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The Impact of Selected Material Flows on the Development of OECD Countries Located in Europe

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Abstract

Mining and processing of raw materials are at the beginning of all industrial value chains. As global demand for raw materials grows, basic raw materials will continue to play a key role. Global value chains have become a dominant feature of world trade. The process of production of goods from raw materials to the finished product, intended for the final consumer, is carried out primarily where the necessary professional and material prerequisites are available, at competitive costs and quality. Although the EU has a long tradition of mining and processing raw materials, as well as rich reserves of aggregates and non-metallic minerals, some metals such as copper and zinc, but also some critical raw materials. However, their use is not optimal for various reasons, such as insufficient investment in geological exploration and extraction, diverse and lengthy national permitting procedures, or low public acceptance. Shortcomings in the EU's mining, processing, recycling, refining and unbundling capacity (e.g. in the case of lithium or rare earths) reflect a lack of resilience and high dependence on supplies from other parts of the world. At the same time, the crisis caused by the COVID-19 pandemic may have an impact on the further direction of industrial policy with an effort to increase diversification and regionalization of production processes, resp. gaining economic sovereignty in strategic areas. Raw materials form the basis of the European economy in order to secure jobs and competitiveness and are essential for maintaining and improving our quality of life. Ensuring reliable, sustainable and unhindered access to and circulation of raw materials in the economy is therefore a growing concern within the EU, not only regionally but also globally. It is for these reasons that it is necessary to examine the consumption of materials in relation to the stage of development of countries.

Keywords

Raw materials, consumption, OECD countries, development

Introduction

It is impossible to study the economic growth of the developing countries in modern times without considering the mutual interactions between these economies and those of the advanced countries (Horák and Machová, 2019; Gavurova et al., 2021c; Bacik et al., 2019). As in the past, the most developed countries were considered to be those in which coal mining and electric power enterprises rapidly developed and did railroads and shipping enterprises (Akamatsu, 1962), today it is countries which have raw materials, mainly critical raw materials (Cehlár et al., 2009; Vochozka et al., 2016a). Although many of us are unaware of this, raw materials have always imagined and made up the country's wealth, while also reflects its level of development (Cehlár and Mihok, 2013; Tausova et al., 2007).

Many authors see that today's global society is economically, socially and culturally dependent on minerals and metals (Pitukhina et al., 2017a; Pitukhina et al., 2017b; Vochozka, 2016). While metals are recyclable, terrestrial mineral deposits are by definition 'non-renewable' over human timescales and their stocks are thus finite. This raises the spectre of 'peak minerals' – the time at which production from terrestrial ores can no longer rise to meet demand and where a maximum (peak) production occurs (Horák et al., 2019; Pavolová et al., 2016). Peak minerals prompts a focus on the way minerals can be sustainably used in the future to ensure the services they provide to global society can be maintained (Prior, 2012; Draganova et al., 2020; Urbancová et al. 2020; Hudáková et al. 2019). At the same time, they are events that change the global economy rapidly, without warning, in principle strongly affect mining, which is one of the pillars of global development (Gałaś, 2021, Cehlár et al., 2013). Raw material prices are constantly rising, many critical minerals are unavailable, resulting in missing chips for the automotive or IT industries (Domanizová et al., 2021). Paradoxically, it is all about the raw materials needed for the 9 technologies needed to develop the 3 main sectors within the EU (see Figure 1), given the realization of a climate-neutral digital economy and a "stronger Europe" (Vochozka and Rowland, 2015). Based on climate neutrality scenarios in 2050, many analyzes show that in these sectors alone we would need 18 times more lithium and 5 times more cobalt in 2030 and almost 60 times more lithium and 15 times more cobalt in compared to current EU-wide consumption (Riley et al., 2021). The need for rare earths (mainly neodymium, praseodymium, dysprosia, samarium) used in permanent magnets, e.g. for electric vehicles, robots or wind generators could increase tenfold (Vochozka et al., 2016b). It is estimated that securing data repositories across the country in 2025 will require 120 times the current neodymium consumption in the EU (Coulomb, 2015).

