Material Consumption in the Czech Republic: Focus on Foreign Trade and Raw Material Equivalents of Imports and Exports

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Abstract

This article presents a comparison of indicators based on an economy-wide material flow analysis, namely imports, exports, domestic material consumption, raw material equivalents of imports, raw material equivalents of exports and raw material consumption. These indicators were calculated for the Czech Republic for 1995–2010 using, besides economy-wide material flow analysis, the hybrid input-output life cycle assessment method, which allows for a calculation of raw material equivalents of imports and exports. The results showed that calculation of indicators including raw material equivalents is useful, as they provided some important information which was not obvious from imports, exports and domestic material consumption. This includes the facts that the latter indicators tended to underestimate environmental pressure related to consumption of materials, high dependency of the Czech production system on metal ores from abroad and quite unequal and unfair distribution of environmental pressures between the Czech Republic and its trading partners.

Keywords

Economy-wide material flow analysis (EW-MFA), hybrid input-output life cycle assessment method (hybrid IO-LCA), raw material equivalents (RME), environmental pressure, foreign trade, Czech Republic

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INTRODUCTION

Our living is based on use of natural resources: raw materials, energy carriers, water and space. The society and economy could not function without these resources. The economy thus behaves like a living organism: it absorbs materials from its surroundings, which are used to satisfy human needs, but at the end all materials are transformed into wastes and emissions and released back to the environment. This

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flow of materials is called industrial or more widely socio-economic metabolism (Ayres and Simonis, 1994; Baccini and Brunner, 1991; Fischer-Kowalski and Haberl, 1993).

The theory of socio-economic metabolism conceives socio-economic system as a sub-system of the environment, which is connected with its surroundings through material and energy flows. These flows presents a pressure, which is exerted on the environment by humans, and can therefore be, together with changes in land-use and other biological and social factors, understood as a key cause of many environmental problems we face today. These problems include structure landscape changes related to extraction of raw materials, biodiversity loss due to biomass production in large-scale agro-ecosystems, global climate change and acidification because of burning fossil fuels, eutrophication due to excessive use of mineral fertilizers, production of waste, which is direct consequence of material use, etc. (Giljum et al., 2005). If the anthropogenic material flows decrease on the global level, it can be assumed that also environmental pressure related to use of materials goes down (Weizsäcker et al., 2009; Bringezu et al., 2003).

The human society experienced unprecedented growth of yearly material requirements and waste flows over 20th century (Sustainable Europe Research Institute and Wuppertal Institute for Climate Environment and Energy, various years; Adriaanse et al., 1997). This was connected with the growth of environmental pressure. Taking into account the changes in global climate system, biodiversity loss and quick depletion of non-renewable resources, it is obvious that environmental pressure related to consumption of materials is approaching or has even exceeding the Earth's carrying capacity (Rockström et al., 2009). It should be noted that resource consumption is not evenly distributed. While average daily resource use is about 43 kg per capita in Europe and even 88 kg per capita in North America, it is only 14 kg per capita in Asia and 10 kg per capita in Africa (Giljum et al., 2009).[2]

The Czech Republic belongs to the economically developed countries, which is reflected by its high material consumption and high related environmental pressures. The aim of this article is to presents a methodology for calculation of material consumption based on economy-wide material flow analysis and hybrid input-output life cycle assessment method, provide a comparison and discuss development of various material flow indicators in the Czech Republic and set this development into an international context. The focus is put on the comparison of indicators based on simple weight of imports and exports and indicators that include so called indirect flows – materials, which are not parts of traded goods, but were consumed during its production.

1 DATA AND METHODS

Material consumption in the Czech Republic is expressed by means of domestic material consumption (DMC) and raw material consumption (RMC) indicators. DMC is a central indicator of economy-wide material flow analysis (EW-MFA) (Eurostat, 2001). It is calculated as sum of domestically extracted raw materials, domestically harvested biomass and total imports (imports of raw materials, semi-manufactured products and final products) minus total exports. DMC is often criticized for being composed of two incoherent parts: domestic extraction of raw materials/biomass and imports/exports, where the latter presents a mixture of raw materials and manufactured products. It means that a decrease in material consumption can be simply achieved by the substitution of domestic production of manufactured products by their imports. This is because the total weight of raw materials needed to produce manufactured products is usually a few times greater than the weight of the products themselves (Wuppertal Institute for Climate Environment and Energy, various years). To overcome this shortcoming, the concept of raw material equivalents (RME) has been developed (Eurostat, 2001; OECD, 2008; Weisz, 2007). When imports and exports are expressed in RME, they comprise all the raw materials/biomass which were needed worldwide to produce imported/exported commodities. The indicator analogous

[2] Resource use is measured by means of raw material consumption indicator which definition is provided further in the text.

to DMC, including imports and exports in the form of RME, is called raw material consumption (RMC). RME are composed of two parts: materials that have become a part of the mass of traded commodities during their production and were physically imported/exported (further denoted as IM and EX) and materials that entered the production process, but were transformed into emissions and waste flows over its course. The latter are called indirect or hidden flows and are calculated as traded commodities in form of RME minus IM or EX.

In EW-MFA, imported and exported goods can be interpreted as shifts of pressure between countries and world regions (Bates and Dale, 2009; Giljum et al., 2009). For instance, when goods are imported to a country, the pressure related to the production of these goods is shifted to other countries. Inversely, an exporting country imports the pressure from abroad. It has been shown that in the course of globalization, developed countries have increasingly shifted the environmental pressure related to the extraction of resources and production of most resources and emission-intensive commodities to newly industrialized and developing countries (Schütz et al., 2004). It is generally acknowledged that to express above mentioned shifts in pressure correctly, it is advisable to include indirect flows into foreign trade data and express the foreign trade flows in terms of RME (Weisz, 2007; Munoz et al., 2009; Bringezu et al., 2003). This is because this method of presentation takes into account the fact that more-processed commodities require more resources to be produced and exert larger pressures on the environment than less-processed commodities, even though the actual weights of these commodities may be similar when they are imported or exported.

