SOCIAL ECOLOGY WORKING PAPER 125

Anke Schaffartzik • Nina Eisenmenger •
Fridolin Krausmann • Helga Weisz

Raw Material Equivalents (RME) of Austria's Trade

ISSN 1726-3816

April 2013

Anke Schaffartzik, Nina Eisenmenger, Fridolin Krausmann, Helga Weisz (2013):

Raw Material Equivalents (RME)
of Austria's Trade

Social Ecology Working Paper 125
Vienna, April 2013

ISSN 1726-3816

Institute of Social Ecology
IFF - Faculty for Interdisciplinary Studies (Klagenfurt, Graz, Vienna)
Alpen-Adria Universitaet
Schottenfeldgasse 29
A-1070 Vienna
+43-(0)1-522 40 00-403

www.aau.at/sec
workingpaper@aau.at

Raw Material Equivalents (RME) of Austria's Trade

Authors:
Anke Schaffartzik
Nina Eisenmenger
Fridolin Krausmann
Helga Weisz

Summary

As is the case for most industrialized countries, imports and exports play an increasingly important role in terms of Austria's material throughput. Material flow analysis (MFA) shows that in 2007, imports accounted for approximately 34% of the direct material input (DMI) into the Austrian economy. The production of traded goods requires upstream inputs of material and energy which must be accounted for in order to obtain a complete understanding of a society's material consumption and the related resource use. However, standard MFA methodology thus far cannot incorporate these flows. With the research presented in the following, we propose a method for the calculation of so-called raw material equivalents (RME), that is, of the import and export flows including their used upstream material requirements. This method is applied to the Austrian economy between 1995 and 2007, allowing us to gain a fuller understanding of Austria's material use over a period of more than ten years.

The results show that the RME are notably greater in magnitude than the trade flows with which they are associated. In 2007, both the mass of exported and imported RME was almost 3 times larger than Austria's exports and imports. By taking the upstream requirements associated with trade flows into account, we obtain a new picture of material use in the Austrian economy. In 2007, Austria's material consumption as expressed in RME (i.e. raw material consumption or RMC) was 30 million t (or 15%) higher than its domestic material consumption (DMC) which does not take the upstream inputs into account. This corresponds to 28 t/cap in terms of RMC compared to 25 t/cap in terms of DMC. These results highlight the need to consider the associated upstream flows of trade when it comes to assessing the dematerialization or development of resource efficiency related to Austrian final demand.

In the calculation of RME, we used a hybrid method, combining an input-output and a life cycle analysis module within one consistent model. We thus obtained results which provide a good approximation of the dimensions of the upstream inputs associated with trade flows and were able to further validate this by comparing our results with those calculated for the Czech Republic and Germany within the framework of other research projects.

Besides the presentation of results, we will also discuss the assumptions which had to be made in the LCA and in the IO module as well as the possible further development of methods. The importance of information on upstream material requirements and this first assessment of their magnitude for the Austrian economy clearly make further investments into the applied method and the underlying data advisable.

Table of Contents

Tables

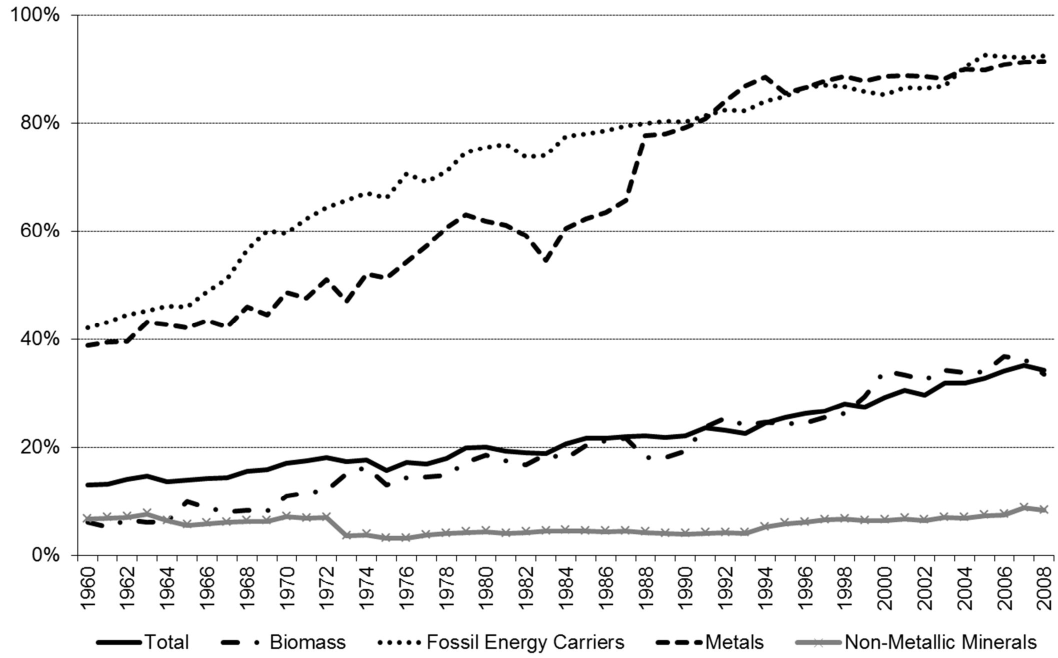
Figures

Introduction: Why Calculate Raw Material Equivalents?

As is the case for most industrialized countries, imports and exports play an increasingly important role in terms of Austria's material throughput. Material flow analysis (MFA) shows that in 2007, 34% of all materials used were imported as opposed to only 13% in 1960. On the output side, 22% of all materials processed in Austria leave the country as exports (Statistik Austria 2011c). Import and export shares are constantly growing, i.e. trade is increasingly gaining importance in the Austrian economy. The same is true in terms of the growing economic significance of trade: Exports contributed 59% to GDP in 2007 and growth in exports surpassed GDP growth by a factor of 1.6 between 1980 and 2010 (Statistik Austria 2012b). For open economies, achieving and maintaining economic growth increasingly depends on international trade. Increasing exports is one of the key political strategies to stimulate growth. Imports, on the other hand, allow nations, industrialized countries in particular, to access foreign markets and resources not available domestically. These economic factors then have an impact on the physical volumes and shares of trade in material use as well.

When we examine Austria's trade flows, we find that Austria is a net-importer of materials both on the aggregate level and on the disaggregate level in terms of biomass, metals, non-metallic minerals, and fossil energy carriers. However, for biomass and in particular non-metallic minerals, materials are still mainly extracted from Austria's territory. For fossil fuels and many important metals, MFA data shows us that they are not (or no longer) available for extraction within Austria so that domestic extraction has either ceased or is decreasing. However, these materials are strategically important to the economy leading to continuous demand regardless of domestic availability. Consequently, a growing share of domestic demand for these raw materials and products is satisfied through imports, increasing Austrian import dependency. Figure 1 shows that in meeting the material requirements of the economy, imports have been on the rise since 1960.

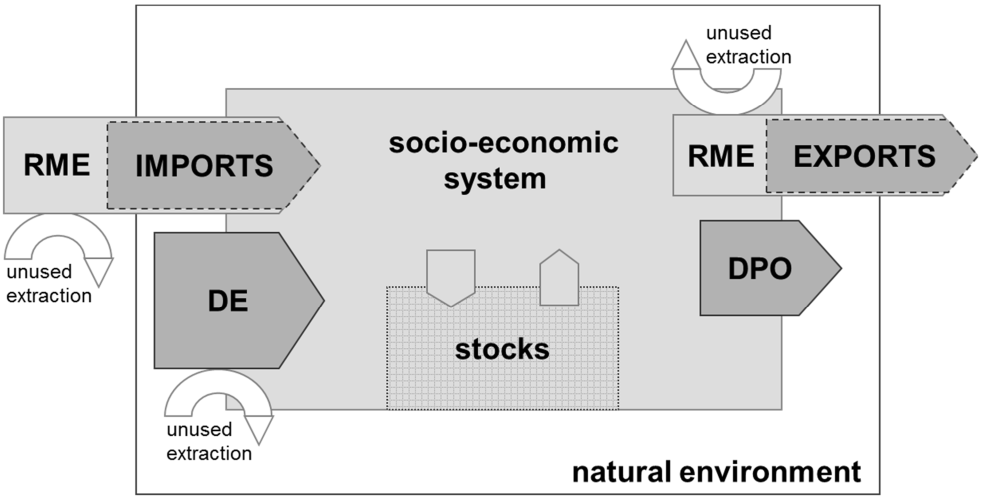
Figure 1: Role of Imports (Imports/DMI) in the Austrian Physical Economy, 1960-2008



Trade includes goods at very different stages of the production process, i.e. basic commodities such as wheat or crude oil, goods such as copper wires, or final products such as bread or cars. In the course of the production processes of these goods, a high amount of raw materials is "consumed", i.e. transformed into wastes and emissions, and not physically included in the final product itself. If processed goods are traded, it means that the wastes and emissions associated with their production occur elsewhere than the consumption of the good. The relative size of trade flows and their composition thus significantly shape a country's resource use pattern as measured by domestic material consumption (DMC): If a country extracts raw materials and further processes these for export, a significant amount of waste and emissions related to this production and thus to final consumption elsewhere stay within its boundaries. Under the MFA framework, these flows are accounted for as part of the domestic material consumption of the producing (and exporting) economy, however under a consumption perspective, they have to be associated with the final consumption of the importing economy. Economies specialised in high-end production tend to import goods that already went through some processing steps in the exporting economies, making them "lighter" in terms of the total material contained therein than raw materials would be. Importing these goods rather than producing them domestically from raw materials leads to a reduction of material use under the current economy-wide material flow accounting framework. Austria, the economy that we based our research on, is a net-importer of material goods. Therefore, it can be expected that the country actually requires more resources through upstream use in other economies than it directly imports. If we want to reach a full understanding of Austria's share in global resource consumption, we must account for these upstream resource requirements.

Methodological approaches which integrate the upstream inputs associated with the production of traded goods into material flow accounting are currently under development. One of these approaches is the calculation of so-called raw material equivalents (RME) for imported and exported goods. Raw material equivalents of traded goods consist of the material inputs required to provide the goods for export and include the mass of the good itself (Eurostat 2001). Raw material equivalents are calculated for both imports and exports, the assumption being that the RME of imports must be included in an economy's consumption while the RME of exports must be deducted in order to arrive at a complete balance of material inputs and outputs (see Figure 2).

Figure 2: The Role of Raw Material Equivalents (RME) in the MFA Framework



Within the framework of research funded by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, we have developed a method for calculating the raw material equivalents of Austria's foreign trade. This approach is derived from well-established input-output methodology. The data required are Austrian MFA data (in tons), Austrian supply and use data (in Euros), and coefficients from life cycle analysis (LCA) (in tons/ton). Our work ties in closely to similar endeavours in Germany (Buyny et al. 2009) and the Czech Republic (Weinzettel and Kovanda 2009).

This Working Paper is composed of two parts: The first provides an overview of the method used in RME calculation, i.e. its base in input-output calculation, its LCA module, the integration of MFA data into the model and a discussion of the choices made and their implications. The second part is devoted to a description of the results obtained for the raw material equivalents of Austrian trade and a comparison to other RME calculations.

Methodology of Raw Material Equivalents (RME) Calculation

Material flow accounts which include raw material equivalents (RME) are still scarce; however, this area of research has been growing quickly in recent years. The major challenge with RME accounts is the calculation of raw material requirements of imports because for this detailed information on inter-industry relations and material requirements at the point of origin of the imported good are needed. In the following, we will describe the different solutions to this problem which have been proposed.

Available RME Accounts and Methodological Approaches

The approaches which have been developed and used in the calculation of RME can be classified into four main groups:

1. Input-Output (IO) Approaches

IO approaches use standardized and for the most part monetary input-output tables (based on supply and use (SU) tables) that are compiled within the national accounts. The advantages of using IO data are:

- the whole economy is covered in a systematic way,
- high compatibility with economy-wide MFA data is given, and
- in most countries, IO (or SU) tables are part of the standard system of national accounting.

However, there are also some problematic issues associated with the use of IO data that have to be considered when interpreting the results:

- Inter-industry flows and final demand are usually reported in monetary rather than in physical terms. In the application to physical flows, the main assumption that must be made is that of homogenous prices per sector. For a discussion of this assumption in the application to physical data see Weisz and Duchin (2006).
- The primary sectors in input-output tables are usually highly aggregated. An example of this is the agricultural sector which, for the case of Austria, encompasses livestock production as well as crop farming both of which require quantitatively and qualitatively different physical inputs. The same problem is illustrated by the mining sector under which very different metallic (e.g. copper and iron) as well as non-metallic minerals are subsumed. In the Austrian IOT, the extraction of fossil energy carriers is additionally reported in the mining sector for reasons of confidentiality.

The IO approach has been used in two distinct ways to calculate the raw material equivalents of trade:

1a. A **Single Region IO (SRIO)** model uses information on domestic inter-industry relations and thus domestic technical coefficients for the calculation of the RME of imports. This approach was applied in the first RME accounts (for example for Austria by Weisz et al. 2008 building on the analysis of the Danish economy by Weisz 2006) and then again more recently in a study of a selection of Latin American countries by Muñoz et al. (2009). The major advantage of the SRIO approach is that it requires only one IO table (that of the importing country). This is possible because domestic production (i.e. input-output) structures and thus domestic upstream requirements are assumed to be equivalent to the structures in the countries from which imports originate. In other words, this approach makes the assumption that domestic production uses the same quantity and mix of inputs as the economies from which the product is imported. Resulting raw material requirements may be interpreted as the additional raw material demand if the country would produce the imported goods domestically.