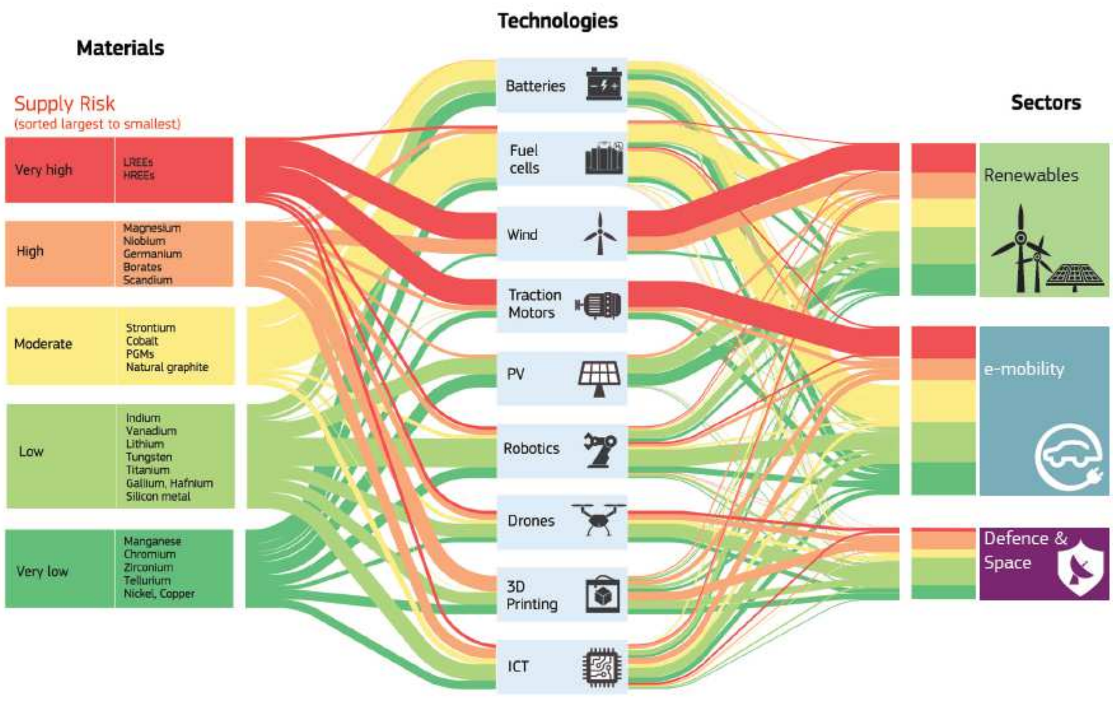

Fig. 1. Raw material flows and their supply risks for nine selected technologies and three EU sectors (EC, 2020)

The current consumption time is causing ever-increasing consumption of raw materials, which in turn creates enormous pressure on our planet, what really requires radical solutions and new approaches (Machová, 2018; Gavurova et al., 2021c; Ivankova et al., 2021; Rigelský et al., 2021; Straka et al., 2018), being in line with the ecological dimension of human well-being (Holotová et al., 2020; Piwowar, 2020; Tvaronavičienė et al., 2021; Zielińska, 2020). In other words, further alternatives with an emphasis on climate change are more than needed

(Horodníkova et al., 2008; Přívara and Přívarová, 2019; Stefko et al., 2021; Straka et al., 2020b). Proof of this is the increasing year-on-year environmental debt (Horák et al., 2021). Although, an interesting fact is that the Covid - 19 pandemic and the many restrictions associated with it have shown that in the short term it is really possible to reduce our consumption and the use of non - renewable natural resources (Straková et al., 2021a). Nevertheless, the forecast of global demand for raw materials is extremely unfavorable as it speaks of an increase from 84 billion tonnes in 2015 to 185 billion in 2050, while the metal mining sector expects an increase of up to 96% (see Figure 2). To the main reasons belong:

- population growth,
- industrialization,
- increasing demand from developing countries,
- new technologies,
- increasing product complexity (EC, 2018).