In order to quantify whether a country is a net importer or a net exporter of environmental pressure, one can calculate physical trade balance (PTB) as difference between imports / raw material equivalents of imports and exports/raw material equivalents of exports. If this measure is positive, country rather shifts environmental pressure abroad than other countries shifts its pressure onto its territory (it is therefore net exporter of environmental pressure) and vice versa. From broader sustainability perspective and its claim for equity in sharing area and resources (Bringezu and Bleischwitz, 2009; United Nations, 1992; Commission of the European Communities, 2006), PTB should be close to zero. With the use of PTB, DMC can be calculated as DE plus PTB based on imports and exports and RMC can be calculated as DE plus PTB based on raw material equivalents of imports and exports.

Figures on DMC and their components (extracted raw materials and harvested biomass – DE; total imports – IM and total exports – EX) were taken from the reports of the Czech Statistical Office (Czech Statistical Office, 2010; Czech Statistical Office, 2006), which compiled these indicators in line with the latest methodological standards (Eurostat, 2009a). RMC indicator, raw material equivalents of import (RME_{IM}) and raw material equivalents of exports (RME_{EX}) were calculated using a hybrid input-output life cycle assessment method (hybrid IO-LCA), as described and discussed by Weinzettel and Kovanda (2009). Hybrid IO-LCA is based on the interconnection of input-output analysis (IOA) and LCA. The basis of IOA is represented by supply, use and input-output tables. These tables were provided by the Czech Statistical Office (various years).

Hybrid IO-LCA method allows for a calculation of raw material equivalents of a group of products comprised in the vector yp ($RMEy_p$) by the following equation:

$$RMEy_p = F \times (I - A)^{-1} S^T \times (diag(x))^{-1} \times y_p \,, \qquad (1)$$

where F is an environmental extension matrix, represented by direct material extraction of individual economic sectors (F_r matrix) divided by economic output of these sectors, I is an identity matrix, A is a technology coefficients matrix (we used a sector by sector input-output table derived under an assumption of fixed product sales structure), S is a supply matrix, ^{T} stands for matrix transposition, diag stands for diagonalization of a vector, and x is a vector of total domestic supply. The expression $S^T \times (\mathrm{diag}(x))^{-1}$ is used to convert final demand expressed in product groups into output of sectors.

The above calculation assumes that imported commodities are produced abroad using the same production technology as corresponding commodities in the domestic economy. Since this assumption need not hold for a range of products (especially when taking into account imports from developing to developed countries), the results can be significantly distorted. To overcome this shortcoming, there are in general two possibilities: build a multi-regional input output model which uses country specific input output tables for the exporting countries, or integrate life cycle inventory (LCI) data into the model for commodities for which the domestic technology assumption does not hold. In this study, we applied the second approach and used LCI data for natural gas, crude oil, metal ores and basic metals (iron, steel and non-ferrous metals) which are not produced in the Czech Republic at all or only in minor quantities. These data were retrieved from the Ecoinvent database (Ecoinvent, various years) and integrated into the F_r matrix. The technology coefficients matrix, supply table and the vector of domestic output were adjusted accordingly, i.e. imports in these matrices were treated as a domestic production.

RME_{IM}, RME_{EX} and RMC are calculated by replacing the vector y_p (see equation 1) with the vectors of imports (the original vector of imports), exports and domestic final demand, respectively.

$$RME_{IM} = F \times (I - A)^{-1} \times S^T \times (\mathrm{diag}(x))^{-1} \times IM\,, \quad (2)$$

$$RME_{EX} = F \times (I - A)^{-1} \times S^T \times (\mathrm{diag}(x))^{-1} \times EX\,, \quad (3)$$

$$RMC = F \times (I - A)^{-1} \times S^T \times (\mathrm{diag}(x))^{-1} \times y\_FD_d = DE + RME_{IM} - RME_{EX}\,, \quad (4)$$

where y_FD_d is a vector of domestic final demand according to the product groups.

The indicators have been calculated for 1995–2010. For ease of presentation of results and comparison of all the indicators, the materials composing the indicators were aggregated into four broader material categories: fossil fuels and products thereof, metal ores and products thereof, non-metallic minerals and products thereof, and biomass and products thereof. For DMC, IM and EX, the manufactured products composed of the mixture of various materials were attributed to one of these material categories according to the prevailing material. For RMC, RME_{IM} and RME_{EX}, these material categories comprise raw materials only because manufactured products are expressed in terms of raw materials needed for their production. A detailed composition of the four material categories is shown in Table 1.

Table 1 Detailed composition of the main material categories

Material category	Particular material flows
Fossil fuels and products thereof	Brown coal, hard coal, crude oil, natural gas, coke, chemical products, plastics
Metal ores and products thereof	Iron ore, non-ferrous ores, pig iron, basic metals (copper, nickel, lead, zinc, tin, etc.), steel, machinery, transport vehicles, weapons, optical instrument
Non-metallic minerals and products thereof	Salt, graphite, kaolin, feldspar, fluorspar, marble, granite, dolomite, magnesite, limestone, sand and gravel, phosphate rock, lime, cement, artificial fertilizers, glass, pottery, ammunition
Biomass and products thereof	Cereals, roots and tubers, fodder plants, by-products from harvesting, grazing from meadows and pastures, wood, pulp and paper, food

