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Economic Importance, Supply and Environmental Risks of Imported Resources in Lithuanian Industry

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Secure raw material supply is one of the most important topics in industry. Growing economies such as China, India, Brazil and others increase the global demand and at the same time the competition for resources. In order to undertake appropriate actions significant raw materials should be identified. The aim of this study was to identify the most important raw materials for Lithuanian economy in terms of economic importance, supply and environmental risks.

The methodology used in the study relies on three sustainability dimensions accordingly expressed by three indicators: Economic Importance (Economic dimension); Supply Risk (Social dimension); Environmental Country Risk (Environmental dimension). The methodology used to define these indicators of imported resources for Lithuanian industry was adopted from the report on critical raw materials for the European Union (Report of the Ad-hoc Working Group on defining critical raw materials 2010) published by the European Commission in June 2010. Critical raw materials are considered to be economically important and a subject to a higher risk of supply interruption.

All materials analysed in this study were combined into five groups: chemicals, metals, building materials, paper, paperboard and wood, other materials. Only the imported raw materials were selected for further analysis. The significance of raw material import was considered important according to the ratio of production and consumption of certain material. After the analysis of statistical information about the raw material import to Lithuania and the actual countries of the origin of these resources, twenty one raw materials were selected for further analysis.

According to the results of assessment the list of critical raw materials for Lithuania was identified. Results of this research have shown that top five materials in terms of economic importance, supply and environmental country risks for Lithuanian economy are: crude oil, natural gas, sulphur, caustic soda, cast iron.

Keywords: *Resource efficiency, Supply risk, Environmental country risk, Economic importance, Cleaner Production.*

1. Introduction

One of the main conditions for competitiveness of industry of every country is secure supply of raw materials. At the same time the growing global demand and competition for raw materials increase the pressure on the environment.

For example, an old rule of thumb that 20% of the world population in Europe, USA and Japan consume more than 80% of the total mineral production is not valid any more (Tiess 2010). With the beginning of the 21st century and the Chinese growth in demand causing historic price hikes and delivery shortages (Rosenau- Tornow et al. 2009), with the integration of India and other populous developing and emerging countries like Brazil and Russia into the world economy, today more than 50% of the world's population account for the largest part of raw materials consumption (Wagner and Huy 2005, Rosenau- Tornaw at al 2009).

On the over hand Rosenau-Tornow et al (2009) claim that with a possible exception of conventional oil, mineral raw materials in general are not short. According to them our planet large enough, only to a

minimum explored, still bears many hidden mineral deposits. Nevertheless, it does not mean that we should use our resources imprudently. Rosenau-Tornow et al (2009) emphasize that it is not the finiteness but the criticality of a sustainable supply which is an important issue to our economies.

Cleaner production is a recognized and proven strategy for improving the efficient use of natural resources and minimising waste, pollution and risks at the source where they are generated. It should be essential part of any comprehensive pollution management system at any enterprise or at the national level (Staniškis et al. 2002). The work in the area of sustainable consumption and production in Lithuania started in 1993 when the first cleaner production projects were implemented (Staniškis et al. 2008).

According to Schilling and Chiang (2011) and Asafu- Adjaye (2005) the criteria of sustainability for natural resources emphasise that the stock of a resource remains the same over time, so the rate of recovery at least equals the rate of destruction. This rule applies to renewable as well as to non- renewable resources. Therefore it is important not only effectively use natural resources but also actively increase recycling and consumption of recovered materials.

Comprehension of the importance of sustainable raw material supply is also reflected in the EU growth strategy Europe 2020. Under the Europe 2020 strategy the flagship initiative for a resource-efficient Europe points the way towards sustainable growth and supports a shift towards a resource-efficient, low-carbon economy. One of the building blocks of this initiative is the European Commission's Roadmap for a resource-efficient Europe, the Communication adopted on 20 September 2011 (EC 2012a). Another important document is the Raw Materials Initiative strategy document published on 2 February 2011 (EC 2012b). In preparation of this strategy, in June 2010 the Commission published a report on critical raw materials which had been developed by an ad hoc group of the Raw Materials Supply Group.