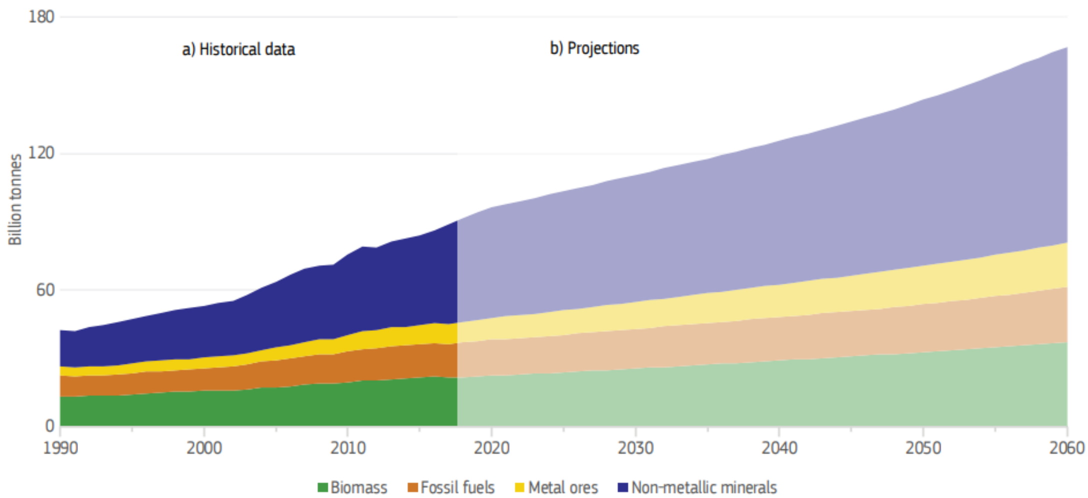

Fig. 2. Global material use by resource type: a) historical data (world, 1990 - 2017) and b) projection (world, 2018 – 2060) (EC, 2021)

On the other hand, raw materials are a life and driving force not only for the EU, but for the whole world (Bednárová, 2020; Straková et al., 2021b). Production and consumption activities in industrialized countries are increasingly dependent on material and energy resources from other world regions and imply significant economic and environmental consequences in other regions around the world (Bruckner, 2012; Haque et al., 2020; Caha, 2017). Thus, the deployment of resources in specific regions makes also positive contributions on economic conditions (Ključnikov et al., 2020a) that provide sustainable economic development in these regions (Ključnikov et al., 2020b; Gavurova et al., 2020b; Koľveková et al., 2019). Kuba and Milichovský (2019) state, that at the same time, however, mineral wealth is geologically unevenly distributed, which causes a disparity in the world's growth and development opportunities, or even geopolitical problems. Especially in relation to natural resources which are depletable and non-renewable (Straková et al., 2018). The global mining industry faces many challenges and risks (Pavolová, 2021). At the end of new geopolitical events, not only the EU but also the whole world is becoming increasingly aware of its dependence on imports of many raw materials (Krulický et al., 2020). Ensuring reliable, sustainable and unrestricted access to raw materials is a matter for Europe to provide information support to the decision-making processes of individual or group decision-makers (Kelemen et al. 2020), but also to examine security issues for critical state and European Union infrastructure Kelemen, Jevčák 2018). This is why new innovative approaches and innovations in business management processes are important (Belas et al., 2020; Civelek et al., 2021; Gavurova et al., 2020a; Gavurova et al., 2021a; Ključnikov et al., 2021; Kolková & Ključnikov, 2021; Rosova et al., 2020; Straka et al., 2020a) considering their impact on economic development (Habánik et al., 2021; Naomi & Akbar, 2021; Oliinyk et al., 2021). Consequently, efficient management of earth resources are in demand, as well as the search for new opportunities.