Source: Charles University Environment Center

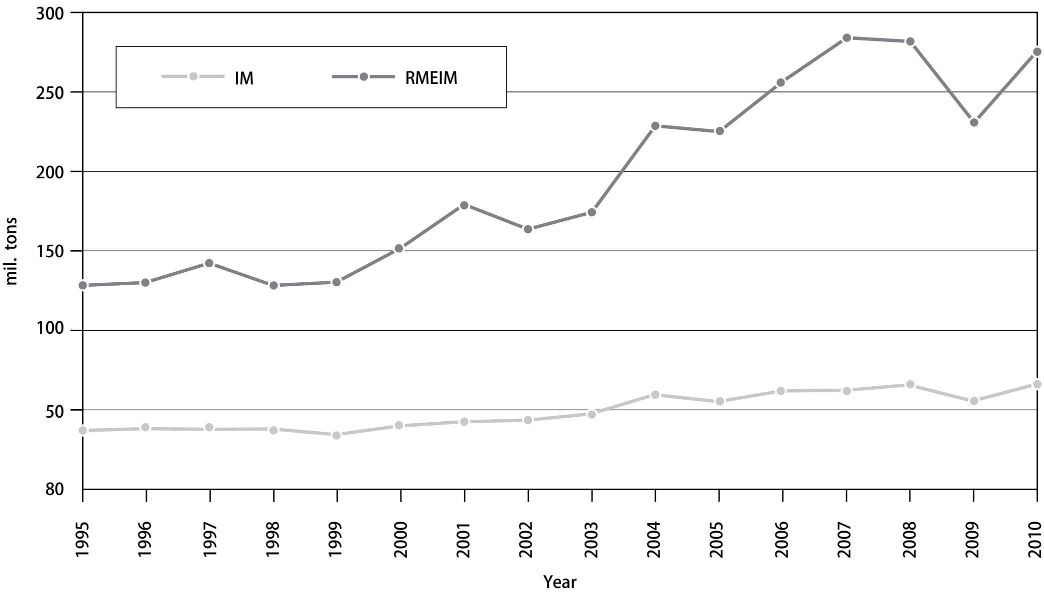
2 RESULTS AND DISCUSSION

2.1 Czech Republic

2.1.1 Foreign trade

According to the definition of DMC and RMC indicators, differences in their volumes and time development are given by differences in IM and RME_{IM} and EX and RME_{EX}, respectively. Figure 1 shows development of IM and RME_{IM} in the Czech Republic in 1995–2010.

Figure 1 IM and RME_{IM}, Czech Republic, 1995–2010



Source: Czech Statistical Office, Charles University Environment Center

Imports recorded gradual growth from 42 mil. tons to 67 mil. tons in 1995–2010. The total growth of imports thus amounted to 59%. The highest growth was recorded in 2004 – it can be attributed to accession of the Czech Republic to the European Union, which was related to abolishment of administrative barriers in foreign trade (economic barriers were gradually eliminated already in the years prior to the Czech Republic accession) (Kovanda et al., 2010). The decrease in imports in 2009 can be attributed to global economic crisis. The trend of raw material equivalents of imports was similar – it grew from 179 mil. tons to 276 mil. tons, i.e. by about 54%. In absolute volumes, however, RME_{IM} grew much more – by 97 mil. tons while IM went up by 25 mil. tons only.

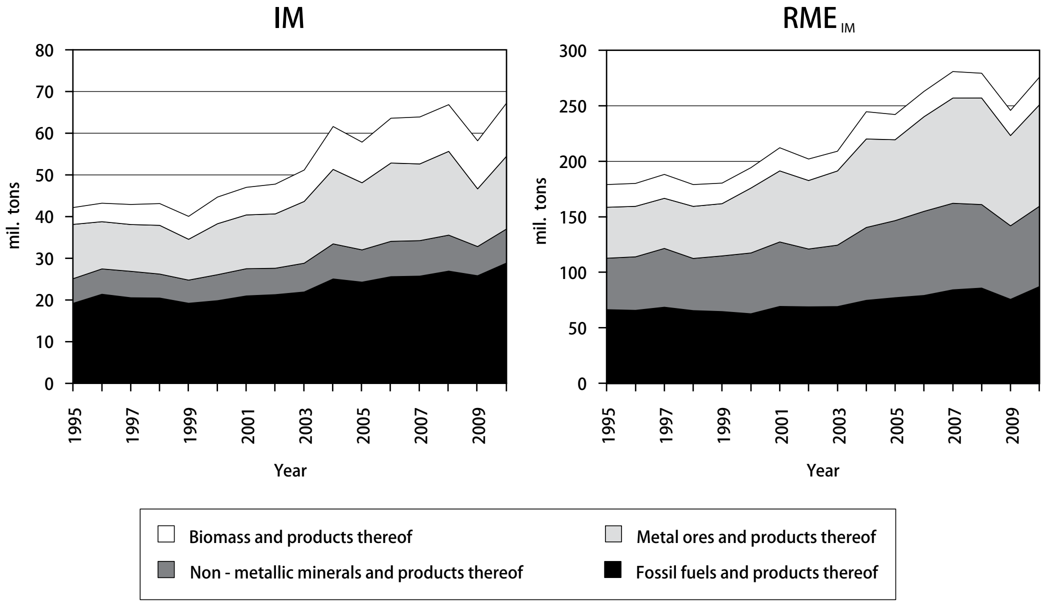
The total weight of RME_{IM} is on average 4.2 times larger than the weight of IM, which means that 4.2 times more raw materials had to be extracted to produce imported commodities. Imports are considered an environmental pressure shifted abroad in EW-MFA. If it is expressed by IM instead of RME_{IM}, this pressure is highly underestimated. The above ratio further suggests that about ¾ of RME_{IM} is composed of indirect flows, which are calculated as RME_{IM} minus IM. These materials we do not consumed, as they are lost during the production process in the form of emissions and waste flows. This is quite a significant share.

Interesting results are yielded by the comparison of RME_{IM} and DE, which varied from 187 mil. tons in 1995 to 163 mil. tons in 2010 with maximum of 198 mil. tons in 1996. This implies that since

1999 the share of DE in RME_{IM} was larger than 1 and thus the environmental pressure abroad related to the production of imported commodities was larger than environmental pressure in the Czech Republic related to domestic raw materials extraction and their processing. While domestic pressure decreased by 13 percent in 1995–2010, environmental pressure caused abroad by Czech production grew by over 54%.

Figure 2 shows development of IM and RME_{IM} in the Czech Republic in 1995–2010 broken down by main material categories. For RME_{IM}, the Figure shows all biomass, metal ores, non-metallic minerals and fossil fuels needed worldwide to produce imported commodities.