The aim of this study was to identify the most important raw materials for Lithuanian economy in terms of economic importance, supply and environmental risks.

2. Methodology

Analysis of the Raw Materials Import

Nowadays many types of raw materials are used in industry. Beginning this research it has been decided to analyse only the most economically and quantitatively significant ones. From 1991 to 2009 the Statistics Lithuania used to form the mass balance for selected raw materials, including data about import, export, production and consumption in different economic sectors. The flows of four main groups of raw materials were observed by the Statistics Lithuania: metals (cast iron, copper, aluminium, lead, zinc, tin, iron and steel), chemical materials (sulphur, sulphuric acid, caustic soda, calcinated soda, polyethylene, polypropylene, polystyrene and copolymers of styrene, polymers of vinyl chloride), paper and paperboard, wood products (round-wood, sawn-wood, particle board of wood, fibre board of wood, plywood), building materials (cement, bituminous roof covering, asbestos-free roof sheets, building glass). In addition, authors have decided to study the flows of a few more raw materials which are obviously important to Lithuanian economy: natural gas, crude oil, natural rubber, cotton.

Only the imported raw materials were selected for further analysis. The influence of raw material import was considered of importance according to the ratio of production and consumption of certain material. If the amount of domestic production of raw material is higher or equal to its consumption, it is considered that Lithuanian economy does not depend on certain raw material supply. The ratio of production and consumption was analysed for every raw material mentioned above. Following the latest available information (2008-2009) provided by the Statistics Lithuania (2011) and the Eurostat (2011), twenty one raw materials were selected for further analysis.

During this research it has been noticed that in some cases the countries that import raw materials to Lithuania are not original producers but only resellers. In order to reflect this situation and to determine the actual countries of origin of selected raw materials it is decided to fulfil deeper analysis. The most important countries in terms of raw materials import are identified: Russia, Belarus, China, the Ukraine, Kazakhstan, Indonesia, Uzbekistan, Peru and others.

Methodology of the Raw Materials Assessment

In June 2010 the European Commission published a report on critical raw materials for the European Union (Report of the Ad-hoc Working Group on defining critical raw materials 2010). The identified critical raw materials are considered to be economically important for the EU and a subject to higher risk of supply interruption. The methodology used to define economical importance, environmental and supply risks of imported resources for Lithuanian industry was adapted from the above-mentioned report.

The methodology relies on three sustainability dimensions accordingly expressed by three indicators:

- Economic Importance (Economic dimension);
- Supply Risk (Social dimension);
- Environmental Country Risk (Environmental dimension).

Economic Importance

Economic importance of the raw material is assessed taking into account the share of consumption

in particular sectors where raw material is used and its gross value added.

$$EI_i = \frac{1}{GDP}\sum_s A_{is}\, Q_S; \qquad (1)$$

Where:

A_{is} – share of consumption of material *i* in given economic sector *s* (according to the Classification of Economic Activities EVRK by the Statistics Lithuania);

Q_s – economic importance of each sector that requires raw material *i*, measured by its value-added, mil LTL;

GDP – Lithuanian gross domestic product, mil LTL.

For presentation purposes, the values of economic importance of each material are scaled to fit in the range from 0 to 10, with higher scores indicating higher economic importance, 10 being the most economically important raw material.

Supply Risk

Indicator of Supply Risk consists of three elements: stability/instability and level of concentration of producing countries, substitutability and recycling rate. To estimate the stability/instability of the country the Worldwide Governance Indicators are used (World bank 2011). The supply risk of a raw material could impact the economy only if this raw material cannot be substituted (the value of substitutability index is 1) or can be substituted with difficulties or additional cost (the value of substitutability index is 0.7). The recycling rate of a raw material is also very important since it shows the share of second raw material in its overall consumption (EC 2010).