Based on the above facts, a number of major problems with regard to raw materials can be defined within the European Union:

1. Raw materials resources are using non-optimal mainly because of insufficient investment to the geological exploration and extraction, also each country have diverse and lengthy national permitting procedures, or low public acceptance, because mining is perceived as negative intervention to environment.
2. Keynote problem is also limitation in a field of quality information about the raw material stocks, which is a necessary for production planning. Raw materials are geographically placed relatively evenly at all

continents, but the potential of raw materials, which is presented by reserves is addicted to geological exploration and interpretation of results.
3. According to circular economy as an actual very important new economic tool is a quiet bog problem missing evaluation of raw material potential in secondary sources, which is not possible realise because of incomplete information on the amount of raw materials in the products, in the extractive waste or in landfills. Mining waste is very important nowadays, because it is rich in critical raw materials, which are missing in EU. These important materials can be re-examined and obtained to reduce import dependence of EU.
4. The problem is also a fact that the evaluation of critical raw materials for the EU is based on historical data and it does not predict future trends. However, strategic planning which is necessary in EU which is highly dependence on import requires the preparation of predictions and the determination of risks with regard to the future or environment, which is full of turbulent changes.
5. The huge potential in this area is generated by waste, which is currently perceived as a treasure containing raw materials and energy potential. Therefore, the lack of research in this area is a serious shortcoming, with many rare raw materials ending up in landfills or being exported outside the EU. The amount of waste or old mining loads (sludge ponds, heaps) form a potential for the recycling of secondary raw materials, which could subsequently change the negative perception of mining and mining on the environment.

Despite the mentioned number of major problems, the importance of raw materials is extraordinary, because they have an irreplaceable role not only in the EU member states, but also in the world (Vaníčková, 2020). However, the efficient use of earth resources will only be possible if the raw materials policy is correctly interpreted and processed, which is still lacking in many countries or, if it exists at all, does not reflect the current unflattering situation with raw materials, which has changed significantly over time. A significant negative is the absence of such strategic documents, which should cover related areas - economic, social and environmental, the level of which reflects the development of each country (Straková et al., 2021c; Cihelková et al., 2020).

The above facts are also confirmed by several studies in the literature available that deal with the necessity of raw materials (Vaníčková et al., 2020). Some of these studies deal with the necessity of taking actions on further development of infrastructure, waste management and application of modern technologies along with complex usage of raw materials and further investing is stated, because in the long run this would ensure the efficient development of industries based on the usage of mineral resources of region (Akhmedov, 2012; Ružinská, 2018; Vochozka et al, 2015; Shuyan and Fabus, 2019; Táncošová and Slaný, 2004; Rajbhandari et al., 2022; Turisová et al., 2021; Petruf et al., 2015). Some of them are dealing with the necessity of raw materials policy elaboration because of the need for raw materials undergoes continuous growth, especially in countries which experience industrial upswing-proper and this is the main reason why they would need the measures to secure the access to domestic raw materials in the long term (Marinescu, 2013). Other authors are focused at the market conditions which dictate necessity of complex management (Civelek et al., 2020a) of the capital of the enterprises of mineral-raw complex, because they are awaring mining company as a risk factor (Vasiltsova, 2011; Civelek et al., 2020b). In the same period, we can find many analyzes which are focused on the raw materials consumption, which prove the importance of mining and compare indicators based on an economy-wide material flow analysis, domestic material consumption, raw material equivalents of imports, raw material equivalents of exports and raw material consumption in each countries for example Czech Republic (Kovanda, 2013), in Germany (Pfaff, 2020), or in Europe as a whole (Bontempi, 2017; Straková et al., 2021d).

Materials and Methods

The aim of the analysis was to evaluate the relationship between the input of selected material flows of solid raw material and development in the sample of the EU part of OECD countries. The above goal was fulfilled through several steps, descriptive analysis was calculated, connections were visualized through scatter plots with a trend line and the links were then verified exactly by regression analysis.