This approach may yield valid results in the case of large and diverse economies in which those goods imported are also produced domestically, i.e. if the domestic production system covers all production sectors and products that are demanded by final consumption and if the type of production used does not differ greatly from the production in the exporting economies. But it can lead to strong distortions for small economies where certain goods are not produced (or some raw materials are not available for extraction). In this case, relevant production processes would not be reflected by the IO data.

1b. In **Multi-Regional IO (MRIO)** models the aforementioned problem of the SRIO model is solved by integrating input-output data from other regions or countries. The specific input-output structure corresponding to the region or country of origin of the imported products is thus represented in the calculation of the raw material equivalents of those imports. This approach can be considered as the most advanced in terms of actually depicting the specific (monetary) inter-industry relations in the economies (or economic regions) producing the imported goods. At the same time, the extremely large amount of data involved can make these accounts very complex and difficult to harmonize (high overall number of sectors and products, different number of sectors from one region or country to the next, and the overall need to harmonize IO tables internationally). Moreover, the calculation with MRIO usually requires major processing power and long-term dedication.

MRIO models may contain input-output data for all countries interacting through trade. Their complexity is sometimes reduced by either using country-specific IO data for the most relevant trade partners and an average IO table for a “rest of the world” (ROW) region or by using average IO tables per region (instead of specific IO tables per economy). In these cases, the impact of the choices as to the grouping of countries must be considered in the analysis of the results: For example, regions may be defined by such divergent characteristics as economic affluence or geographic location and a geographically defined Southeast Asian region could include economies so different as Cambodia and Singapore. Additionally, it must be taken into consideration that choosing the countries to represent in detail based on the import-structure of one country could render this MRIO model inapplicable to any other economy. The consequence would be that a specific MRIO model (with all the aforementioned data work) would have to be constructed for each economy under investigation.

At present, four MRIO models can be identified that are most promising in their application to calculate RME: The MRIO models based on the Global Trade Analysis Project GTAP (Narayanan et al. 2012), the multi-regional environmentally extended supply and use / input output model EXIOBASE (Tukker et al. 2009) and its follow-up CREEA, the multi-region IO database Eora (Lenzen et al. 2012), and the World Input-Output Database WIOD (Timmer 2012).

2. Coefficient Approaches

These approaches use product- or resource-specific coefficients to assess the upstream material requirements associated with a certain import. While the IO-based approaches previously described seek to reach economy-wide coverage, the coefficient approaches tend to focus on certain products or product groups. This can be considered a bottom-up approach to compiling economy-wide data. Often, the coefficients used are derived from life-cycle analysis (LCA). The main challenge here lies in ensuring full coverage while avoiding double-counting.[1] Examples of coefficient approaches include water footprint accounts (Chapagain and Hoekstra 2008) as well as carbon or greenhouse gas accounting for individual economies. The coefficient approach was used by the Wuppertal Institute in its material intensity analysis (MAIA) by Ritthoff et al. (2002). The calculation of the Wuppertal Institute results in Total Material Requirements (TMR), which unlike the other approaches to RME calculation presented here including the one applied to the Austrian economy, also includes unused extraction. Additionally, the TMR coefficients allocate the upstream material requirements to the material category of the observed product. This means, upstream fossil energy carriers used to produce bread are allocated to the material category "biomass". Thus, results from TMR calculations cannot be directly compared to RME accounts (Eurostat 2001). For an example of the application of the TMR approach, see Dittrich et al. (2012).

3. **Hybrid Approaches**

The term 'hybrid approach' is used here to refer to the combination of input-output and life cycle analysis as developed by the LCA community to solve system boundary issues (Suh et al. 2003). In RME applications, an SRIO approach is extended by an LCA module for non-competitive imports, i.e. for those products/activities which are not or not sufficiently represented by the domestic input-output structures. The RME calculation for Austria presented in this paper is based on a hybrid approach and described in detail in the following section. The Austrian approach is highly comparable to calculations performed for Germany (Buyny et al. 2009) and the Czech Republic (Weinzettel and Kovanda 2009) and most recently for the EU27 (Schoer et al. 2012).

An overview of the different approaches described above as well as of existing studies utilizing these approaches is provided in Table 1.

[1] The LCA-based approach poses two major difficulties with regard to simultaneously ensuring as full a coverage as possible and avoiding double counting. The former has to do with the fact that any given LCA coefficient involves a somewhat arbitrary truncation decision somewhere along the production process. This has to do with the degree of complexity the production process is considered both on a spatial and on a time scale. The second problem is that of allocation. Different principles exist by which intermediate inputs can be assigned to specific products. This decision must be made whenever one and the same production process produces more than one good (e.g. rape seed oil for nutrition and biofuel production and rape seed cakes as animal fodder from rape agriculture). The allocation can be made based on the share of each of the products in overall economic value or based on physical properties such as share in overall mass or energy or based on the amount of material input that could be avoided by producing something in coupled production rather than as a single-product process. Unfortunately, the results of these different allocation approaches can be completely contrary so that the decision as to which procedure is used has a major impact on the overall results.

Table 1: Overview of Case Studies Accounting for Raw Material Equivalents (RME)

Approach	Reference	Countries covered	Time Coverage
Single-Region IO (SRIO) Approach	Muñoz et al. 2009	Brazil, Chile, Colombia, Ecuador, Mexico, USA	2003 (Chile: 1977, 1986, 1996, 2003)
	Weisz 2006	Denmark	1990
Multi-Regional IO (MRIO) Approach (i.e. GRAM)	Bruckner et al. 2012	15 countries or aggregate regions grouped to OECD and non-OECD countries	1995, 2005
	Wiebe et al. 2012	Russia, South Africa, Brazil, Argentina, India, China, OECD, Rest of the World	1995, 2000, 2005
Coefficient Approach	Dittrich et al. 2012[2]	Global	1962, and 1970-2005 in 5-year-steps
Hybrid IO Approach	Buyny et al. 2009, Buyny and Lauber 2010	Germany	2000-2005, 2000-2007
	Weinzettel and Kovanda 2009	Czech Republic	2003
	Schoer et al. 2012	EU27	2000-2009
	Study at hand	Austria	1995-2007

2 The Dittrich et al. study also includes unused extraction. This refers to materials displaced during extraction activities but not extracted themselves (e.g. overburden moved during mining activities). Unused extraction is not subject to further processing.

Calculating RME: The Austrian Hybrid Method

Generally speaking, in order to be able to calculate the raw material equivalents of Austrian trade, we need to know how much material input was required to produce those goods which Austria imported and exported in a given year. In order to ensure that our approach is consistent with the economy-wide MFA framework, we applied a top-down or system perspective and not a bottom-up or product perspective wherever possible. So far, economy-wide MFA – for the most part – treats the socio-economic system as a black box, focussing on the inputs into and outputs from that black box and not on the material flows within the socio-economic system. For the purposes of calculating raw material equivalents, however, we need to open this black box to be able to trace in what quantity and quality materials are required for the production of specific goods in a particular sector.

These types of inter-industrial relations are documented in the **monetary supply and use tables (SUT)** which are part of the United Nations' System of National Accounts (SNA) and are annually published by Statistics Austria (Statistik Austria 2011a). While the supply tables indicate how much of a given product (or group of products) is provided (or supplied) by which sector of the economy, the use tables indicate how much of a given group of products is used by which sector. The SUT form the basis from which input-output tables (IOT) for an economy can be constructed. These IOT depict the inter-industry relations in monetary terms. For each group of products, they indicate which other products were needed in the production process.

Table 2: IOT for a Hypothetical 3-Product Economy

	Wood	Paper	Books	Final Demand	Total Output
Wood	85	90	0	20	195
Paper	10	10	90	200	310
Books	5	5	20	500	530
Value Added	95	205	420	350	1070
Total	195	310	530	1070	2105

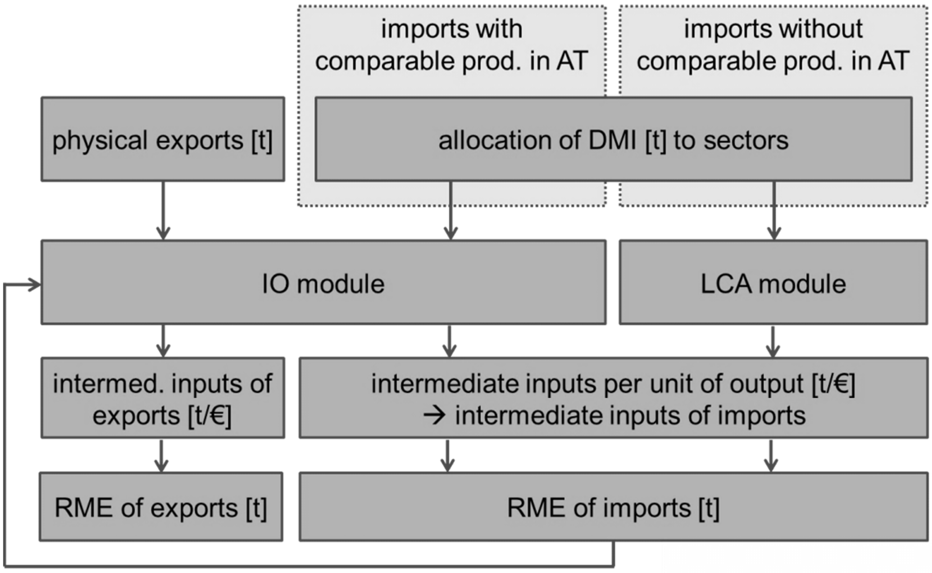
Table 2 shows a very simple IOT for a hypothetical economy which produces only three goods: wood, paper, and books. The values in the columns show which inputs are required for the production of all the wood, paper, and books in this economy. In this case, 90 units worth of wood, 10 units worth of paper and 5 units worth of books are needed to produce the total amount of paper in this economy. While the top left 3x3 section of the table depicts the inter-industry flows, the fourth column shows the final demand for wood, paper, and books in this economy. The total output of each of the products corresponds to the sum of inter-industry use and final demand and is represented in the column on the very right. In monetary terms, value is added to a product during the production process. This happens because labour, taxes, interest, rent, and profit have to be paid for. This value added is shown in the fourth row of the table. Only as man units of a product can be consumed within the economy as are generated. Therefore, the totals by column and by row have to match. The example of a 3-product economy is, of course, a highly simplified IOT, included here only to introduce the type of information contained in these tables.

For the Austrian economy, the IOT provides information about the monetary inputs into the production of each group of goods. This is exactly the structure of information which is required for calculating the RME of Austria's exports. For each unit of output of a certain group of goods, the IOT can be used to calculate which intermediate direct and indirect inputs were necessary to produce this good. The direct inputs are those which can easily be read out of Table 2 for our hypothetical economy: For example, roughly 0.44 units of intermediate inputs of wood are required for each single unit of wood output (85 / 195 ≈ 0.44). At the same time, each additional unit produced of any given product also leads to indirect input requirements. In our 2-product economy, the 0.44 units of (direct) intermediate input of wood in turn require (indirect) intermediate inputs in their production. Rather than reiteratively performing these calculations until the impact on the overall result becomes negligible, we use a generalized input-output model based on the work of Wassily Leontief (Leontief 1936, Leontief 1941). As will be illustrated in the following section of this Working Paper, this model allows us to take care of the reiterations of inter-industry relations in one simple step.

In calculating the material requirements not of a hypothetical 3-product economy but of Austria, we used monetary supply and use data for the Austrian economy from which we calculated annual IOTs. The available data allows us to base our calculations on 57 product groups and sectors. This corresponds to a fairly high level of aggregation as, for example, all agricultural products are part of the same product group. In order to be able to perform the calculations which were illustrated above of a hypothetical economy and will be explained in more mathematical detail below, we had to make the assumption of homogenous production and prices in each sector. This means that we have to assume that each group of products is in fact only one homogenous product with one homogenous price. In our 3-product economy this means that we have to assume that there is only one kind of wood and cannot allow for that group of products to encompass spruce and teak wood with their highly different prices, for example. In using the supply and use information available for the Austrian economy, it means that we must assume that there is only one average agricultural product with one price and cannot reflect the differences between meat and corn, for example. Once we have allowed for this assumption, however, we can use the available IO information to calculate how much intermediate material input was required for the production of Austria's exports and can thus determine the RME of these flows (see "The Input-Output Module" below for the step-by-step description of this calculation).

Calculating the upstream requirements of imports is somewhat more complicated. Assuming the same input-output structure we used for Austria's exports to hold true for Austria's imports would most likely lead to a misrepresentation. Some of the goods which Austria imports are not produced in the Austrian economy, some are produced with different inputs. The highest degree of precision could be attained by combining bilateral trade data with country-by-country input-output data (i.e. by MRIO tables). Unfortunately, this information is not readily available and the resources required to generate it are disproportionately large in relation to the degree of precision thus attained. Rather than following such a route, we aimed to contribute towards the development of an approach that can be applied to other countries and other points in time with relative ease.

Figure 3: Schematic Representation of the RME Calculation



In calculating the RME of Austria's imports, we combined a generalized input-output model (Lenzen 2001) with a component based on life cycle analysis (LCA) data in a modular fashion: MFA data on DE and imports were applied as environmental extensions to the monetary input-output data in order to calculate upstream inputs required for the production of Austrian exports. In the calculation of RME of imports, we substituted imports with the RME of imports calculated using a coefficient approach. For non-competitive imports (imports of those goods for which no comparable production exists within Austria), we compiled LCA-based coefficients reflecting the array of material requirements associated with the production of a specific good.Figure 3 offers a schematic representation of the interplay between MFA data and the IO and LCA modules in the calculation process. Each of the individual modules and the data involved in the calculation procedures will be described in the following.