Figure 2 IM and RME_{IM} by main material categories, Czech Republic, 1995–2010



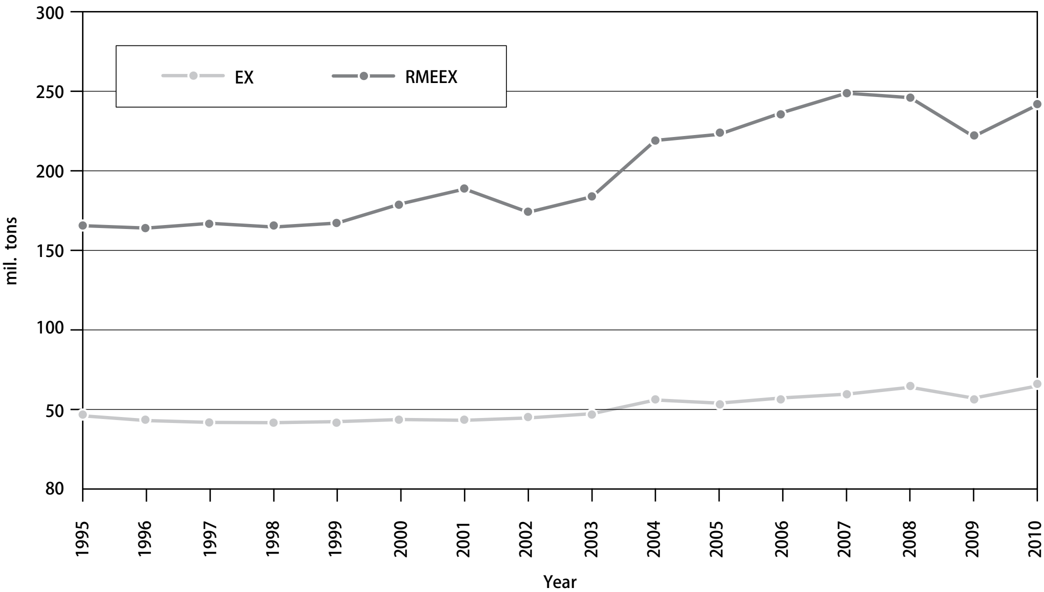
Source: Czech Statistical Office, Charles University Environment Center

RME_{IM} has a different composition than IM. Fossil fuels and biomass have on average lower shares in RME_{IM}, but the shares of non-metallic minerals and metal ores are higher. The higher share (and larger absolute volume) of metal ores is given by the high share of sectors in the Czech economy requiring metals (e.g. manufacturing of machinery and manufacturing of motor vehicles) (Eurostat, various years) and the fact the DE of metal ores is close to zero. This is because domestic metal deposits suitable for mining are very scarce in the Czech Republic (Czech Geological Survey – Geofond, 2009).

Political and strategic documents in the Czech Republic such as the State Energy Policy (Ministry of Industry and Trade, 2004), Raw Material Policy (Ministry of Industry and Trade, 2009) and the Strategic Framework for Sustainable Development (Government Council for Sustainable Development, 2010) fully acknowledge and address the fact that the Czech Republic has been very much dependent on fossil fuel energy and that a large share of its energy requirements have to be imported. The RME_{IM} further emphasizes the high foreign trade dependency of the Czech Republic on non-metallic minerals and metal ores. While this is not a serious issue for non-metallic minerals because they are quite abundant in the Czech Republic (Czech Geological Survey – Geofond, 2009) and demand for them could be covered from domestic sources, for metal ores this can pose a serious problem, as their vast majority has to be imported. If the share of metal ores in RME_{IM} grows further, the vulnerability of the Czech economy to an incidental shortage of metal commodities abroad, an increase in their price or an upheaval in terms of other barriers to foreign trade may rise to unacceptable levels.

Figure 3 shows development of EX and RME_{EX} in the Czech Republic in 1995–2010.

Figure 3 EX and RME_{EX}, Czech Republic, 1995–2010

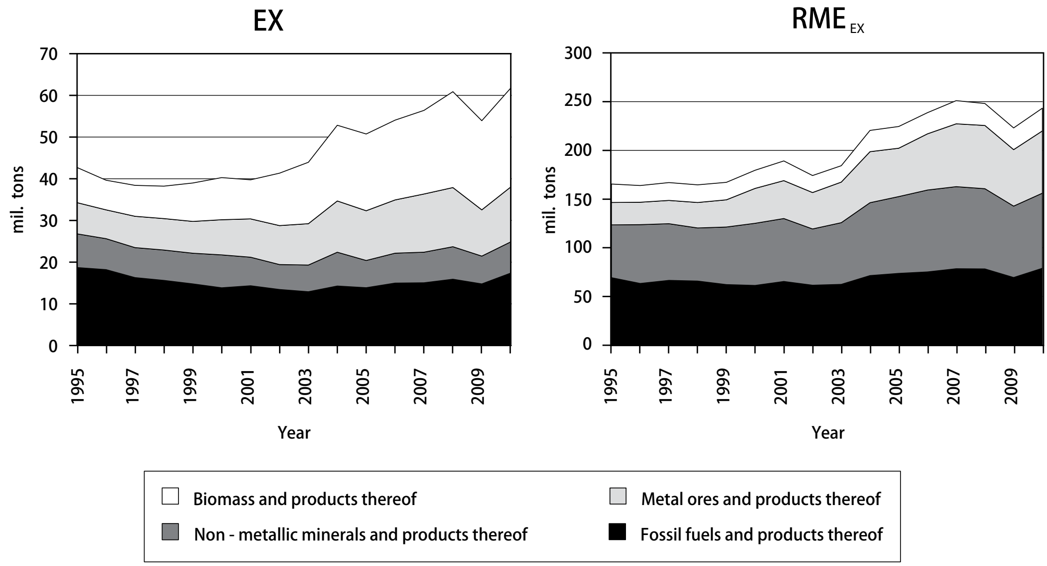


Source: Czech Statistical Office, Charles University Environment Center

Exports and raw material equivalents of exports increased a bit less compared to imports and raw material equivalents of imports. They grew by 45% and 47%, respectively. This means that environmental pressure shifted abroad by the Czech Republic grew faster than pressure shifted to the Czech Republic by other countries. In absolute volumes EX and RME_{EX} went up by 19 mil. tons and 78 mil. tons.