The sample consisted of selected countries of Organization for Economic Co-operation and Development (OECD), which are also geographically located in Europe. Specifically (n = 26): Austria (AUS), Belgium (BEL), Czech Republic (CZE), Denmark (DEU), Estonia (EST), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Hungary (HUN), Iceland (ICL), Ireland (IRL), Italy (ITA), Latvia (LVA), Lithuania (LTU), Luxembourg (LUX), Netherlands (NDL), Norway (NOR), Poland (POL), Portugal (POR), Slovak Republic (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR).

Material area data were obtained from OECD databases (2021) and the human development index was obtained from the Human Developt Report (2021).

In the presented research, 3 areas of variables from the area of materials were processed and they were structural minerals: Construction minerals – non-metallic construction minerals whether primary or processed. They comprise marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate);

chalk and dolomite; sand and gravel; clays and kaolin; limestone and gypsum (direct material input thousands kilograms per capita); Non metallic minerals – non-metallic industrial minerals whether primary or processed (e.g. salts, arsenic, potash, phosphate rocks, sulphates, asbestos) (direct material input thousands kilograms per capita a Metals – metal ores, metals and products mainly made of metals (direct material input thousands kilograms per capita). Material input is computed as Domestic extraction used plus imports (OECD, 2021).

HDI can be described as a composite index measuring average achievement in three basic dimensions of human development—a long and healthy life, knowledge and a decent standard of living (index 0-1 – higher value more positive evaluation) (Human Developt Report, 2021). Variables from 2010 to 2019 were included in the analyzes.

To achieve the above goal were used the methods of basic data description, visualization using scatter plots with linear line marking and 95% confidence interval marking. In the field of intervention statistics, regression analysis methods were used, namely a linear regression model Ordinary Least Squares (OLS) and quantile regression model in the 25., 50. and 75. percentiles.

Results

Part of the analysis was divided into processes aimed at approximating variables (such as descriptive analysis in Table 1), visualizing univariate relationships (scatter plots in Figures 3 to 5) and evaluation the significance of connections through regression models (Table 1).

Tab. 1. Statistical description of selected variables

Statistic	HDI	Construction minerals	Non metallic minerals	Metals
N	260	254	260	260
N NA	0	6	0	0
min	0.824	2.774	3.182	0.431
max	0.957	20.547	21.878	9.898
median	0.902	7.422	8.405	1.565
mean	0.899	7.968	9.493	2.381
SE.mean	0.002	0.221	0.272	0.137
std.dev	0.036	3.522	4.391	2.204

Table 1 presented a statistical description in selected variables. Except the variable Construction minerals the sample made 260 observations, with the variable Construction minerals 6 missing observations were identified - they were not listed in the database. The selected sample shows an average HDI value of 0.824, which due to the fact that the theoretical maximum is equal to 1 can be evaluated positively. As expected, the highest input was identified in the area of Non metallic minerals. Conversely, the lowest average value was measured for Metals. Looking at the minima and maxima, it can be concluded that there are clear differences between the countries that entered the sample.