RME of Exports and Competitive Imports: The Input-Output Module

The basic model underlying the method for calculating the raw material equivalents of Austria's trade was a generalized input-output (IO) model extended by material flow data. Input-output analysis is based on the work of Wassily Leontief who began developing models depicting inter-industrial relations in a sector by sector and product by product approach in the 1930s (Leontief 1936, Leontief 1941). Since the late 1970s, input-output analysis has been used to examine the interrelations between economy and environment. The focus was of these analyses was on energy use and emissions (e.g. Bullard und Herendeen 1975). In a few cases, IO tables were also extended by material flows, recently opening up the debate on possibilities of methodological standardization (Muñoz et al. 2009, Bruckner et al. 2012). As we have outlined in the section on existing RME accounts, the use of input-output analysis in conjunction with material flow data is currently gaining popularity rapidly.

The input-output model which we used in this module for RME calculation has the following general form:

$$\mathbf{Z} + \mathbf{y} = \mathbf{x} \qquad (1)$$

Z is an n by n matrix consisting of the elements $\{z_{ij}\}$ which depicts the intermediate inputs of goods and services (rows) required by each sector (columns) in monetary units. y is the n by 1 vector of final consumption consisting of the elements $\{y_i\}$ and x is the n by 1 vector of the gross production of each economic sector with the elements $\{x_i\}$. The relationship between the matrix Z and these two vectors is as described in equation (1). In essence, this means that the gross production of each sector is made up of the production of intermediate inputs and the production for final consumption.

$$\mathbf{(I-A)^{-1}y = x} \quad \mathbf{(2)}$$

Equation (2) is a mathematical transformation of equation (1) rendering a functional form for our model. A is the n by n matrix of the direct input coefficients. This matrix is obtained by dividing matrix Z by vector x column by column. Consequently, A is equal to Zx^{-1} and the elements of A are $\{a_{ij} = z_{ij}/x_i\}$. I is the n by n identity matrix and $(I-A)^{-1}$ is the Leontief inverse, the functional heart of the IO model. Each element of the Leontief inverse represents the direct as well as the indirect inputs required by a sector for the production of one unit of output. The indirect inputs are those inputs all along the chain of intermediate supply which are required due to the demand of the sector in question for direct inputs.

For Austria, input-output tables are only compiled every 5 years. The supply and use tables are, however, available annually. We therefore derived the IOT from the SUT as described by Miller and Blair (2009). The matrix A of direct input coefficients can be calculated based on the supply matrix V and the use matrix U in that

$$A = BD \quad (a)$$

The matrix of commodity inputs per industry output B is calculated by

$$B = Ux^{-1} \quad (b)$$

where x is the vector of total industry outputs.

The matrix of industry sources of commodity outputs D is more commonly referred to as the matrix of market shares.

$$D = Vq^{-1} \quad (c)$$

where q is the vector of total commodity outputs. These outputs are equal to the sum of the rows in the use matrix (intermediate use) plus final consumption y:

$$q = Ui+y \quad (d)$$

We can re-write equation (b) as

$$U = Bx \quad (b')$$

and then substitute U from equation (b') into equation (d):

$$q = Bx+y \quad (e)$$

Since the total industry outputs x are equal to the row sums in the make matrix V, x=Vi and by inserting this in equation (c), we obtain:

$$D = xq^{-1} \text{ and } x = Dq \quad (f)$$

Inserting equation (f) into equation (e) yields:

$$q = B(Dq)+y \quad (g)$$

which can, through simple equivalency operations, be transformed into what is the functional core of our model as put forth in equation (2):

$$q = (I-BD)^{-1}+y \quad (g')$$

where A = BD (equation (a)).

Sectoralized vectors had to be formed from the MFA data on domestic extraction and imports and exports before it could be introduced into the input-output model (Weisz et al. 2008). Several 1 by n vectors are required for the both the raw materials extracted by each of the sectors (domestic extraction DE) as well as for those goods imported by the sectors. In the following, for the sake of presenting simple equations to describe our IO model, we will aggregate the material inputs into one single vector containing both DE and imports (i.e. direct material input DMI). It should be kept in mind that on a more disaggregated level, this procedure would be repeated for the different material inputs for which vectors can be formed. This vector is denoted as f in the following equation.

$$\mathbf{r = f\, x^{-1}\, (I\text{-}A)^{-1}} \qquad \mathbf{(3)}$$

Vector r is a 1 by n vector with the elements $\{r_j\}$ describing the direct and indirect physical intermediate inputs required by each sector for the production of one unit of monetary output. The elements contained in this vector thus have the unit kg/€. The elements in r are calculated using the material intensity (f x^{-1}), i.e. the *direct* material inputs per unit of economic output. The elements in f are in physical units, e.g. tons or kilograms. Vector x represents the gross production of the economic sectors and is in monetary units. A is the matrix of the direct input coefficients and I is the identity matrix with ones along the main diagonal and zeros elsewhere. The inverse of the difference between these two is the Leontief inverse $(I\text{-}A)^{-1}$. The latter forms the core of the input-output model. Each cell of the Leontief inverse contains the information on the amount of direct and indirect inputs required by each sector for the production of one unit of output. The direct inputs are those which flow directly into the sector, the indirect inputs are those which are required for the production of the direct inputs along the economy-wide supply chain.

By multiplying this vector r (kg/€) with the final consumption vector y (€), the intermediate inputs required for the production of traded goods can be approximated:

$$\mathbf{e = r \langle y \rangle} \qquad \mathbf{(4)}$$

By adding the intermediate inputs to the mass of the traded goods themselves, the raw material equivalents of trade can be calculated.

RME of Non-Competitive Imports: The LCA Module

The LCA module is used to calculate intermediate inputs for those (groups of) goods for which no comparable production exists in Austria. This module covers the extraction and first processing of metals (iron, copper, and aluminium), the processing of raw materials for fertilizer production, and petroleum and gas extraction (cf. Table 3).

Table 3: MFA Data for Imports Computed in the LCA Module (2000)

MFA	SITC Rev.3		Imports 2000 [t]	Share
2.1	**Iron**			
	281	Iron ore and concentrates	5.426.249	60,62%
	282	Ferrous waste and scrap; remelting scrap ingots of iron or steel	700.528	7,83%
	Div.67	Iron and steel	2.824.472	31,55%
2.2.1	**Copper**			
	283	Copper ores and concentrates; copper mattes, cement copper	182	0,11%
	682	Manufactured goods classified chiefly by material: Copper	164.125	99,89%
2.2.7	**Aluminium**			
	285	Aluminium ores and concentrates (including alumina)	79.784	16,36%
	684	Manufactured goods classified chiefly by material: Aluminium	407.755	83,64%
3.1	**Ornamental or building stone**			
	273	Stone, sand and gravel	740.541	33%
	661	Lime, cement, and fabricated construction materials (except glass and clay materials)	1.480.113	67%
3.6	**Chemical and fertilizer minerals**			
	272	Natural calcium phosphates, natural aluminium calcium phosphates and phosphatic chalk	274.258	29%
	278	Minerals, crude, n.e.s.	88.414	9%
	562	Fertilizers (other than those of group 272)	596.354	62%
4.2	**Hard coal**			
	321	Coal, whether or not pulverized, but not agglomerated	3.412.666	
4.3	**Petroleum**			
	Div.33	Petroleum, petroleum products and related materials	12.212.435	
4.4	**Natural gas**			
	342	Liquefied propane and butane	136.870	3%
	3432	Natural gas, in the gaseous state	4.548.516	97%
	344	Petroleum gases and other gaseous hydrocarbons, n.e.s.	391	0%

Source of MFA Data: Statistik Austria 2011c

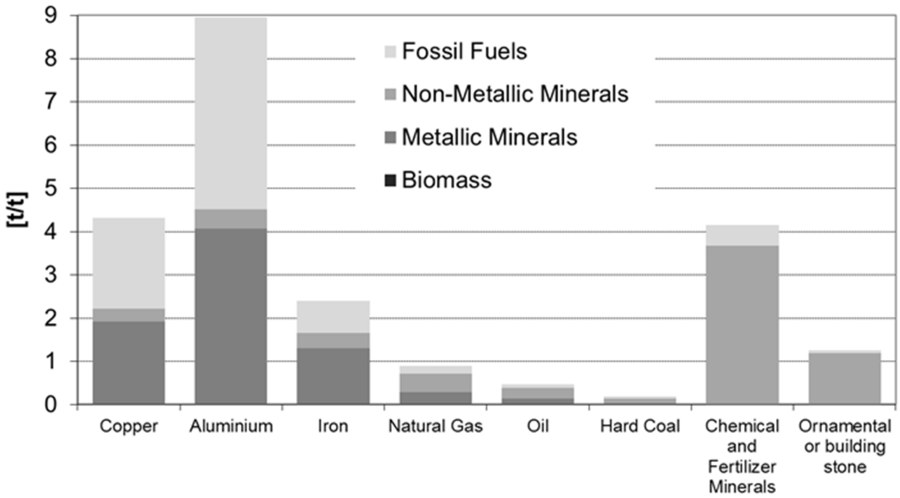
The LCA module consists of a matrix the rows of which contain the intermediate input coefficients per product, differentiated by material category along the columns. These coefficients represent the material input required per unit of output in the production of imported goods and are in the unit of t/t. Some disaggregation from the four main MFA categories was necessary because the intermediate inputs required differ greatly at different stages of production, e.g. between metal ores and consumer goods produced from these metals, between crude oil and gasoline. In order to adapt the coefficients to the level of aggregation at which the underlying MFA trade data are available, a weighted average of the coefficients for different production processes / goods at different degrees of manufacturing was calculated. The UN Comtrade data was disaggregated to the group level (3) of the SITC Rev. 3 classification where 261 different products are distinguished.[3] Based on this data, the share of the different raw materials and consumer goods under each relevant material category was calculated. For example, in 2000, 61% of Austria's iron imports (mass) were iron ore and concentrates while 39% were products of iron and steel. The LCA coefficients applied to iron (on the 3digit level of SITC rev.3) were selected from the LCA database and then weighted according to the composition of Austria's iron imports. The different types of intermediate inputs are aggregated to the four main MFA categories (cf. Table 3).

Figure 4 shows a selection of the weighted, LCA-based coefficients for the intermediate inputs into the production of imported goods. Since these coefficients reflect the composition of Austrian imports, they cannot be applied to other

[3] For the calculation of these coefficients, UN Comtrade data (and not the MFA data provided by Statistics Austria) was used because it was the only available source of data that offered the necessary amount of detail to characterize the Austrian imports by product group. It was verified that the aggregated import sums match those reported by Statistics Austria.

economies directly. In order to make the high intermediate inputs of energy in metal production readily visible in Figure 4, for the metal ores, the surrounding rock (waste rock) which – together with the metal itself – makes up gross ore has been excluded. Figures including waste rock for metals are described in the next paragraph.

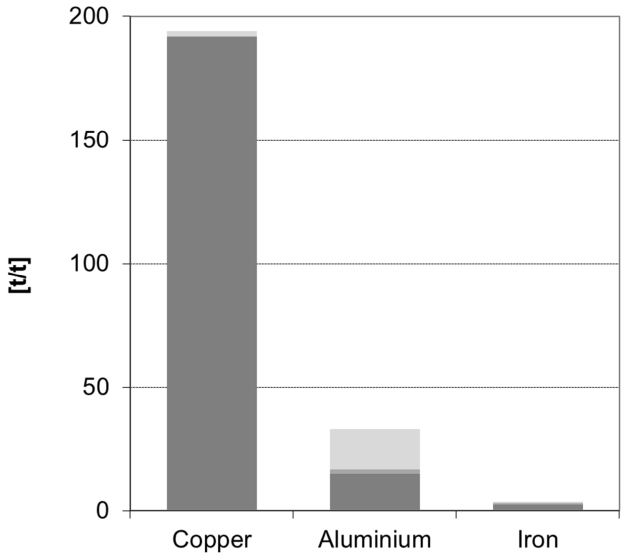
Figure 4: Selection of Weighted, LCA-based Coefficients of Intermediate Inputs by MFA Categories



Source of LCA coefficients: Öko-Institut 2009

These coefficients illustrate the high energy input required in the extraction and refining of metals (copper, aluminium, iron). Additionally, considering that the factors shown here are not in gross ore for metals, it becomes apparent that high amounts of metals are required in the processing of the mined metal ores to the concentrated metal that is then exported. Within the category of chemical and fertilizer minerals (second column from the right), the fertilizers and especially the potassic (K) and phosphate (P) fertilizers are dominant. The explanation for the high inputs of non-metallic minerals required here is twofold: On the one hand, the average K or P content of the mineral mined is only around 20%-40% so that between 3 and 5 tons of non-metallic mineral must be mined in order to obtain 1 tonne of potassic or phosphate fertilizer. On the other hand, the mining processes themselves have infrastructure requirements that are also reflected in input of non-metallic minerals.

Figure 5: Weighted, LCA-Based Coefficients of Intermediate Inputs for Metals, Gross Ore



Source of LCA Coefficients: Öko-Institut 2009

MFA calculates metals as gross ores, i.e. including the waste rock. The average metal content of around 1% in the case of copper ore means that the value of the intermediate inputs rises by a factor of approximately 100. Figure 5 shows that the surrounding rock constitutes the dominant category of intermediate inputs for copper while for aluminium and iron, the energy input remains important due to the higher metal contents that prevail for these minerals. For this calculation, standard factors for metal content were extracted from the data of the US Geological Survey (copper 1%, iron 50%, aluminium/bauxite 25%).

In accordance with the MFA framework (Eurostat 2001, Eurostat 2009), water and air were not considered as inputs for the sake of consistency. However, their contribution to the intermediate inputs is in no way irrelevant with approximately 70 tons of water required for the production of 1 tonne of aluminium (Öko-Institut 2009).