Also the share of EX in RME_{EX} was 4.2 on average over 1995–2010. This implies, similarly to imports, that large share of raw materials consumed for production of exports is lost in terms of emissions and waste flows and that pressure shifts related to exported commodities are highly underestimated when expressed by means of EX instead of RME_{EX}. Regarding changes in structure of EX and RME_{EX}, RME_{EX} shows lower shares of fossil fuels, biomass and metal ores, but significantly higher share of non-metallic minerals (Figure 4). The latter suggests that production system in the Czech Republic is very demanding on infrastructures, which requires large amounts of non-metallic minerals (mostly construction minerals) to be built and maintained.

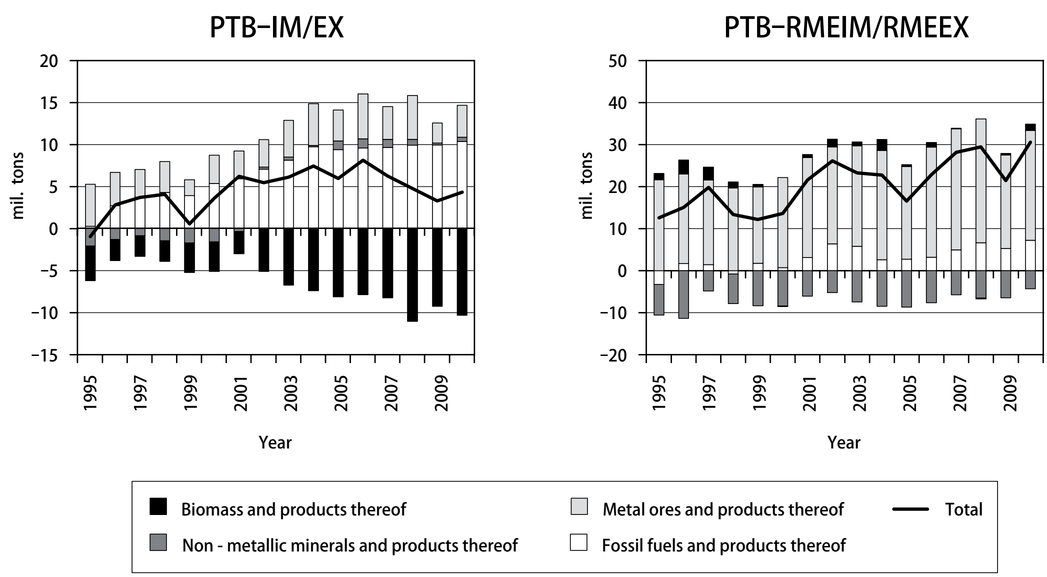
Figure 4 EX and RME_{EX} by main material categories, Czech Republic, 1995–2010



Source: Czech Statistical Office, Charles University Environment Center

In order to assess whether the Czech Republic is a net importer or a net exporter of environmental pressure, we calculated the PTB indicator. Figure 5 shows both PTB based on IM and EX and PTB based on RME_{IM} and RME_{EX}, i.e. after inclusion of indirect flows.

Figure 5 PTB by main material categories, Czech Republic, 1995–2010



Source: Czech Statistical Office, Charles University Environment Center

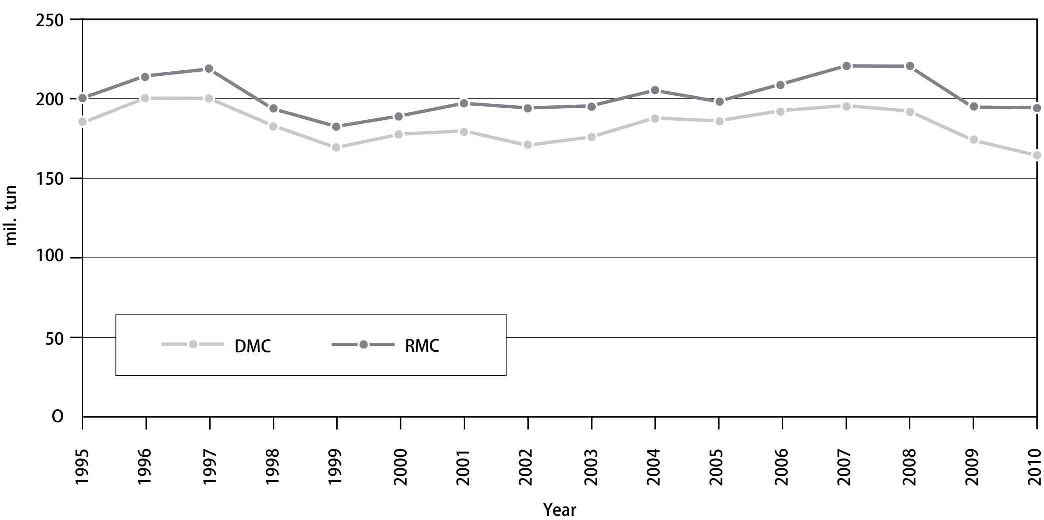
Figure 5 shows that the Czech Republic is a net exporter of environmental pressure, i.e. it rather shifts environmental pressure abroad than other countries shifts its pressure onto its territory. Although both PTB based on IM and EX and PTB based on RME_{IM} and RME_{EX} are positive, the latter indicates quite a steeper growth and also overall higher absolute levels. It can be therefore concluded that also for the PTB indicator, it is better to stick to RME_{IM} and RME_{EX}, as IM and EX can deliver underestimated results. The advantage of PTB based on RME_{IM} and RME_{EX} became even more obvious when studying PTB of particular material groups. While PTB of biomass in terms of its simple imports and exports is negative, when taking into account all biomass needed to produce imported commodities, PTB turns into slightly positive figures. This can be explained by the fact that we import biomass which needs a lot of biotic resources to be produced such as dairy products, meet and soy oil, but exports less biotic resource-intensive biomass such as cereals. Another material category strongly influenced by the selection of the indicator is metal ores, which shows more than four times higher positive results with the use of PTB based on RME_{IM} and RME_{EX}. This is because the Czech Republic imports metal ore concentrates and basic metals, which – when recalculated into the form of metal ores – significantly increase their weight due to often very low metal ore grades. On the other hand the differences in metal ore grades between imported metal ore concentrates and exported metal commodities are not so large. For fossil fuels, the overall lower levels of PTB with the use of PTB based on RME_{IM} and RME_{EX} can be explained by the fact that the Czech Republic rather imports crude oil and nature gas, which are related to lower indirect flows than exported coal.