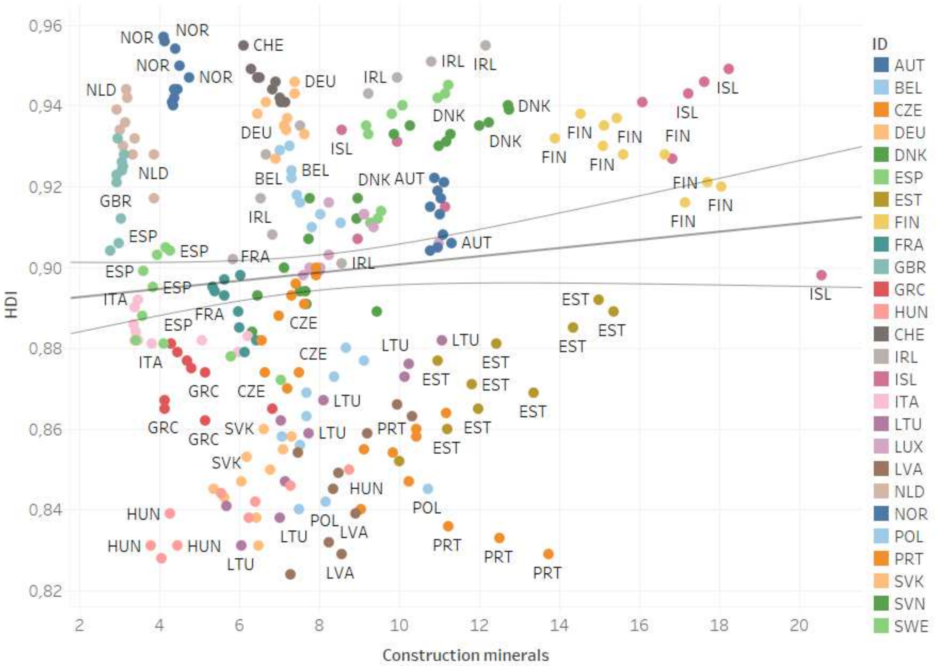

Fig. 3. Connection Construction minerals and HDI

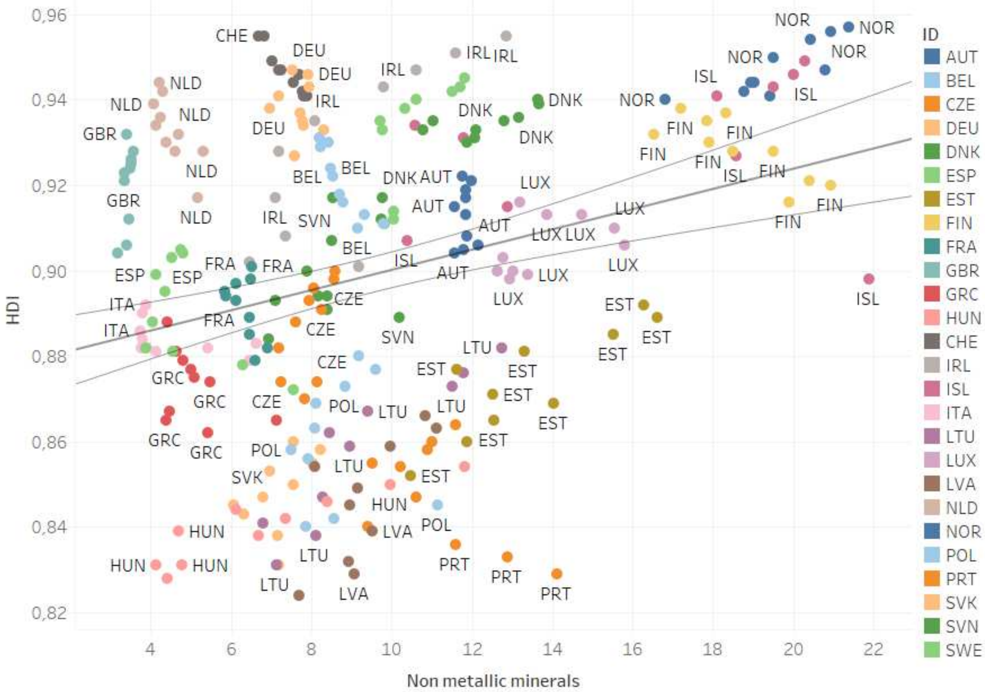

Fig. 4. Connection Non metallic minerals and HDI

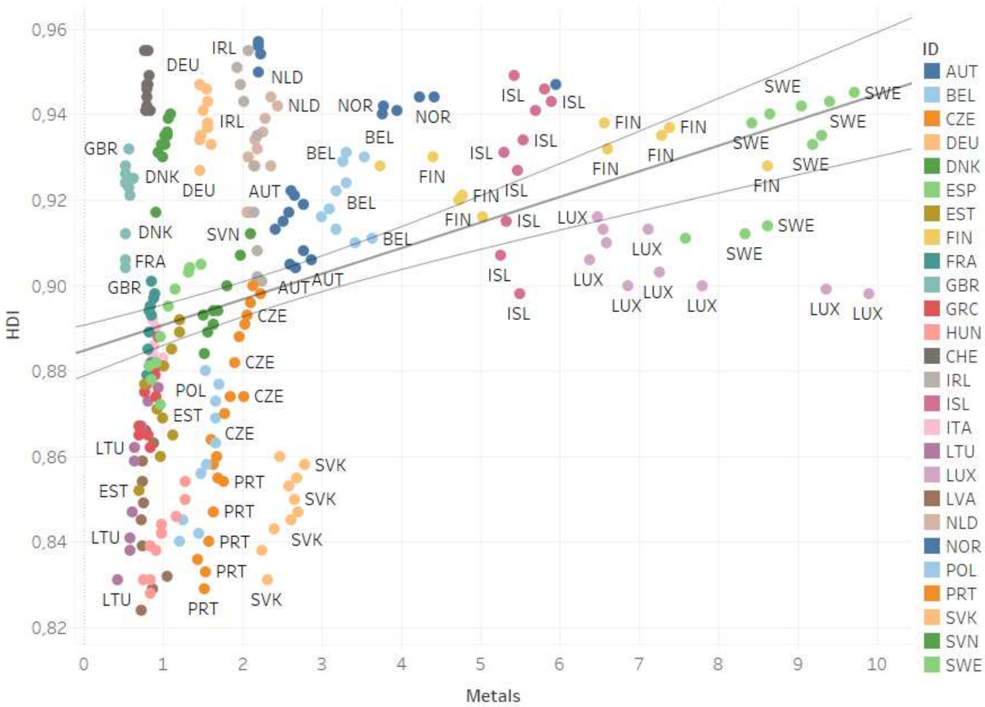

Fig. 5. Connection Metals and HDI

Figures 3 to 5 show the connection points of the individual values of Construction minerals (Figure 3), Non metallic minerals (Figure 4), Metals (Figure 5) and HDI together with the identification of the countries. Based on these, the level of individual countries in selected variables can also be assessed. The strength of the assumed connection is represented by a linear line. The more diagonal the line, the stronger the relationship. The strongest bivariate relationship could be identified in Figure 5. In all three cases, a positive linear trajectory was identified.

The subsequent part of the research was devoted to the assessment of interconnections. Three independent variables entered the regression models, while in the first step the multicollinearity was verified, which acquired a value lower than 5 for all these variables (VIF: Construction minerals = 0.25; Non metallic minerals = 2.58; Metals = 1.38). Based on this information, it is not possible to perceive multicollinearity as a factor that would significantly affect the output. Prior to the application itself, the condition of variability of residue constancy was also evaluated by Breusch-Pagan test. This test presents with