The vector l of LCA coefficients (t/t) is multiplied with the import vector i (t) in order to calculate the intermediate inputs required for the production of these imports:

$$\mathbf{e} = \mathbf{l}\ \mathbf{i} \qquad (5)$$

These imports including their intermediate input requirements are then introduced into the IO module in order to calculate the raw material equivalents of Austria's imports.

Data Used

The intermediate inputs into the production of traded goods also had to be disaggregated in a manner suitable to the MFA categories in the LCA module. This way, it is ensured that the two modules are compatible and sums can be formed from the results of both modules. In addition, this is a prerequisite to the integration of

RME into the existing MFA framework. In the IO module, the material flows had to be assigned to the sectors and product groups of the supply and use tables. The procedure by this compatibility was ensured and the allocation of material flows to IO sectors was performed will be described in the following.

Material Flow Data

The material flow data for 1995 to 2007 are taken from the MFA data compiled and published by Statistics Austria (Statistik Austria 2011c). The data were aggregated according to the MFA categories as published in the current version of the Eurostat standard tables (Eurostat 2009). The allocation of domestic extraction to the primary production sectors (agriculture, forestry, and mining) is a straight-forward procedure with the exception of the allocation of construction minerals. In Austria more or less half of the non-metallic minerals used for construction purposes are extracted directly in the construction sector and not in the mining sector. We therefore allocated 50% of DE of non-metallic minerals to the mining and 50% to the construction sector. Initially, the allocation of the MFA data for imports to the sectors was also performed manually. The expansion of the time series to include all those years for which Austrian input-output data are available (1995, 1997, 1999, and 2000-2007) greatly increased the amount of data involved and required methodological standardization. Therefore, for imports, allocation matrices were developed for all examined points in time. These are based on correspondence tables between the SITC, CPA and MFA classification schemes and on coefficients derived from the detailed physical trade data provided by the UN (UN Comtrade 2011). The latter is available at such a level of disaggregation that the allocation to sectors is unambiguous. UN Comtrade data was extracted for Austrian imports between 1995 and 2007 in kg, SITC Rev 3 in as much detail as needed (down to AG5) for allocation to NACE sectors. For the purposes of allocation, not all data not reported in physical terms were estimated. It was ensured however, that at least 95% of imports as recorded in material flow accounting by Statistics Austria were covered. This was seen to be sufficient in order to achieve a fairly accurate allocation of imports to sectors. Where gap-filling was necessary (most notably for natural gas (SITC code 343) and iron ore (SITC code 281) between 1997 and 2002), it was performed with the help of the existing MFA data. Tables depicting the allocation of MFA data to the input-output categories are provided in the Annex of this Working Paper.

All calculations of RME of Austrian trade were based on the MFA data provided by Statistics Austria. The more detailed UN Comtrade data was only used as auxiliary data in order to allocate the import flows to the given economic sectors.

LCA Coefficients

The LCA coefficients used in the LCA module stem from a different accounting approach than both the monetary supply and use data and the physical MFA data. While the latter two are both based on an economy-wide perspective which seeks to understand the contribution of different sectors or material groups to total amounts (e.g. GDP or DMC) within a given time frame (usually one year), LCA is a process- or product-based approach which takes a very close look at one particular (production) process or product within the economy. The approaches are complementary in the sense that both shed light on different aspects of resource use. Including both approaches within the same model, however, as we do in this proposed RME calculation, requires consideration of the methodological differences in order to avoid errors where possible and to correctly interpret the results. With regard to the LCA coefficients used in this study, two aspects are especially important:

1. Suitability of LCA Coefficients
   The coefficients are usually based on one particular production process, i.e. on a specific use of technology and of material and energy inputs. These production processes, however, vary in space and time. The required inputs can differ from one geographic region to the next: Using the example of iron, in terms of tailings, it would make a difference whether the iron was mined in Brazil with a metal content of over 60% or in Canada where metal content averages at around 50%. Similarly, the technology used in production processes can change over time or also differ from one site to the next. Basic oxygen steelmaking and the use of electric arc furnaces require different inputs when it comes to making steel from iron.

2. System Boundaries Applied
   Even though LCA manages to cover a very large fraction of the inputs into any given production process, there remains a point at which the branching out into upstream input processes is or has to be terminated so that a complete economy-wide coverage is not possible (Chapman 1974, Wilting 1996). Additionally, the processes involved will often deliver inputs for more than one downstream process so that a choice must be made as to how these requirements are allocated to the different processes.

In selecting the database of LCA coefficients used in this model, three criteria were of particular importance: 1) the production processes relevant for Austria's imports must be included, 2) the intermediate inputs must be declared in mass units or physical units convertible to mass, 3) the system boundaries applied must be transparent. Choosing a database which could be used free of charge was an additional criterion in order to avoid obstacles to the reproducibility of our results for other scholars. Based on these deliberations, we decided to use *GEMIS* (Global Emissions Model of Integrated Systems). GEMIS provides both an extensive database as well as the software with which to compile and process the data required for a particular analysis. The software additionally affords the advantage of allowing the user to define some of the system boundaries applied, most notably on including transport and on allocating inputs in case of coupled production. GEMIS is published by the German Institute for Applied Ecology and the current version 4.5 we used during our research covers over 10.000 processes and 1.440 products (Öko-Institut 2009).

GEMIS allows for the depiction of intermediate inputs of material in units of mass (e.g. t, kg) and of energy in the according units (J, kWh). In order to render all intermediate inputs comparable and to enable the formation of totals, the intermediate inputs of energy must therefore be converted to units of mass. This was achieved by using a set of standard factors for the energy content or the calorific value respectively of the different energy carriers. The material inputs corresponding to the energy input vary according to the assumptions made about which energy mix is used in the given production processes. By using the energy mix reported in GEMIS for each production process and differentiating between nuclear energy, hard coal, lignite, oil, gas, renewable energies (biomass, wind, water, geothermal) and waste incineration, a good approximation of the material inputs corresponding to the energy used in production could be made.

Input-Output Data

The input-output module of the model was built on the basis of the monetary supply and use tables (SUT) published by Statistics Austria for the years 1995, 1997, and 1999-2007 (Statistik Austria 2011a). These tables are disaggregated into 57 sectors and product groups. Among these, Austrian SU tables distinguish 7 primary products or sectors:

biomass: agriculture and hunting, forestry, fishery

minerals: coal and peat, oil and gas, mining and quarrying, construction[4]

The transformation of the SU tables to the Leontief inverse required for RME calculation was based on the methodological descriptions provided by Statistics Austria (ÖSTAT 1994, Kolleritsch 2004) and standard input-output works of reference (Miller and Blair 2009). This process was described in mathematical detail in the section entitled "RME of Exports and Competitive Imports: The Input-Output Module".

Results: RME of Austrian Trade 1995-2007

Using our model, we were able to calculate the raw material equivalents of Austria's trade for all years for which monetary supply and use data is available from Statistics Austria, i.e. 1995, 1997 and 1999-2007. The time series now makes it possible to analyse the development and trends of the RME of Austrian trade in greater detail.

In accounting for the raw material equivalents of Austrian trade, both the RME of imports and of exports must be calculated. The RME of imports (RIM) include the imported flows as well as the intermediate material requirements that were used in the production of these goods in other economies. The RME of exports (REX) include the exported flows as well as the intermediate material inputs that were dedicated to the production of these exported goods within the Austrian economy. Based on these two indicators and the information on domestic extraction as available from the Austrian material flow accounts, we can then calculate the traditional MFA indicators in their raw material equivalents: raw material trade balance (RTB), raw material consumption (RMC), and raw material input (RMI) (see Table 4).

It is important to note that these raw material equivalents are classified according to the material group (biomass, fossil energy carriers, metal ores, non-metallic minerals, or other products) that the intermediate inputs belong to. This means that the category "metal ores" in the RME of imports includes the metal imports as well as all metal ores used in the production of all imports. This category is *not* the sum of the intermediate inputs into the imported metals. Instead, these intermediate inputs are biomass, fossil energy carriers, metal ores, non-metallic minerals, or other products depending on what they consist of and allocated to the respective material category. The material category "other products" has to be introduced for the intermediate

[4] As was previously explained, we made the assumption that in Austria, 50% of the sand and gravel DE is extracted directly by the construction sector.

inputs because some of the product groups which exist in the IO data are composed of more than one type of four basic MFA material categories and a main fraction cannot be unambiguously identified.

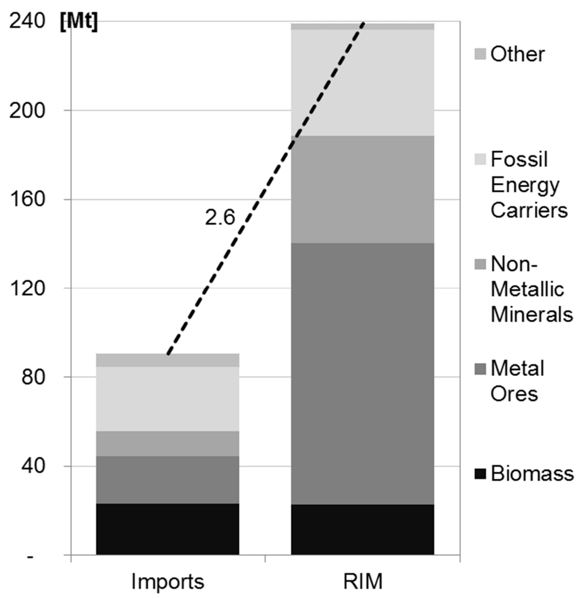
Table 4: Indicators Derived from Economy-Wide MFA and RME Accounts

MFA Indicators	RME-Based Indicators
Direct Material Input (**DMI**) = Domestic Extraction (DE) + Imports	Raw Material Input (**RMI**) = DE + RIM
Physical Trade Balance (**PTB**) = Imports – Exports	Raw Material Trade Balance (**RTB**) = RIM – REX
Domestic Material Consumption (**DMC**) = DE + Imports – Exports	Raw Material Consumption (**RMC**) = DE + RIM – REX

RME of Austrian Imports

In the year 2007, Austria directly imported approximately 91 million tons of material. The production of these goods was associated with upstream material inputs in the economies of origin. In the case of Austria's imports, these inputs were highly significant. If we add the upstream inputs to the import flows, we obtain the raw material equivalents of Austria's imports (RIM). In 2007, they amounted to approximately 239 million tons and thus surpassed imports by a factor of 2.6 (see Figure 6).

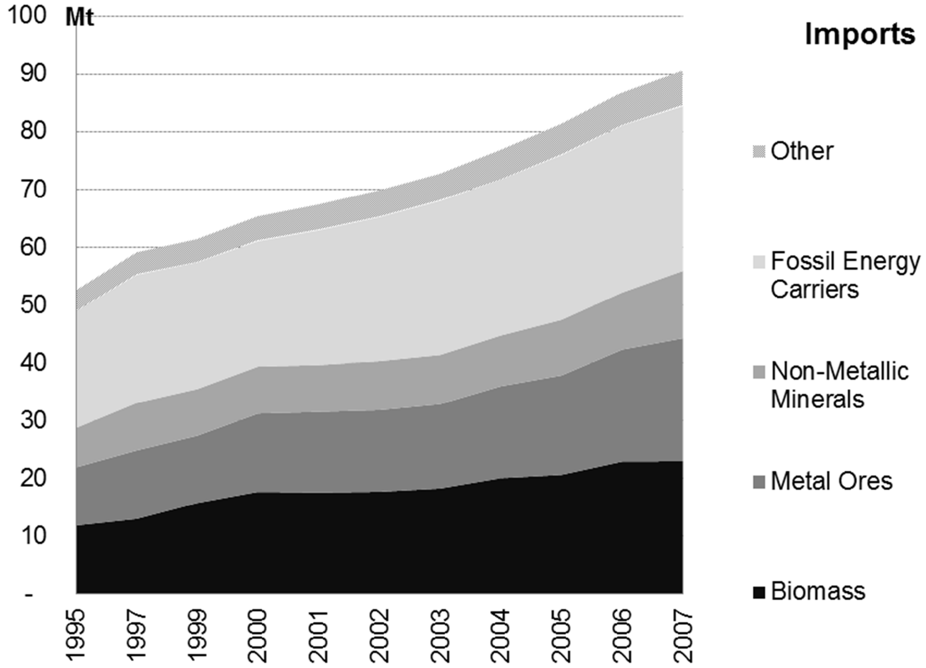
Figure 6: Austria's Imports and RIM in 2007 in Million Tons



The major share of Austria's imports was made up of fossil energy carriers (31%), biomass (25%) and ores (23%). This relationship is noticeably different in the RME of imports (RIM) where metal ores make up the largest share (49%) and are followed by fossil energy carriers (20%) and non-metallic minerals (20%). This shift is especially due to the fact that metals are imported mainly in the shape of metal concentrates or metals products. From the extraction of metal ores via the concentration of these metals to the completion of metal products, however, a steady reduction of the material mass occurs. While this is obviously not included in the imports, it does become visible in the RME of these imports. The second factor making ores a much larger fraction in RIM than in the imports are the metal requirements of infrastructure for the production of many of the imported goods, especially also of the fossil energy carriers. Overall, this means that the RME of metal imports surpasses metal imports by a factor of 5.5. While fossil energy carriers are not subject to the reduction of mass along the chain of production to such an extent as metals are, they are important intermediate inputs in virtually all other production processes and are therefore significantly higher (factor 1.7) when measured in RIM than as imports. A very noticeable difference between imports and RIM is also given for non-metallic minerals. These are imported in very small amounts only and make up 13% of Austria's imports. However, non-metallic minerals are also required in large amounts in the construction of infrastructure as required for other production processes so that the RME of Austria's non-metallic mineral imports is 4.1 times larger than the imports of this category.