As noted above the positive and significantly growing PTB of the Czech Republic can be perceived controversial from the sustainability point of view, as it allows for an increased consumption and effective environmental protection at home hand in hand with increasing environmental pressure and pollution levels in other countries.

2.1.2 Material consumption

Figure 6 shows development of DMC and RMC in the Czech Republic in 1995–2010.

Figure 6 DMC and RMC, Czech Republic, 1995–2010

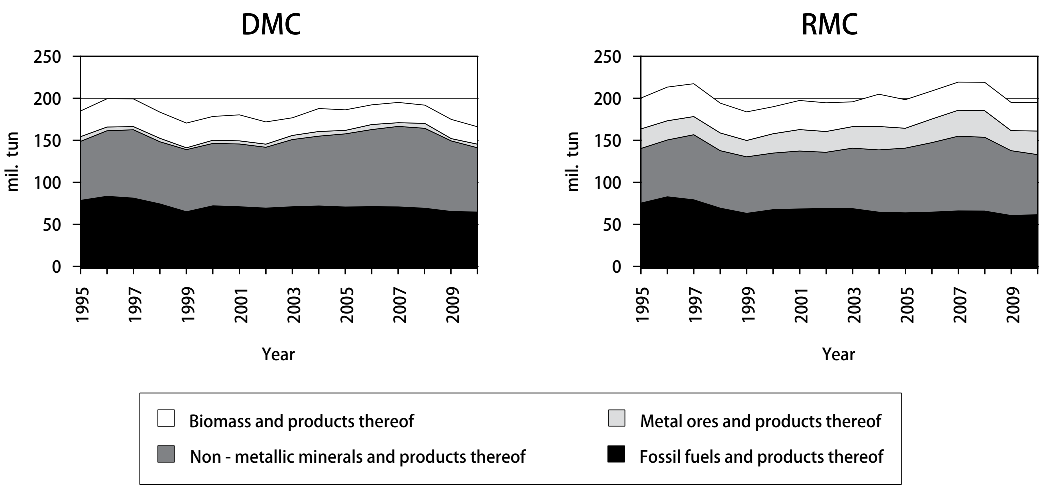


Source: Czech Statistical Office, Charles University Environment Center

DMC and RMC are interpreted as environmental pressure related to material use for domestic final demand. The difference between DMC and RMC was on average 7% till 2000, it started growing in the later years, however, and reached as much as 17% in 2010. DMC therefore consistently underestimated the environmental pressure related to domestic final demand compared to RMC, but the difference was not by far so large as in the case of IM and RME_{IM} and EX and RME_{EX}, respectively. This is because RME_{IM} and RME_{EX} netted out in RMC in a similar way as IM and EX in DMC. While DMC decreased by 10% in 1995–2010 (an absolute decrease by about 19 mil. tons), RMC went down by 3% only (a decrease by 5 mil. tons). DMC thus gives wrong signals about the time development of related environmental pressure.

Figure 7 shows development of DMC and RMC in the Czech Republic in 1995–2010 broken down by main material categories.