In general, *Stability/instability and level of concentration of producing countries* HHI_{WGI} is a modified form of Herfindahl-Hirschmann-Index. Stability/instability levels of producing countries are estimated by using the Worldwide Governance Indicators (*WGI*) provided by the World Bank. WGI includes six indicators: *voice and accountability index, political stability, government effectiveness, regulatory quality, rule of law, control of corruption* (World Bank 2011).

$$HHI_{WGI} = \sum_c (S_{IC})^2\, WGI_c, \qquad (2)$$

Where:

WGI_c – *Worldwide Governance Indicator for country c.* The values of WGIc lie in the range from -2.5 to 2.5, with higher scores indicating better governance. To create an indicator resembling a perceived risk, these values are scaled to the range 0 to 10 and their order inverted in the way that a higher score corresponds to poor governance and thus to a high risk (EC 2010).

S_{ic}, – share of producing country c in the amount of imported raw material, %.

The values of the HHI_{WGI} lie in the range 0-100000. These values are scaled to fit between 0 and 10, with higher scores indicating higher instability and a smaller number of producing countries at the same time meaning the higher supply risk of raw material.

The overall *Substitutability* index is calculated as a weighted average over the economic sectors:

$$\sigma_{\ i} = \sum_s A_{is}\, \sigma_{is}; \qquad (3)$$

Where:

A_{is} – share of consumption of material *i* in given economic sector *s* (according to the Classification of Economic Activities EVRK by the Statistics Lithuania);

σ_{is} – substitutability of raw material *i:*

- *0,0* – easily and completely substitutable at no additional cost;
- *0,3* – substitutable at low cost;
- *0,7* – substitutable at high cost and/or loss of performance*;*
- *1,0* – not substitutable.

In this study the substitutability of each raw material is assessed by using the expert opinions and other sources of information.

Recycling Rate ρ_i for raw material *i* is expressed by the share of recycled content. The production waste is not taken into account. In the case of metals it corresponds to the term of 'old scrap'.

In this study the recycling rate of each raw material is assessed by using the expert opinions and other sources of information.

The three indicators mentioned above are aggregated to one value:

$$SR_i = \sigma_i(1-\rho_i)HHI_{WGI} \qquad (4)$$

Where:

σ_{is} – substitutability of raw material *i*, with values from 1 to 0;

ρ_i – recycling rate of raw material *i*, with the values from 1 to 0.

HHI_{WGI} – stability/instability and the level of concentration of producing countries with the values from 0 to 10.

For presentation purposes, the values for supply risk of each material are scaled to fit in the range from 0 to 10, with higher scores indicating higher supply risk and with 10 being the most risky raw material in terms of supply.

Environmental Country Risk

The value of the Environmental Country Risk indicator depends on the Environmental Performance Index of the producing countries, substitutability of the raw material and the recycling rate. The indicator

of the Environmental Country Risk is calculated similarly to the indicator of the Supply Risk.

$$EM_i = \sigma_i(1 - \rho_i)HHI_{EPI}, \quad (5)$$

Where:

σ_{is} – substitutability of raw material *i*, with values from 1 to 0;

ρ_i – recycling rate of raw material i, with values from 1 to 0.

HHI_{EPI} – environmental country risk and the level of concentration of producing countries with the values from 0 to 10.

Environmental country risk and level of concentration of producing countries for the Environmental Country Risk indicator:

$$HHI_{EPI} = \sum_c (S_{iC})^2 \, EPI_c; \quad (6)$$

Where:

S_{ic}, – share of producing country *c* in the amount of imported raw material, %.

EPI_c – Environmental Performance Index provided by Yale University. The Environmental Performance Index (EPI) ranks the countries on performance indicators tracked across policy categories that cover both environmental public health and ecosystem vitality (Yale University 2011).

The values of the HHI_{EPI} lie in the range of 0-100000. These values are scaled to fit between 0 and 10, with higher scores indicating a higher environmental country risk and a smaller number of producing countries.