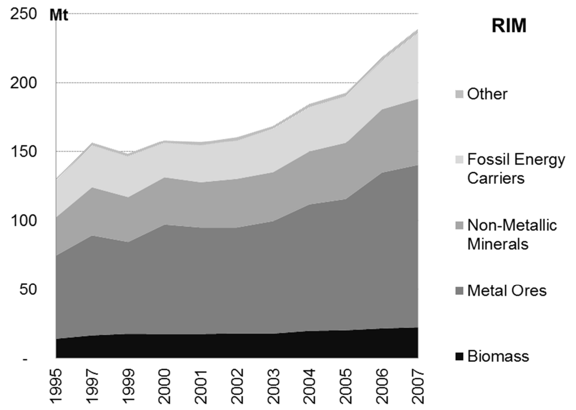
In 2007, the goods with the highest raw material equivalents were imported for the manufacture of basic metals and fabricated metal products. In large part, this is due to the imported metals and/or metal ores which, following the conventions of material flow accounting, are included not in their metal content but as gross ore. The sector with the second highest RIM was the extraction of crude petroleum and natural gas. Together, these two sectors accounted for over 50% of the RIM in 2007.

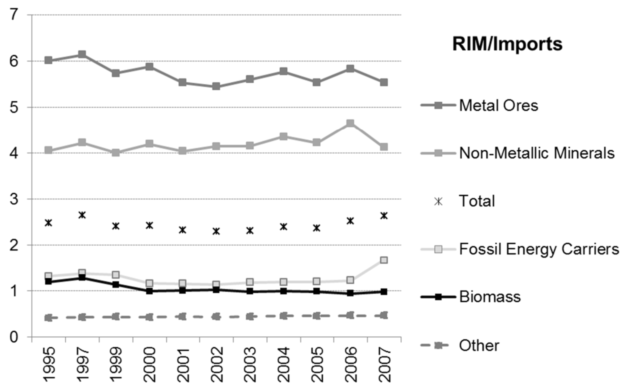
Figure 7: Austria's Imports 1995 - 2007 in Million Tons



Across the period of time under investigation, Austria's imports grew by a factor of 1.7 (Figure 7) and played an increasingly important role in meeting the economy's resource demand. In 1995, imports accounted for 24% of Austria's direct material input (DMI = DE + Imports). In 2007, this share had already increased to 36%. The growing importance of traded goods underlines the relevance of considering upstream material requirements through the calculation of the raw material equivalents. The share of biomass in imports grew slightly from 23% in 1995 to 25% in 2007. The share of metal ores grew from 19% to 23% across the same period of time. Non-metallic minerals remained constant at 13%. The share of fossil energy carriers decreased from 38% to 31% but still made up the largest fraction of imports.

Figure 8: Austrian RIM in Million Tons (left) and Ratio between RIM and Imports (right), 1995-2007





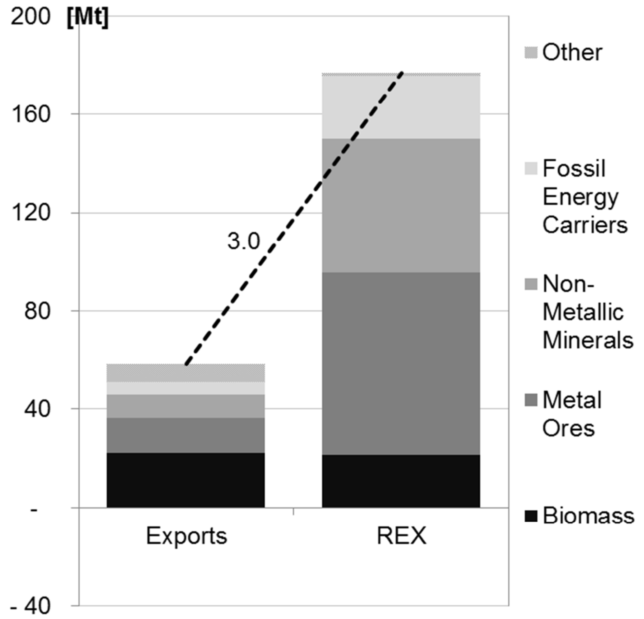
Between, 1995 and 2007, the Austria's RIM also grew by a factor of 1.8, i.e. by almost the same factor as imports (Figure 8). This accordance is not a methodological artefact but the aggregate effect of changes in the composition of imports and changes in the upstream material requirements. The shares of the different material categories in the overall RIM remained fairly constant. The share of biomass decreased slightly from 11% to 9%. Metal ores made up 46% in 1995 and 49% in 2007. The share of non-metallic minerals fell slightly from 21% to 20%. Fossil energy carriers remained constant at 20% across the period under investigation.

The ratio of RIM to imports remained fairly constant between 1995 and 2007, varying from 2.5 to 2.6. As can be seen on the right-hand side in Figure 8, this ratio between RIM and imports remained almost constant for all material categories between 1995 and 2007.

RME of Austrian Exports

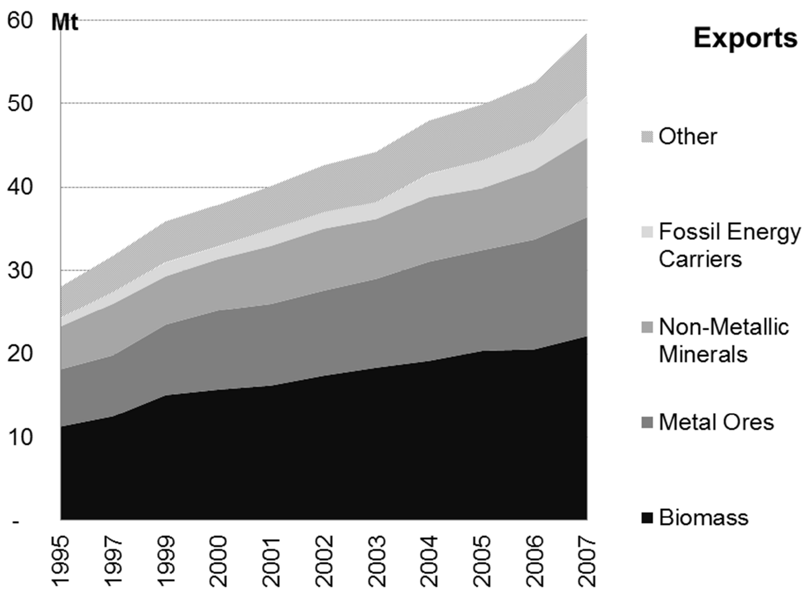
Measured in mass units, the Austrian economy is a net-importer of resources, i.e. the mass of imports exceeds that of exports. In 2007, Austria directly exported approximately 58 million tons of material. Like most industrialized economies, Austria mainly exports highly processed goods for the production of which it imports raw materials or less processed goods. What is uncommon for an industrialized economy is the high share of biomass-products in the economy's exports. A considerable amount of the material mobilized within the Austrian economy or imported from other economies is used to produce exports. This amount of material can be made visible by calculating the RME of Austria's exports (REX). In 2007, the latter amounted to approximately 177 million tons and were thus about 3.0 times larger than the exports (Figure 9).

Figure 9: Austria's Exports and REX in 2007 in Million Tons



In 2007, the major share of Austria's exports was made up of biomass (38%) followed by metal ores (24%) and non-metallic minerals (16%). Other products which cannot unambiguously be allocated to one material group due to their heterogeneous composition made up 13% of exports. With a share of only 9%, fossil fuel based goods were the smallest fraction of exports. Most of the upstream inputs required in the production of all exported goods were metal ores for which REX was 5.2 times larger than exports. For non-metallic minerals and fossil energy carriers, the factor between exports in this material category and material-specific REX was approximately 5.7 and 5.0, respectively. Biomass only made up 12% of REX (as opposed to 38% of exports). As was the case for imports, there is no direct correspondence between the exports and their RME by material category, i.e. not all upstream inputs of ores were required for the production of exported metals. Instead, especially metals and construction minerals are required to build up and maintain infrastructure for almost all production processes. Fossil energy is also an input that feeds into all production processes.

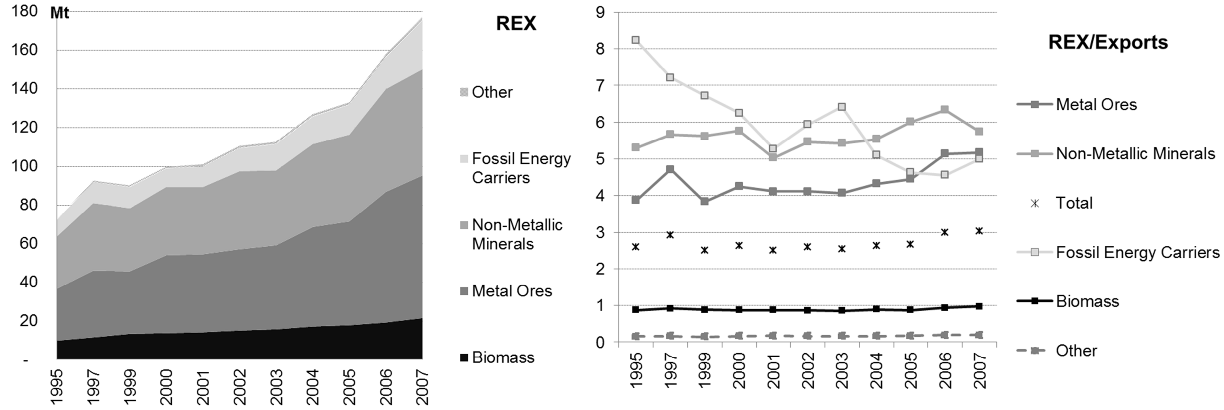
Figure 10: Austria's Exports 1995 - 2007 in Million Tons



The importance of trade grew noticeably between 1995 and 2007. This is true not only for the contribution of imports to meet domestic demand, but also for the role of imports in providing the resource base for export production. Across the 12 year period, exports grew by a factor of 2.1 (Figure 10). The strongest growth occurred for fossil energy carriers, i.e. the smallest fraction of the exports, which grew by a factor of almost 5. This growth may seem surprising at first considering that Austria has very few domestic sources of fossil energy carriers and is dependent on imports to meet its demand. Petroleum refinery is, however, an important branch within the Austrian economy: It contributes a significant share to GDP and the mineral oil authority OMV is the biggest Austrian enterprise in terms of capital and employment. The refinery at Schwechat processes approximately 90% imported and 10% domestic petroleum resources; roughly 20% of the production is exported (Fachverband der Mineralölindustrie Österreichs 2010). Exports of biomass doubled between 1995 and 2007. The same is true for exports of metal ores, non-metallic minerals, and other products.

The Austrian REX grew by a factor of 2.4 between 1995 and 2007, i.e. slightly faster than exports (Figure 11). In 1995, REX amounted to approximately 73 million tons and increased to 177 million tons in 2007.

Figure 11: Austrian REX in Million Tons (left) and Ratio between REX and Exports (right), 1995-2007

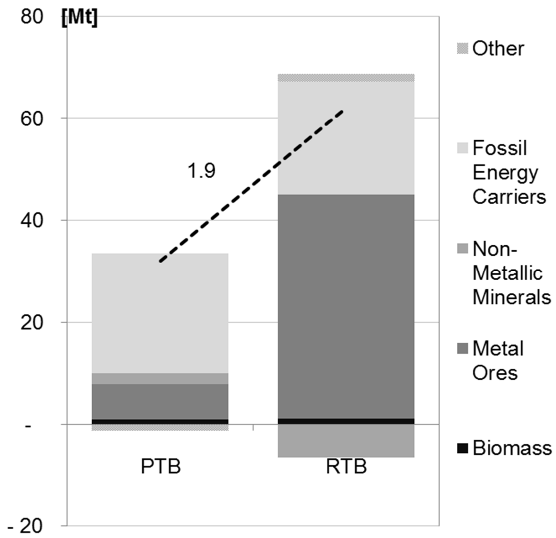


As was the case for the RME of imports, the shares of the different material categories in the overall REX remained fairly constant over time. The strongest growth occurred in the REX of fossil energy carriers with a factor of 3.0. Their share in total RME increased during the 12 year period from 12% to 14% in 2007. The REX of all other material groups slightly more than doubled in the observed period (factor 2.0 to 2.8). The ratio of REX to exports increased from 2.6 in 1995 to 3.0 in 2007, indicating, that the aggregate material intensity of exports goods is growing: 3 times the mass of exported goods is used within the Austrian economy in the production process of these commodities.

Austria's Trade Balance

As was outlined above, the Austrian economy is a net importer of goods, i.e. the mass flow of imports exceeds that of exports. An indicator for this relationship is the physical trade balance (PTB) which corresponds to the total imports minus the total exports in a given year. If the PTB is positive, that economy is a net importer, if it is negative, a net exporter. In 2007, Austria's PTB was slightly above 32 million tons. The highest net imports occurred for fossil energy carriers at 23 million tons (see Figure 12). This reflects that Austria imports significantly more fossil energy carriers than it exports. In 2007, the second largest material group in the PTB was metal ores (7 million tons). As is the case with fossil energy carriers, metals are resources with limited domestic availability in Austria and a high share of imports in DMC. For all other material categories, the PTB is not as large, meaning that import and export flows are more or less of the same size. Imports of non-metallic minerals exceed exports by about 2 million tons. For biomass, import and export flows are almost equal, resulting in a PTB of just 0.9 million tons. Other products are the only material group for which exports exceed imports resulting in a negative PTB (-1 million tons). As an industrialized economy, Austria tends to produce these rather heterogeneous goods and export them rather than import them.