its output revealed a significant occurrence of heteroskedasticity (BP = 12.694, df = 3, p-value = 0.0053) and for this reason, a robust estimation method with an estimator was applied to assess the significance of the coefficients HC3.

Tab. 2. Relationship assessment - OLS model.

Coef	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.883	0.005	183.487	< 2.2E-16
Construction minerals	-0.003	0.001	-5.593	5.85E-08
Non metallic minerals	0.003	0.000	9.058	< 2.2E-16
Metals	0.005	0.001	5.425	1.37E-07

Table 2 shows the outputs of the regression model, where the last column shows the value of p, which in all cases confirmed the hypothesis of the statistical significance of the relationship between material flows (consumption in the economy) and economic development. Coefficients for variables of Non metallic minerals and Metals, on the contrary Construction minerals presents a positive direction of the relationship. Overall, the model was significant (F-statistic: = 20.94, p-value = 3.898E-12, Multiple R-squared = 0.2008, Adjusted R-squared = 0.1912).

The following regression models present the relationship in quantile expression of 25. percentile (tau = 0.25) 50. percentile (tau = 0.5) and 75. percentile (tau = 0.75) of dependent variable HDI. This method de facto divided the sample of countries into 3 groups. For countries with low development, countries with development around the median and for countries with a high level of development.