Evaluation of three dimensions

Since all three dimensions have equal weight, the results are scaled to fit between 0 and 10, where a higher value means a higher risk. In this study the overall result for each raw material is expressed by the mathematical average of three indicators.

$$CRM_i = (EI_i + SR_i + EM_i) / 3 \quad (7)$$

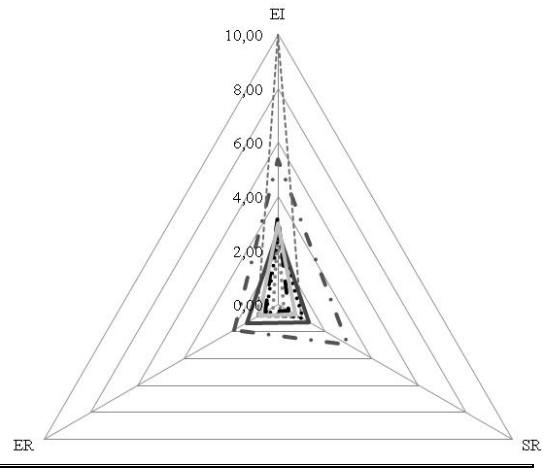
The values of CRM for raw material i lies in the range 0-10 with higher result showing the higher importance for Lithuanian economy as well as higher supply and environmental country risks.

3. Results

Only imported raw materials were seleted for the determination of Economic Importance, Environmental and Supply Risks. For the representation purpose quantitive results of the assessment are presented also graphicaly on the three-axis radar graph. In general larger area of the triangle shows the greater raw material importance for Lithuanian economy.

Table 1. Results of the assessment of Economical Importance, Supply Risk and Environmental Country Risk for imported chemicals

Chemicals	EI	SR	EM
Sulphur	5,38	2,99	1,88
Caustic soda	10,00	0,98	0,89
Calcinated soda	2,72	1,31	1,36
Polyethylene	2,68	0,24	0,22
Polypropylene	3,30	0,44	0,55
Polystyrene and copolymers of styrene	2,52	1,06	0,52
Polymers of vinyl chloride	2,99	0,74	0,81



Results of the assessment of chemicals (Table 1) show that caustic soda has the greatest economic importance (EI=10) while the supply and environmental country risks are relatively insignificant (SR=0,98; EM=0,89). In this group of raw materials the greater supply and environmental country risks are assigned to sulphur (SR=2,99; EM=1,88) while its economic importance is slightly above average (EI=5,38).

Results of the assessment of metals (Table 2) show that in this group of raw materials aluminium is of the greatest economic importance (EI=4.75), while its supply and environmental country risks are insignificant (SR=0.39; EM=0.35). The highest supply risk and environmental country risks are estimated for cast iron (SR=1.86; EM=1.70).

Table 2. *Results of the assessment of Economical Importance, Supply Risk and Environmental Country Risk for imported metals*

Metals	EI	SR	EM
Cast iron	3,18	1,86	1,70
Aluminium	4,75	0,39	0,35
Lead	3,54	0,32	0,31
Tin	3,35	1,31	1,07
Zinc	2,70	0,48	0,48
Copper	3,45	0,81	0,52
Iron and steel	3,89	0,46	0,31

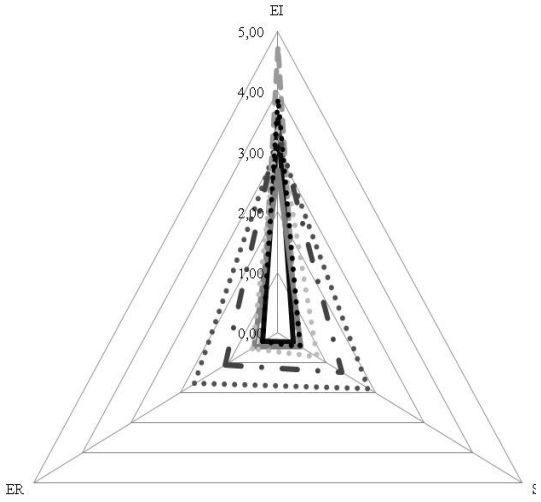


Table 3. *Results of the assessment of Economical Importance, Supply Risk and Environmental Country Risk for imported building materials, paper and paperboard, wood*

Building materials, paper and paperboard, wood	EI	SR	EM
Building glass	1,67	1,10	1,19
Plywood	5,81	0,76	0,48
Paper and paperboard	3,47	0,06	0,07