Figure 12: Austria's Physical Trade Balance (PTB) and Raw Material Trade Balance (RTB) in 2007 in Million Tons



By calculating the trade balance from RIM and REX, we obtain the Raw Material Trade Balance (RTB). In the year 2007, the RTB was considerably higher than the PTB (factor 1.9). For comparison: RIM was higher than imports by a factor of 2.6 and for REX and exports this factor was 3.0. The large amount of metal ores required as upstream inputs for the production of imported goods accounts for the major part of this difference. The RTB for this material category shows that 44 million tons more were imported than exported. The next largest fraction in the RTB are fossil energy carriers of which approximately 22 million tons more were imported than exported. The RTB of non-metallic minerals which was a category of small net imports (approximately 2 million tons) in the PTB, is a category of net exports (-6.6 million tons) when measured in raw material equivalents. This is an interesting finding because it shows that while construction minerals are generally not traded in large amounts due to their ubiquity and their low price, they are very relevant to trade as upstream inputs into production processes. Biomass is a category of (almost balanced) net imports in both PTB (0.9 million tons) and RTB (1.1 million tons). The other products RTB amounts to 1.4 million tons.

Figure 13: Austria's Physical Trade Balance (left) and Raw Material Trade Balance (right) in 2007 in Million Tons

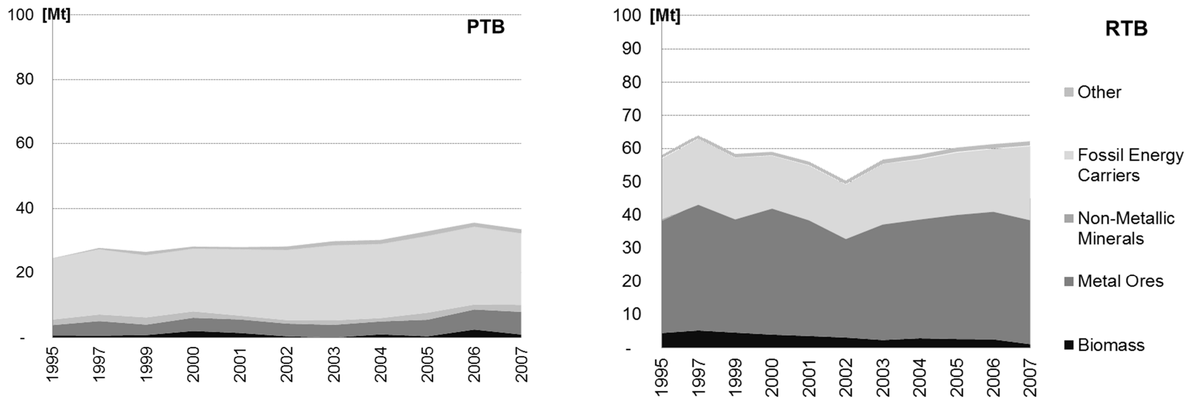
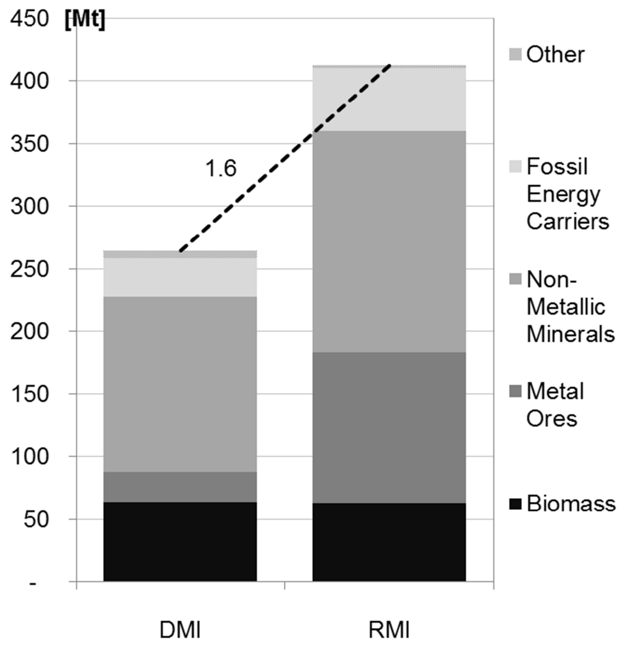


Figure 13 illustrates the large difference between PTB and RTB: From 1995 to 2007, the PTB grew from approximately 25 to 32 million tons by a factor of 1.3. During the same period of time, the RTB decreased slightly from approximately 58 to 62 million tons by a factor of 1.1. This stagnation in the trade balances in comparison to the growth that we have seen in other indicators across the 12-year period is due to the fact that exports and imports as well as the RME of these flows grew to roughly the same extent.

Austria's Material Inputs

Based on the calculation of the raw material equivalents of imports and exports, the MFA indicators can now also be presented both in terms of RME. An economy's direct material inputs correspond to domestic extraction plus imports.

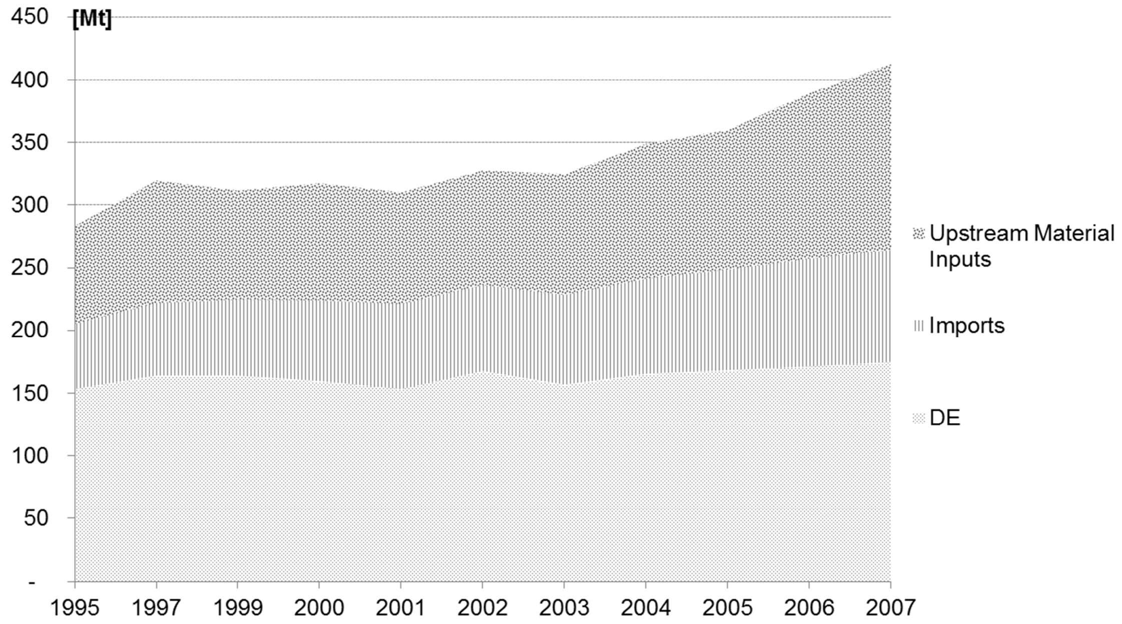
Figure 14: Austria's Direct Material Input (DMI) and Raw Material Input (RMI) in 2007 in Million Tons



In 2007, Austria required approximately 264 million tons of DMI over half (53%) of which was accounted for by non-metallic minerals (Figure 14). Out of 140 million tons of non-metallic mineral DMI, 92% (128 million tons) were domestic extraction and only 8% were imports. The total RMI (raw material input) in 2007 was 1.6 times the DMI and amounted to 413 million tons. Non-metallic minerals still made up the largest fraction of RMI and contributed 43% to the total, followed by metal ores which contributed 29% to RMI (as opposed to just 9% to DMI). Fossil energy carriers contributed 12% to RMI (and 12% to DMI). Biomass contributed 24% to DMI and 15% to RMI.

Between 1995 and 2007, Austria's RMI grew from 283 to 413 million tons by a factor of 1.5. In examining the RMI by its components (Figure 15), it can be seen that domestic extraction remained fairly constant across the period under investigation, increasing only slightly from 153 to 173 million tons (factor 1.1). Imports grew from 53 to 91 million tons (factor 1.7). The upstream material inputs into those imports increased by a factor of 1.9 from 78 to 148 million tons.

Figure 15: Austria's RMI by Components 1995-2007 in Million Tons

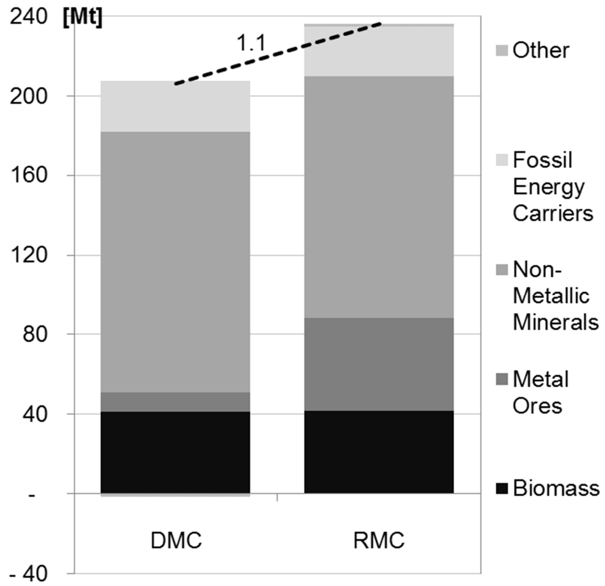


This means that the share of upstream inputs in Austria's RMI increased from 28% in 1995 to 36% in 2007. During the same period of time, imports increased from a share of 19% to 22% while the share of domestic extraction (DE) in RMI decreased from 54% to 42%. This development means that Austria's demand for raw materials is increasingly supplied by foreign economies and that, overall, raw material input from abroad (imports and associated upstream material requirements) contributes more to RMI than do the materials extracted in Austria.

Austria's Material Consumption

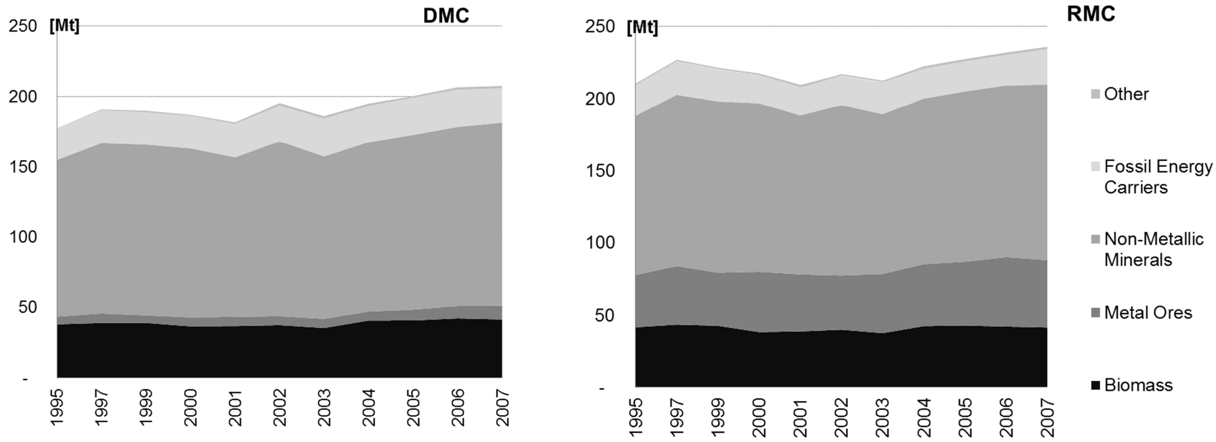
In 2007, Austria's domestic material consumption (DMC = DE + imports - exports) reached 206 million tons (Figure 16) or a total of approximately 25 t/cap. The major share of DMC consisted of non-metallic minerals (130 million tons or 63% of DMC) followed by biomass (41 million tons, 20% of DMC), and fossil energy carriers (26 million tons, 13% of DMC). Calculating DMC in terms of its raw material equivalents renders the indicator Raw Material Consumption (RMC = DE + RIM - REX), which quantifies all raw materials used globally to satisfy Austrian final demand. In 2007, RMC reached a total of approximately 236 million tons, corresponding to 28 t/cap. This means that when upstream material inputs are taken into account, Austria's total resource consumption was 3 t/cap (factor 1.1) higher than as indicated by DMC. While this only corresponds to a slight overall increase, the composition of RMC differs significantly from that of DMC. Non-metallic minerals continue to make up the major share (52%) but are now followed by metal ores (20%), and then by biomass (18%) and fossil energy carriers (10%). When we account for Austria's global resource use in the form of the RMC, we find an increased consumption of metal ores (+ 4 t/cap) and a decreased consumption of non-metallic minerals (- 1 t/cap) indicating that the latter materials play an important role in the production of exported goods.

Figure 16: Austria's Domestic Material Consumption in DMC and RMC in 2007 in Million Tons



Some of this outsourcing of the material requirements associated with Austrian consumption may help protect the domestic resource base. At the same time, it must be taken into account that the higher level of consumption can also be associated with a higher contribution to global environmental impacts: When raw material equivalents are considered, the total fossil energy input into the Austrian economy is 19 million tons higher than as measured in DMI. In consequence, the associated CO_2 emissions are also much higher. Using an average factor of 9.1 tons of CO_2 equivalent per ton (based on the Austrian import-mix) for the greenhouse gas emissions resulting from this material input (Öko-Institut 2009), this corresponds to an additional 174 million tons of CO_2 emissions.

Figure 17: Austria's DMC (left) and RMC (right) between 1995 and 2007 in Million Tons



Between 1995 and 2007, Austrian DMC almost stagnated, growing only slightly from 177 to 206 million tons (factor 1.2) and Austrian RMC grew from 211 to 236 million tons (factor 1.1). This means that the global demand for raw materials is slightly higher in terms of raw material equivalents than compared to domestic material consumption. This is due to the upstream material requirements associated with imported goods and exported goods being comparably. Overall, Austria is not increasingly outsourcing material use but is both indirectly using materials in and providing materials to other economies. Thus, figures for Austria do not support the assumption that industrialized countries increasingly outsource material-intensive production. At least for the past 10 years, this is not the case in Austria. It might, however, still be a development valid for phases of stronger economic growth such as in Austria prior to 1995.

