of petrographic properties of bituminous coal on the quality of metallurgical coke). *Zesz. Nauk. IGSMiE PAN* **2017**, *100*, 49–66.
145. The Observatory of Economic Complexity (OEC). Coke—Exporters and Importers. Available online: https://oec.world/en/profile/hs92/coke (accessed on 2 April 2021).
146. Gospodarka Morska. 2019. Available online: https://www.gospodarkamorska.pl/porty-transport-zobacz-zaladunek-koksu-w-pge-w-gdansku-trafi-do-usa-39525. (accessed on 2 April 2021).
147. Galos, K.; Szlugaj, J.; Lewicka, E.; Burkowicz, A.; Guzik, K.; Kamyk, J.; Kot-Niewiadomska, A. *Wstępna Ocena Ekonomiczna Możliwości Udostępniania i Eksploatacji Zasobów Przemysłowych Wyznaczonych w Poszczególnych Obszarach Perspektywicznych i Prognostyczne Węgla kamiennego*; Mineral and Energy Economy Research Institute PAS: Poland, Kraków, 2019; Unpublished. (In Polish)
148. Mertas, B.; Ściążko, M. Zmienność właściwości węgli koksowych w zależności od ich uziarnienia (Coking coal properties changes depending on grain size fraction). *Zesz. Nauk. IGSMiE PAN* **2019**, *108*, 111–126. [CrossRef]
149. Schipperac, W.B.; Lin, H.-C.; Meloni, M.A.; Wansleeben, K.; Heijungs, R.; Voet, E. Estimating global copper demand until 2100 with regression and stock dynamics. *Resour. Conserv. Recycl.* **2018**, *132*, 28–36. [CrossRef]
150. Top 3 Copper Trends to Watch in 2019. Copper Aliance. Available online: https://sustainablecopper.org/top-3-copper-trends-to-watch-in-2019/ (accessed on 2 April 2021).
151. The International Copper Study Group. Available online: https://www.icsg.org/ (accessed on 5 January 2021).
152. Oszczepalski, S.; Speczik, S.; Małecka, K.; Chmielewski, A. Prospective copper resources in Poland. *Gospod. Surowcami Miner. Miner. Resour. Manag.* **2016**, *32*, 5–30. [CrossRef]
153. Pozytywny Wpływ Gospodarki Obiegu Zamkniętego na Środowisko Naturalne. Serwis Gazeta Prawna. Available online: https://serwisy.gazetaprawna.pl/forumbiznesu/artykuly/1445625,pozytywny-wplyw-gospodarki-obiegu-zamknietego-na-srodowisko-naturalne.html (accessed on 2 April 2021).
154. Badera, J. Geneza konfliktów społeczno-środowiskowych związanych z górnictwem (Origin of socio-environmental conglicts connected to mining activity). *Górnictwo Odkryw.* **2018**, *3*, 28–30.
155. Polish Press Agency. Poland is Europea's Third-Largest Ceramic Tile Producer. 2016. Available online: https://www.pap.pl/en/news/news,622947,poland-is-europes-third-largest-ceramic-tile-producer.html (accessed on 2 April 2021).
156. Rynek Płytek Ceramicznych 2019. Monitoring Branżowy. *Analizy Sektorowe. PKO Bank Polski*. 2019. Available online: https://www.pkobp.pl/media_files/2f69d180-db0f-4c03-87c7-9111714f48d3.pdf (accessed on 2 April 2021).
157. Paving the Way to 2050. The Ceramic Industry Roadmap. The European Ceramic Industry Association. 2017. Available online: https://www.ceramtec.com/files/cu_ceramic_industry_roadmap_en.pdf (accessed on 2 April 2021).
158. Przemysł Chemiczny w Polsce. Raport Polskiej Izby Przemysłu Chemicznego. (Chemical Industry in Poland. Report of The Polish Chamber of Chemical Industry). Available online: https://www.pipc.org.pl/files/Publikacje/Raportyroczne/666095045/lib/raport_ekonomiczny_2018.pdf (accessed on 2 April 2021).
159. Zalewski, A.; Piwowar, A. *Światowy Rynek Nawozów Mineralnych z Uwzględnieniem Zmian Cen i Nośników Energii (The Global Market of Mineral Fertilizers, Taking into Account Changes in the Prices of Raw Materials and Direct Energy Carriers)*, 1st ed.; Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej—Państwowy Instytut Badawczy: Warszawa, Poland, 2018.
160. Integrated Report of Grupa Azoty. 2018. Available online: https://raport2018.grupaazoty.com/ (accessed on 2 April 2021).
161. *Sole Potasowo-Magnezowe. (Potassium-Magnesium Salts)*; Państwowy Instytut Geologiczny—Państwowy Instytut Badawczy: Warszawa, Poland, 2019.
162. Glass Alliance Europe. Statistical Report 2018–2019. Available online: https://www.wko.at/branchen/industrie/glasindustrie/statistical-report-glass-alliance-europe-2018-2019.pdf (accessed on 3 April 2019).
163. Glass Industry. Polish Glass Manufactures Federation. Available online: http://www.polish-glass.pl/?menubok=oszkle&page=oszkle_przemysl (accessed on 3 April 2021).
164. Burkowicz, A.; Galos, K.; Guzik, K. The Resource Base of Silica Glass Sand versus Glass Industry Development: The Case of Poland. *Resources* **2021**, *9*, 134. [CrossRef]
165. Guzik, K.; Galos, K. Wystarczalność zasobów kamieni łamanych i blocznych (Sufficiency of resources of crushed and dimension stone resources in Poland). *Krus. Miner.* **2020**, *4*, 55–68.
166. Górniak-Zimroz, J.; Pactwa, K. Identification of Social and Environmental Conflicts Resulting from Open-Cast Mining. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *44*, 1–7. [CrossRef]
167. Ptak, M.; Belzyt, J.I.; Badera, J. Rozwiązywanie Konfliktów W Górnictwie. Polskie i Saksońskie Doświadczenia w Ramach Projektu Życie z Górnictwem (MineLife). 2020. Available online: https://www.oba.sachsen.de/download/2020-03-13_OBA_MineLife_Konfliktleitfaden_PL.pdf (accessed on 10 March 2021).
168. Kaźmierczak, U.; Górniak-Zimróz, J. Accessibility of Selected Key Non-Metallic Mineral Deposits in the Environmental and Social Context in Poland. *Resources* **2021**, *10*, 6. [CrossRef]