Figure 7 DMC and RMC by main material categories, Czech Republic, 1995–2010

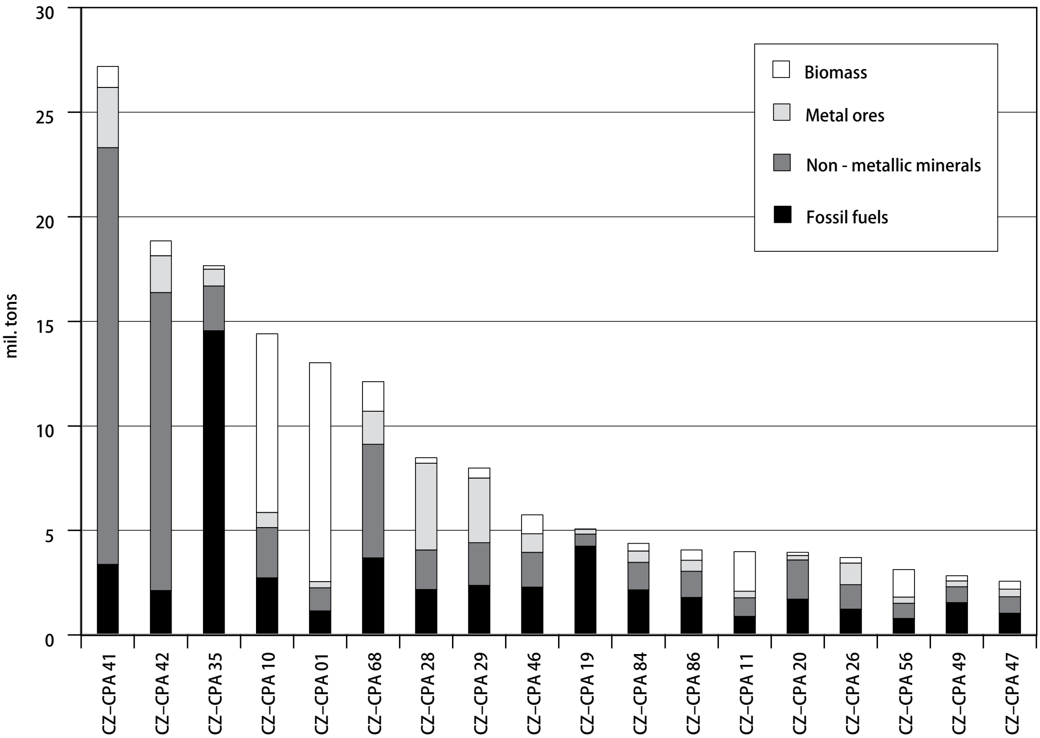


Source: Czech Statistical Office, Charles University Environment Center

RMC shows somewhat lower shares of fossil fuels and non-metallic minerals, a bit higher share of biomass, but a significantly higher share of metal ores compared to DMC. This share is on average 2 percent in DMC, but 12 percent in RMC, which represents an increase in absolute volume by more than 500 percent. It is obvious that environmental pressure related to metal ores is substantially underestimated when using DMC. Apart from this, RMC also indicates the high importance of metal ores for Czech system of production and consumption, which is not very well visible from DMC. This can have serious consequences for securing the sufficient amount of metal resources from abroad through foreign trade (see discussion on structure of RME_{IM}).

The fact that RMC is calculated with the use of hybrid IO-LCA method allows for a breakdown of RMC by product groups going to domestic final demand. This breakdown is shown for 18 product groups with highest RMC in Figure 8.

Figure 8 RMC by product groups going to domestic final demand, Czech Republic, 2010



Source: CZ-CPA – Czech classification of products by activities; CZ-CPA 41 – Buildings and building construction works; CZ-CPA 42 – Civil engineering construction works; CZ-CPA 35 – Electricity, gas, steam and air conditioning; CZ-CPA 10 – Food products; CZ-CPA 01 – Products of agriculture, hunting and related services; CZ-CPA 68 – Real estate services; CZ-CPA 28 – Machinery and equipment n.e.c.; CZ-CPA 29 – Motor vehicles, trailers and semi-trailers; CZ-CPA 46 – Wholesale trade services, except of motor vehicles and motorcycles; CZ-CPA 19 – Coke and refined petroleum products; CZ-CPA 84 – Public administration and defense services; compulsory social security services; CZ-CPA 86 – Human health services; CZ-CPA 11 – Beverages; CZ-CPA 20 – Chemicals and chemical products; CZ-CPA 26 – Computer, electronic and optical products; CZ-CPA 56 – Food and beverage serving services; CZ-CPA 49 – Land transport services and transport services via pipelines; CZ-CPA 47 – Retail trade services, except of motor vehicles and motorcycles.
Source: Charles University Environment Center

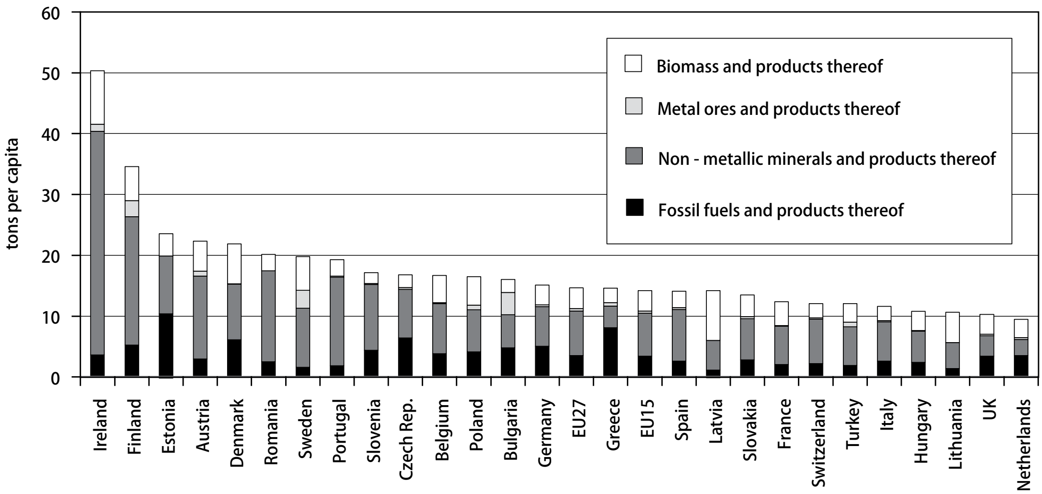
The highest RMC is connected with construction (CZ-CPA 41 and 42), it is however mostly composed of non-metallic minerals, which consumption has lower environmental impacts than consumption of biomass, metal ores and fossil fuels. Construction is followed by electricity and gas (CZ-CPA 35), food products (CZ-CPA 10) and products of agriculture (CZ-CPA 01). Quite high RMC is also related to some services such as real estate services (CZ-CPA 68), wholesale trade services (CZ-CPA 46), public administration and defence services (CZ-CPA 84) and human health services (CZ-CPA 86). This result violates the common assumption that services are completely immaterial.

2.2 International Comparison

Methods for the calculation and analysis of DMC are quite standardized and this is the reason why this indicator is calculated by a range of statistical offices and incorporated into many national and international sets of sustainable development indicators and environmental reports (Federal Statistical Office Germany, 2010; Federal Ministry of Agriculture Forestry Environment and Water Management, 2009;

Department for Environment Food and Rural Affairs, 2009; Kovanda and Hak, 2009; Eurostat, 2009b; United Nations, 2007). This fact makes its international comparison quite easy and straightforward. Figure 9 shows international comparison of DMC for selected European countries.