The material composition of both indicators also remained constant with non-metallic minerals contributing over 60% to DMC, followed by biomass (20%) and fossil energy carriers (13%). In terms of RMC, non-metallic minerals also consistently contributed the largest share (around 50%) followed by metal ores and biomass (each around 20%), and fossil energy carriers (10%). Austria’s high domestic extraction of non-metallic minerals remains visible as do the high upstream material inputs associated with the given level of metal consumption.

Impacts of the Methodological Approach

As was outlined in the section on existing RME accounts, different methods for the calculation of RME are available. The hybrid method used in this study to quantify the RME of Austrian trade was developed from a single region input-output (SRIO) approach. In the original SRIO approach, performed for the year 2000 only, it is assumed that the input-output structure of the Austrian economy holds true for its imports as well.

Figure 18: Comparison of the Results of an SRIO and a Hybrid Approach, Austria 2000 in Million Tons

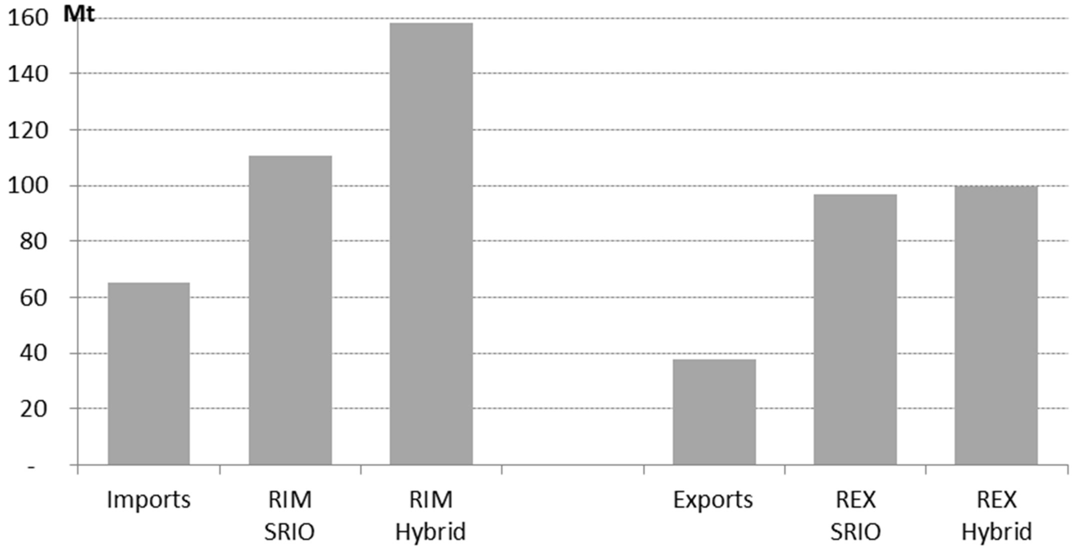


Figure 18 illustrates that the assumption of straight-forward applicability of domestic input-output structures to the production of imported goods resulted in a considerable underestimation of the RME of import flows for the year 2000 compared to the hybrid approach. Imports amounted to approximately 65 million tons in the year 2000. Using the SRIO approach, RIM was calculated to be 110 million tons, i.e. higher by a factor of 1.7 than the imports. By using a hybrid approach, we were able to better account for the upstream inputs into the production of non-competitive imports. This resulted in higher values (factor 1.4) for RIM than using the SRIO-based calculation. RIM according to the hybrid approach are approximately 159 million tons and they are 2.4 times the size of imports. For exports, the results from the two calculation methods are almost identical. The slight difference is due to the fact that imported goods were used for the production of exports (RIM are considered in the calculation of REX).

Adding Economic Detail: Results by Sectors

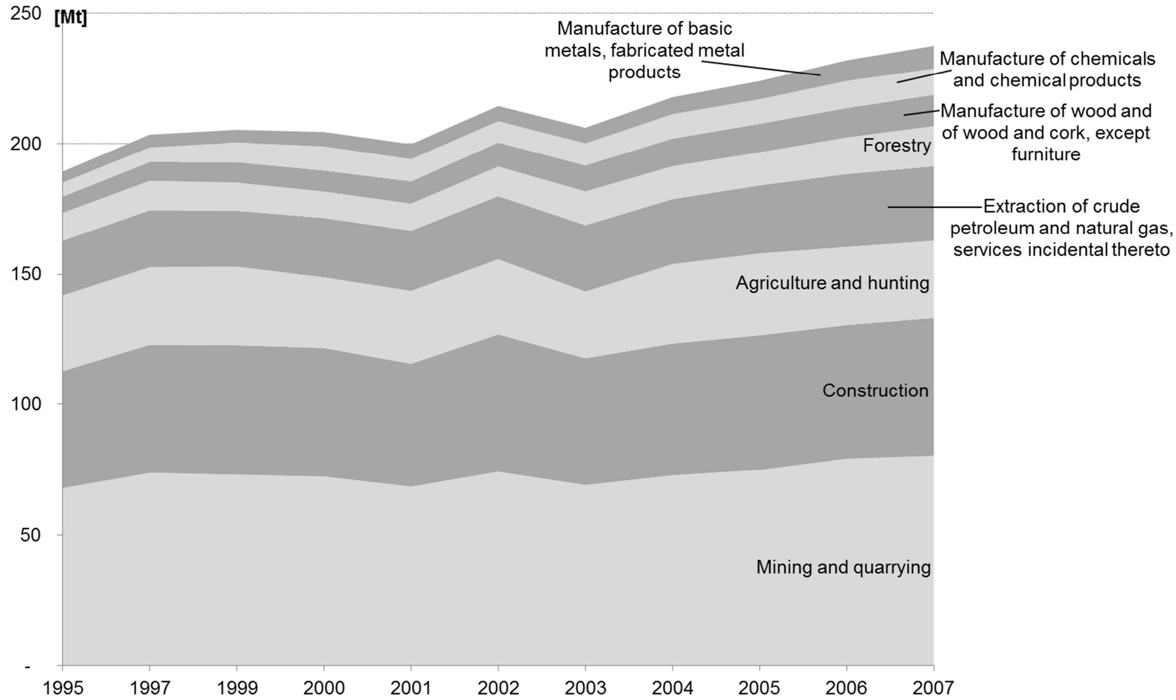
Through the work on the raw material equivalents of Austria's trade it has become possible to directly link high-quality data on material flows with existing economic accounts. This adds a new dimension to the analyses of economy-wide MFA data: Due to the information on inter-industry relations provided by the economic supply and use tables, it is possible to open up to some degree the 'black box' that, within the MFA framework, is the economy. In the following, we will present some of the insights gained concerning the sectorial distribution of material demand in the Austrian economy.

The Material Requirements of the Sectors

In order to be able to link the physical MFA data with the monetary information contained in the supply and use tables, it was necessary to develop a method for the allocation of the material flows of both domestic extraction and imports to the economic sectors (for a more detailed description of this procedure, please refer to the section on Calculating RME: The Austrian Hybrid Method).

In terms of domestic extraction, the results show that the largest share of material within Austria is extracted by the mining sector (about 75 million tons in the year 2007), followed by the construction sector (53 million tons), agriculture (approximately 26 million tons), forestry (14 million tons), and the crude petroleum and natural gas sector (5 million tons). The ranking of the sectors remained unchanged across the 12-year period under investigation and the amounts extracted were fairly constant.

Figure 19: Austria's DMI by Sectors, 1995-2007

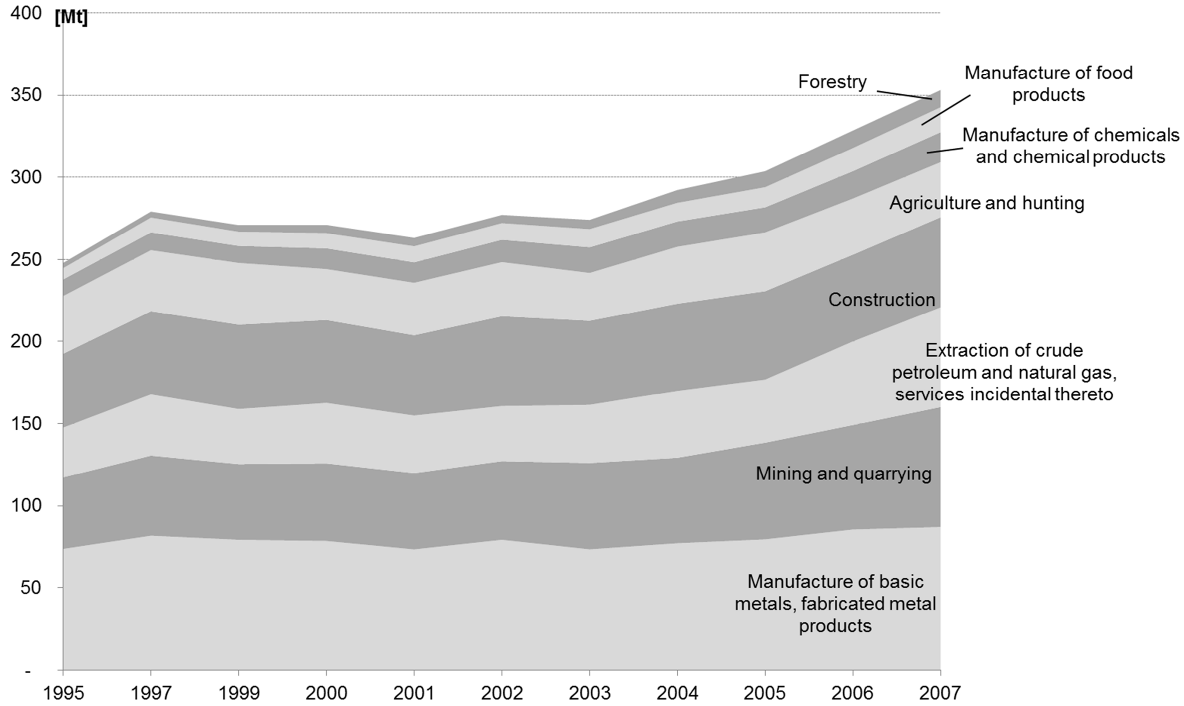


When the import flows are also taken into account, 8 sectors were responsible for 90% of Austria's direct material input in 2007 (see

Figure 19, bottom to top): mining and quarrying, construction, agriculture and hunting, extraction of crude petroleum and natural gas, forestry, manufacture of chemical products, manufacture of wood and of wood and cork products, and manufacture of basic metals and fabricated metal products. The Austrian DMI is dominated by construction minerals extracted by the mining and the construction sector which account for over 50% of total DMI. As was outlined above, this is in large part due to the high domestic extraction of construction minerals. The latter are used in large quantities in most economies but are of comparatively low economic value. Therefore, the statistical coverage on the extraction of these materials is often incomplete. Through a concerted effort of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, Statistics Austria, and the Institute of Social Ecology, the data for the Austrian economy could be greatly improved (cf. Milota et al. 2011). The more complete coverage of construction minerals has highlighted the quantitatively large role they play in overall resource use.

The picture of sectorial material input changes drastically if the raw material equivalents of imports are taken into account in the raw material input (RMI = DE + RIM, see Figure 20). Austria hardly extracts ores: Imports make up 89% of the country's metal DMI. Metals are imported in the form of concentrates or manufactured products. This means that large fractions of the excavated ores (especially the surrounding rock) as well as the other material requirements associated with mining and metal processing are accounted for as DMC in the exporting countries and not in the Austrian domestic economy. Therefore, when we include the upstream material requirements associated with Austrian imports, the manufacture of basic metals and fabricated metal products becomes the sector with the highest share in total RMI. It is followed by mining and quarrying, for which imports do not play a very important role, contributing only 5% to total imports and 3% to total raw material equivalents of imports in 2007. The mining sector continues to play a dominant role in the RMI due to its high domestic extraction.