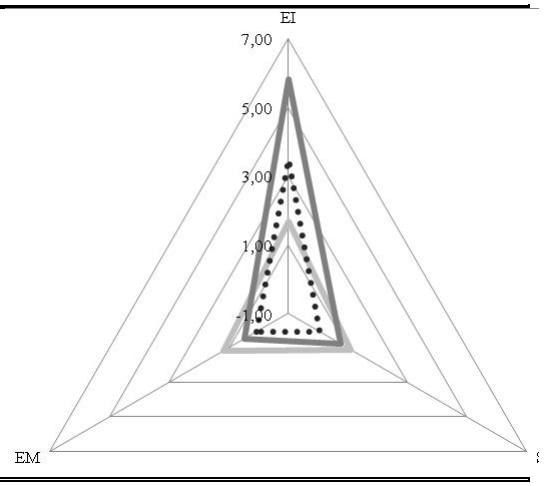
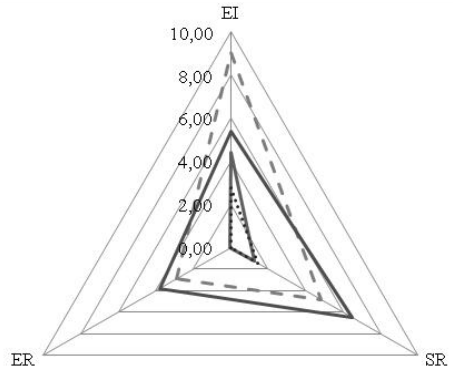


Table 4. *Results of the assessment of Economical Importance, Supply Risk and Environmental Country Risk for other imported materials*

Other materials	EI	SR	EM
Cotton	4,40	1,24	0,05
Natural rubber	2,78	1,41	0,01
Natural gas	9,05	4,81	2,89
Crude oil	5,38	6,50	3,78



The results of building materials, paper and paperboard and wood assessment were combined for the presentation purposes. Results show (Table 3) that the importance of building glass is relatively insignificant (EI=1,67; SR=1,10; EM=1,19). The economic importance of plywood is slightly above average (EI=5,81) while its supply and environmental country risks are relatively low (SR=0,76; EM=0,48).

Results show (Table 4) that amongst other materials selected for the investigation natural gas has the most significant economic importance (EI=9,05). Its supply and environmental country risks are also relatively high (SR=4,81; EM=2,89). Crude oil has the highest supply and environmental country risks (SR=6,50; EM=3,78) likewise its economic importance is also relatively high (EI=5,38).

4. Conclusions

1. After the analysis of statistical information about raw materials import in Lithuania and the actual countries of origin of these resources twenty one raw material was selected for further investigation. All selected materials were grouped into five groups: chemicals, metals, building materials, paper, paperboard and wood, other materials.
2. Using the adapted methodology for assessment of economic importance, supply and environmental country risks the list of critical raw materials for Lithuanian economy was identified (Table 5).
3. Research results show that top five materials in terms of economic importance, supply and environmental country risks for Lithuanian economy are: crude oil (CRM=8.46; consumption in 2009- 8 407 thou.t/yr), natural gas (CRM=8.03; consumption in 2009- 2 427 M m^3 /yr), sulphur (CRM=4.98; consumption in 2009- 381 thou.t/yr), caustic soda (CRM=4.62; consumption in 2009- 6 496 t/yr); cast iron (CRM=3.51; 139 t/yr).
4. The application of cleaner production instruments could enable industrialists to reduce the supply risk and environmental country risk in terms of raw material criticality for Lithuanian economy. The implementation of technological innovations, adaptation of life cycle approach, increased recycling rate and other instruments for resource efficiency could reduce the dependence on imported raw materials.