Tab. 3. Relationship assessment – 25. percentile quantile model

Coefficients:	Value	Std. Error	t value	Pr(>|t|)
tau = 0.25				
(Intercept)	0.8555	0.0097	88.1863	< 2.2E-16
Construction minerals	-0.0037	0.0011	-3.4511	6.60E-04
Non metallic minerals	0.0037	0.0008	4.5048	1.00E-05
Metals	0.0065	0.0013	4.8678	< 2.2E-16

Table 3 shows the results of related testing in countries with lower levels of development. In this case, a significant degree can be observed in all three variables, with the coefficient acquiring a negative trajectory in the variable Construction minerals.

Tab. 4. Relationship assessment – 50. percentile quantile model

Coefficients:	Value	Std. Error	t value	Pr(>|t|)
tau = 0.5				
(Intercept)	0.8790	0.0080	110.0195	< 2.2E-16
Construction minerals	-0.0026	0.0011	-2.3272	2.08E-02
Non metallic minerals	0.0026	0.0009	3.1064	2.11E-03
Metals	0.0066	0.0016	4.0355	7.00E-05

Table 4 shows the results of related testing in countries with middle levels of development. Even in this case, a significant correlation can be found for all coefficients. As in the above cases, a negative trajectory rate was identified at Construction minerals and positive at Non metallic minerals and Metals.

Tab. 5. Relationship assessment – 75. percentile quantile model

Coefficients:	Value	Std. Error	t value	Pr(>|t|)
tau = 0.75				
(Intercept)	0.9201	0.0073	126.6332	< 2.2E-16
Construction minerals	-0.0023	0.0009	-2.5196	1.24E-02
Non metallic minerals	0.0019	0.0007	2.8272	5.08E-03
Metals	0.0025	0.0015	1.6554	9.91E-02

Table 5 shows the results of related testing in countries with high levels of development, whereas, based on the p value given in the last column of the table, it was possible to find that Metals does not acquire a significant rate of HDI-related. As in previous cases, construction minerals acquired a significant negative degree of related and Non metallic minerals, on the other hand, had a significant positive degree of related.

Conclusion

From time immemorial, the wealth of countries has been associated with raw materials, as well as the possibilities of their use. In this context, the European Union is a major global player in both production and consumption. At the same time, global materials consumption is projected to be double by 2030. Global energy and water demand is projected to increase by 30% to 40% over the next 20 years. Similarly, overall demand for food, feed and fiber is expected to increase by around 60% by 2050 compared to the current situation. The escalation of the scarcity of resources and the increase in the fight for them, raise concerns about the security of access to stocks of key resources. At the same time, the ecological footprint of most European countries exceeds their currently available biologically productive area or "biocapacity". In addition, as a result of the EU's trade with the rest of the world, a significant proportion of the environmental pressures associated with EU consumption are outside the EU. In addition, the share of the EU's environmental footprint that appears outside the EU has increased over the last ten years in terms of land, water and material use, as well as air emissions. These predictions are also slowly beginning to show in society, the economy, financial systems, political ideologies and knowledge systems, which are already working with the idea that this planet has its end, a limited number of key resources. In a global economic system that is bound by limited resources and that is facing growing global demand and environmental degradation, the only real option is a green economy that uses resources efficiently. This ultimately creates a huge paradox, as on the one hand, countries compete for first place within modern technologies of current times that depend on raw materials and raw material resources, but on the other hand, there is an effort to reduce dependence on raw material resources. However, their common denominator is still development, the size of which is reflected in the consumption of selected materials.

This is also confirmed by the analysis in the article, where in general, based on the presented results, it can be said that the relationship between the input of selected material flows of solid raw materials and the development of the European part of OECD countries is significant. Non metallic minerals and acquired a positive significant rate of β coefficients in almost all cases. This result can be interpreted as meaning that in countries where a higher output of consumption of selected areas of materials was observed, a higher output of development was also identified. The described relationship also applies in the reverse direction, and thus lower consumption of Non metallic minerals and Metals can be associated with lower development. The negative trajectory of Construction minerals indicates that a higher rate of consumption in this material area can be associated with a lower rate of development.

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