Figure 9 DMC, international comparison, 2009

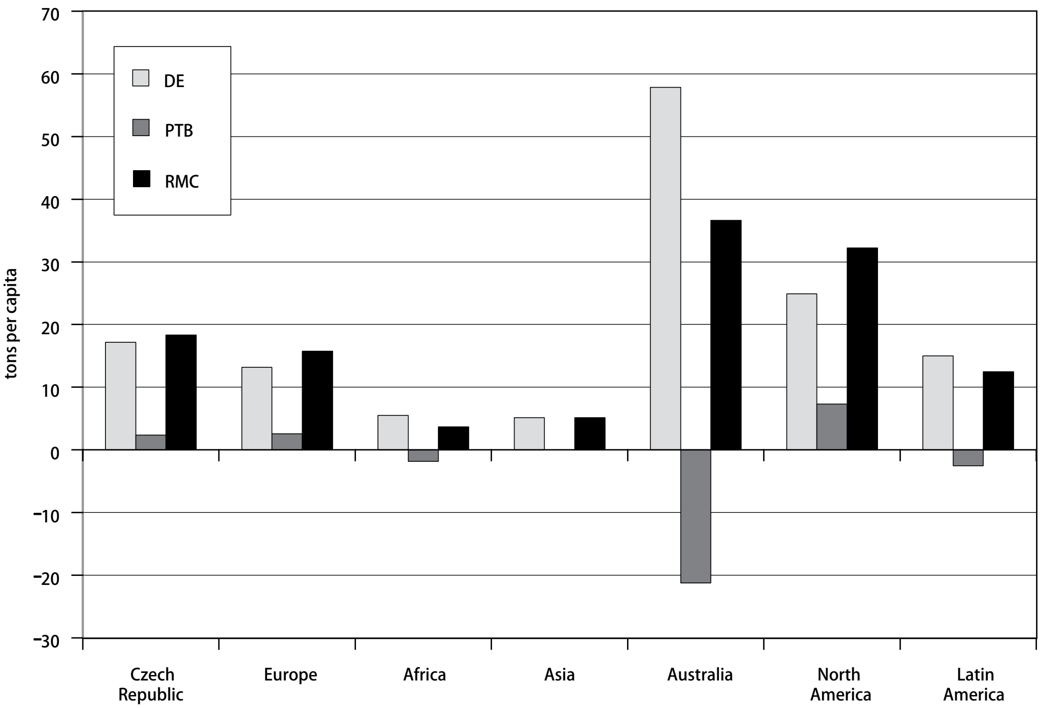


Source: Eurostat

DMC per capita in the Czech Republic is by about 15% higher than the average of EU27 and by 18% higher than the average of EU15. DMC per capita in some countries, however, is significantly higher than in the Czech Republic. Very high level of DMC is determined by high consumption (and extraction) of non-metallic minerals in Ireland, Finland, Romania, Austria and Portugal and by high consumption of fossil fuels in Estonia. Relatively high levels of DMC per capita in the Czech Republic are given by high consumption of fossil fuels and non-metallic minerals. On the other hand the consumption of biomass is the third lowest after Slovenia and Bulgaria. The high consumption of fossil fuels can be explained by high share of solid fossil fuels in primary energy supply and by high energy intensity of the Czech production and consumption system. The latter is among others determined by significant share of industry in the Czech economy.

The calculation of RMC is currently much less developed than the calculation of DMC and is still at the research phase (Giljum et al., 2008; Weisz, 2007; Munoz et al., 2009; Weinzettel and Kovanda, 2009; Wiedmann et al., 2007). Its international comparison must therefore be understood as tentative. Figure 10 shows the comparison of RMC per capita and its two components – DE and PTB based on RME_{IM} and RME_{EX} – for the Czech Republic and particular world regions.

Figure 10 DE, PTB based on RME_{IM} and RME_{EX} and RMC, international comparison, 2000



Source: Charles University Environment Center, Giljum et al. (2009)

The highest RMC is recorded by Australia and North America followed by Europe, Latin America, Asia and Africa. The RMC of the Czech Republic is by about 16% higher that the European average. It is obvious that high raw material consumption is typical for regions with prevalence of economically developed countries (Australia, North America, Europe) while low raw material consumption is typical for poor regions (Asia, Africa). RMC is thus 37 tons per capita per year in Australia which is an equivalent of 100 kg per capita per day. Similarly, RMC is 88 kg per capita per day in North America, 43 kg per capita per day in Europe, but only 14 kg per day in Asia and 10 kg per day in Africa. If poor regions aim at achieving similar standard of living as developed countries and follow the path of increasing material consumption at their level, it will, e.g. in Asia, lead to 3–7 time higher raw material consumption. Taking into account the Asia large population, this would mean up to three times higher global resource extraction. This amount of raw materials could be obtained with large obstacles only and would lead to additional pressure exerted on the environment including the global climate system.

The highest positive PTB based on RME_{IM} and RME_{EX} is recorded for North America, followed by Europe (and the Czech Republic). These blocks of countries thus exports environmental pressure abroad. On the other hand Africa, Latin America and in particular Australia are recipients of environmental pressure, as their economies are based on exports of raw materials to a large extent. It should be noted that Australia is an exceptional case with respect to all three indicators: it shows extremely high resource extraction, PTB and raw material consumption at the same time. RMC is almost equal to extraction of raw materials in Asia. It means that its PTB is close to zero and Asia is neither net importer nor net exporter of environmental pressure.

CONCLUSION

The calculation of indicators including RME improves the most widely used EW-MFA indicators such as DMC. It addresses some criticisms made against this indicator, namely the facts that it is composed of two incoherent parts (DE and IM/EX) and does not properly account for environmental pressure related to foreign trade. The article presented a new innovative method for calculation of RME with the use of hybrid IO-LCA method.

RME_{IM}, RME_{EX} and RMC calculated for the Czech Republic brought about some important information which was not obvious from IM, EX and DMC indicators. Above all, they showed that indicators, which did not include indirect flows, tended to underestimate environmental pressure related to imports, exports and domestic use of materials. Second, they pointed out at high dependency of the Czech production system on metal ores from abroad, which is determined by high share of metal-demanding industrial branches in the Czech economy and the limited deposits of metal ores in the territory of the Czech Republic. Third, they suggested quite unequal and unfair distribution of environmental pressures between the Czech Republic and its trading partners. These points have not been more thoroughly addressed by Czech economic, environmental and sustainability policies so far and present open issues which will have to be dealt with in future. Can, for instance, the Czech Republic base its material welfare on pollution and damage to the environment abroad while preserving its own environment?

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