Table 5. List of critical raw materials for Lithuanian economy

No.	Raw Material	Result CRM_i	Consumption (2009)
1	Crude oil	8,46	8 407 thou. t yr^{-1}
2	Natural gas	8,03	2 427 M m^3 yr^{-1}
3	Sulphur	4,98	381 thou. t yr^{-1}
4	Caustic soda	4,62	6 496 t yr^{-1}
5	Cast iron	3,51	139 t yr^{-1}
6	Calcinated soda	2,78	6 883 t yr^{-1}
7	Plywood	2,75	34 thou. m^3 yr^{-1}
8	Tin	2,73	7,6 t yr^{-1}
9	Building glass	2,17	3 578,5 thou. m^2 yr^{-1}
10	Cotton	2,15	1 838,5 t yr^{-1}
11	Aluminium	2,09	6 193 t yr^{-1}
12	Polymers of vinyl chloride	2,09	13 579 t yr^{-1}
13	Copper	2,02	2 926 t yr^{-1}
14	Polystyrene and copolymers of styrene	1,84	14 704 t yr^{-1}
15	Polypropylene	1,81	10 646 t yr^{-1}
16	Steel and iron	1,81	307 255 t yr^{-1}
17	Natural rubber	1,66	44,7 t yr^{-1}
18	Lead	1,62	153 t yr^{-1}
19	Zinc	1,57	664 t yr^{-1}
20	Paper and paperboard	1,25	152,9 thou. t yr^{-1}
21	Polyethylene	1,21	45 495 t yr^{-1}

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Lietuvos pramonėje naudojamų importuojamų žaliavų ekonominė svarba, apsirūpinimo rizika ir aplinkosauginė rizika

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(gauta 2012 m. kovo mėn., priimta spaudai 2012m. birželio mėn.)

Patikimas žaliavų tiekimas yra viena iš svarbiausių sėkmingos pramoninės veiklos sąlygų. Augančios ekonomikos valstybės: Kinija, Indija, Brazilija ir kitos, didina pasaulinę žaliavų paklausą, kartu ir konkurenciją dėl išteklių. Siekiant tinkamai reaguoti į susiklosčiusią situaciją, pirmiausia turėtų būti įvardytos prioritetinės žaliavos. Šio tyrimo tikslas – nustatyti Lietuvos ūkiui svarbiausias žaliavas ekonominės svarbos, apsirūpinimo ir aplinkosauginės rizikos atžvilgiu.

Tyrime taikoma metodika remiasi trimis darnumo dimensijomis, atitinkamai išreikštomis trimis indikatoriais: ekonomine svarba (ekonomine dimensija), apsirūpinimo žaliava rizika (socialine dimensija), aplinkosaugine rizika (aplinkosaugine dimensija). Šių rodiklių nustatymas Lietuvos pramonėje naudojamoms importuojamoms žaliavoms pagrįstas metodika, kurios esmė buvo adaptuota iš ataskaitos dėl Europos Sąjungos kritinių žaliavų (*Ad-hoc* darbo grupės ataskaita dėl kritinių žaliavų nustatymo 2010, angl. *Report of the Ad-hoc Working Group on defining critical raw materials* 2010), kurią 2010 m. birželį paskelbė Europos Komisija. Kritinėmis žaliavomis laikomos tokios žaliavos, kurių ekonominė svarba šaliai yra didelė, o rizika, susijusi su jų tiekimo užtikrinimu, reikšminga.

Atliekant tyrimą, visos analizuotos žaliavos buvo suskirstytos į penkias grupes: cheminės medžiagos, metalai, statybinės medžiagos, popierius, kartonas ir mediena, kitos žaliavos. Tik importuojamos žaliavos buvo atrinktos tolesnei analizei. Žaliavos importo reikšmingumas nustatytas remiantis apskaičiuotu žaliavos gamybos šalyje ir sunaudojimo santykiu. Remiantis statistine informacija, atliktas medžiagų importo į Lietuvą tyrimas, nustatytos tikrosios žaliavų kilmės šalys. Remiantis šiais duomenimis, tolesnei analizei buvo atrinkta 21 žaliava.

Įvertinus rodiklius, buvo sudarytas Lietuvai svarbiausių žaliavų sąrašas. Tyrimo rezultatai parodė, kad ekonominės svarbos, apsirūpinimo ir aplinkosauginės rizikos atžvilgiu Lietuvos ūkiui svarbiausių žaliavų penketukas yra šis: žaliavinė nafta, gamtinės dujos, siera, kaustinė soda, ketus.