Figure 20: Austria's RMI by Sectors, 1995-2007



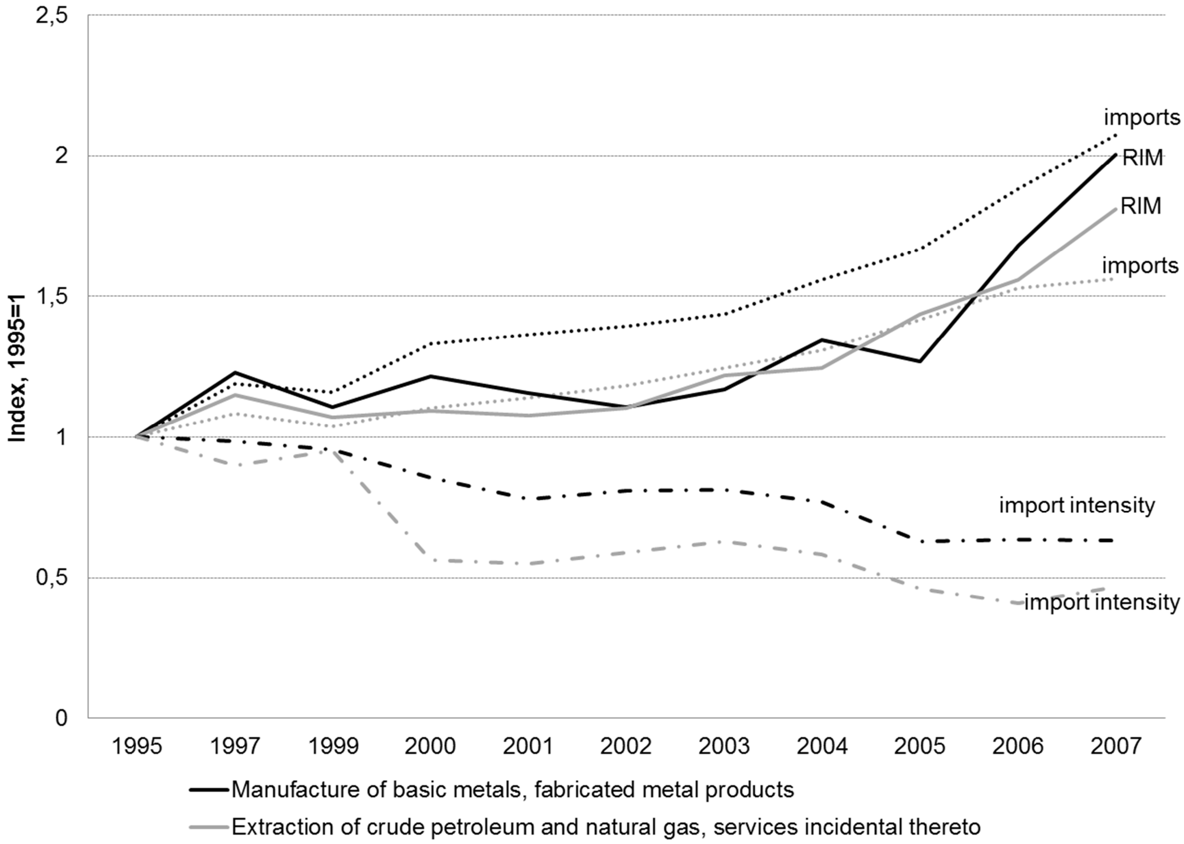
Fossil energy carrier imports also play a very important role in Austria's material inputs. This was the largest material import category in 2007 and imports made up 92% of the country's fossil energy carrier DMI. The extraction of crude petroleum and natural gas is the sector with the third largest share in RMI. It is followed by construction – still mainly due to its high amount of domestic extraction, agriculture, manufacture of chemical products, manufacture of food products, and forestry.

Sectorial Import Intensity

The aforementioned sectors processing metals and (crude) petroleum merit special attention because of the particularly high degree to which Austria depends on imports of these resources. As shown on the dotted lines in

Figure 21, the imports of these sectors increased by a factor of more than 2 for the metals and more than 1.5 for the petroleum sector. The full lines in the same diagram show the RIM by each of these sectors. The RIM for the petroleum sector increased by a factor of 1.8; for the metals sector, this factor was slightly higher at 2.0.

Figure 21: Indexed Development of Austria's Imports in the Metals and Petroleum Sectors, 1995-2007

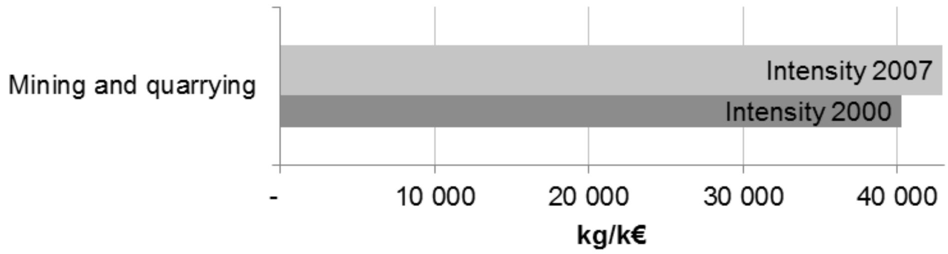


The explanation for this development lies in the intensity of the imported goods. The intensity is a measure of the amount of physical input (in kg) required for one monetary unit of imports (measured, in our case, in deflated 2005 1000 €) of a given sector. The intensities are used in the IO module of the RME calculation to convert monetary flows (as depicted in the supply and use tables) into physical flows. For both the metal and the crude oil and natural gas sector, the material intensity of the goods imported decreased between 1995 and 2007. This means that less material was required per unit of imported goods. In the case of the metals sector, the intensity of imports was decreased by 37%. For the petroleum sector, the decline was even steeper at 53%. However, the intensity of the imports of the petroleum sector was much higher to begin with and decreased to 10 947 kg/k€ while the imports of the metals sector decreased to 4 386 kg/k€. The decreasing intensity is not so much a result of decreasing material inputs but of growth of monetary output (for more detail see below).

The Austrian input-output data is provided in current prices. Therefore, in all time series analysis of monetary (or mixed units) data, the values were deflated (to 2005 €) according to the information provided in Statistik Austria (2012a).

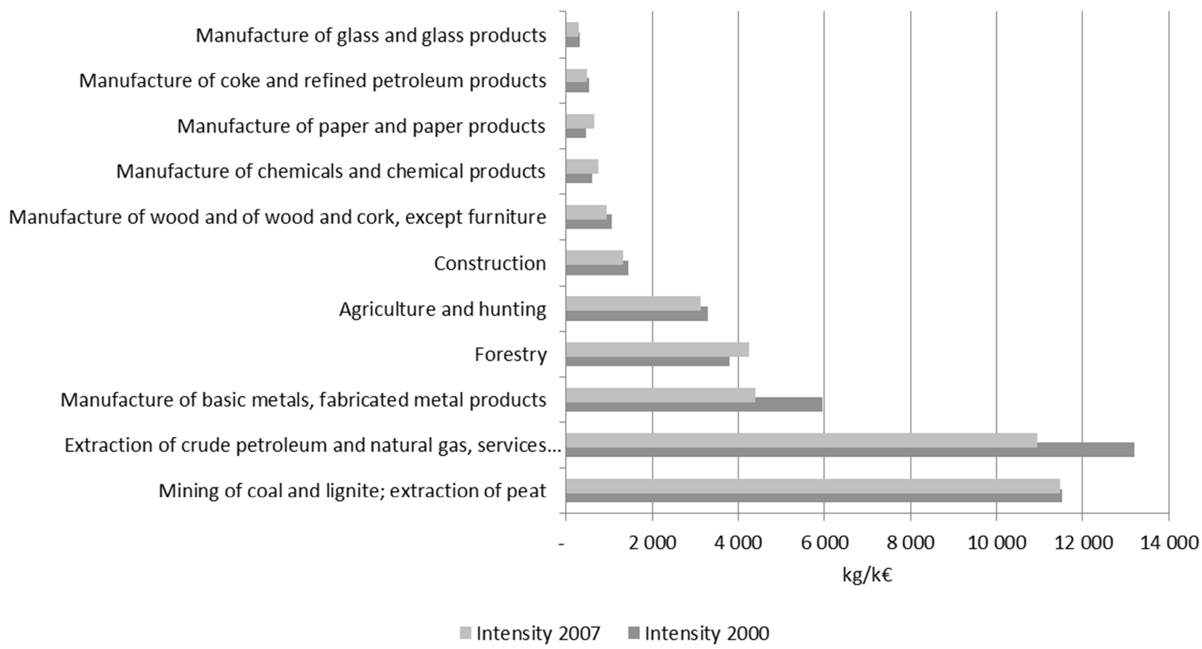
The trend of decreasing material intensities of the RIM that could be observed for the metals as well as the petroleum sector is one that has generally been evident across the period under investigation. Figure 22 and Figure 23 illustrate the material intensity of the sectorial RIM in 2000 and 2007.

Figure 22: Material Intensity of Austria's Imports in the Mining and Quarrying Sector in 2000 and 2007



The year 2000 (rather than 1995 as the first point in time under investigation) was chosen here due to a change in the supply and use (SU) data reported by Statistics Austria between 1999 and 2000 which limits comparability of the earlier data. Prior to the year 2000, the monetary SU data were reported at a more highly aggregated level with the fishery and the forestry sector included in the agricultural sector. In order to provide more detail, we therefore compared the material intensity in the years 2000 and 2007. The mining and quarrying sector had the most material intensive imports in both years: Per 1000 € worth of imports, 40 228 kg of material were required in 2000 and 42 917 kg in 2007 (Figure 22). While the intensities are high, it must be kept in mind that most of the stones and earths required by this sector are not imported but rather extracted domestically. In 2007, the imports of this sector – non-metallic minerals only – made up only 5% of Austria's total imports. When the upstream inputs required for the production of imported goods are taken into account, it becomes apparent that the sector also requires inputs of fossil energy carriers. The latter, however, make up only 2% of the RIM, while non-metallic minerals contribute 98%. The dominance of this fraction is what leads to the high intensity of these imports because the materials are used in bulk but have a relatively low price.

Figure 23: Material Intensity of Austrian Imports in kg/k€ in 2000 and 2007



The intensities of the imports of other sectors are significantly lower. Between 2000 and 2007, these intensities either remained relatively constant or decreased. The second highest intensity is exhibited by the imports of the mining of coal and lignite sector (11 521 kg/k€ in 2000 and 11 470 kg/k€ in 2007), followed by the extraction of crude petroleum and natural gas, manufacture of metals and metal products, forestry, agriculture, construction, manufacture of wood products, manufacture of chemicals and chemical products, manufacture of paper and paper products, manufacture of coke and refined petroleum products, and manufacture of glass and glass products and other non-metallic mineral products (from bottom to top in Figure 23).

Out of these 11 sectors, material intensity decreased in 8 sectors and increased only in forestry, the manufacture of chemical products, and the manufacture of paper products. The decreasing intensities that occur are due to the fact that the material inputs required by the respective production grew at a slower pace than the gross monetary output of the producing sectors. In the case of the coal and lignite mining sector, for example, material input grew by a factor of 1.8 between 2000 and 2007, while the gross monetary output (in 2005 €) thereby generated grew by 1.9. Neither these slight nor the more pronounced efficiency gains could be translated into an absolute reduction in the sectorial resource demand. For those sectors for which the material intensity of imports *decreased*, the raw material input *increased* by a factor between 1.1 for agriculture and 2.1 for the manufacture of coke and refined petroleum products. This phenomenon is commonly referred to as the rebound effect or Jevons' paradox by which efficiency gains are offset by higher amounts of total consumption (Weizsäcker et al. 2009).

Austria's RME in Comparison to Other Countries

Austria in Comparison to the Czech Republic and Germany

In this section, results of RME calculations for Austria, the Czech Republic and Germany will be compared. For all three countries, a comparable methodological approach, i.e. the hybrid approach which combines an IO model with LCA coefficients, has been used to calculate RME.

The German study was performed by the German statistics office (DESTATIS) and the underlying empirical database is highly detailed: The IO matrix differentiates 120 sectors and 3000 products and the LCA coefficients applied were derived from detailed case studies for 122 production processes which were specifically conducted for this calculation. The Czech study was performed by a team at the Charles University in Prague and is highly comparable to the Austrian calculation: A comparable level of detail was applied and the LCA coefficients were derived from the same database (GEMIS).

Table 5: DMC and RMC per capita for Austria, the Czech Republic, and Germany, 2003

2003	DMC per capita [t/cap]	RMC per capita [t/cap]	RMC/DMC [factor]
Austria	23	26	1.1
Czech Republic[5]	18	22	1.3
Germany[6]	16	23	1.4

Table 5 presents DMC and RMC (per capita) data for the three countries in 2003. For all three countries, RMC is higher than DMC. The difference is about the same for the Czech Republic and Germany where RMC exceeds DMC by a factor of 1.3 and 1.4, respectively, and slightly lower for Austria where this factor is 1.1. In terms of total amounts, Germany and the Czech Republic exhibit a similar level of material use. The Czech Republic uses 18 tons per capita measured as domestic material consumption (DMC) and an additional 4 tons per capita in upstream material requirements. Total raw material consumption (RMC) thus amounts to 22 tons per capita. In Germany, domestic consumption is slightly lower at 16 tons per capita, but another 7 tons per capita of upstream material requirements must be added. Total raw material consumption in Germany is 23 tons per capita.

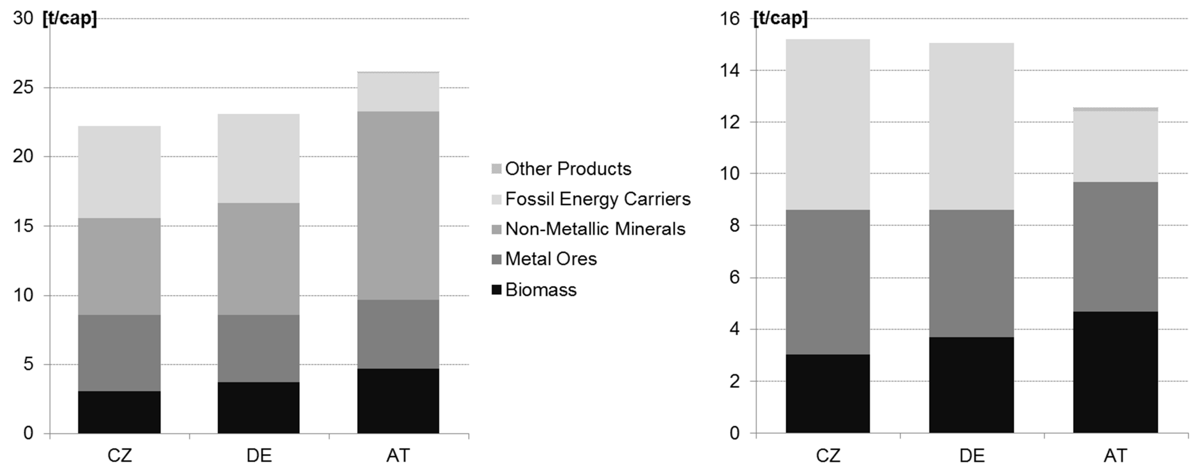
At 23 tons per capita in terms of DMC and 26 tons per capita in terms of RMC, Austria's material use is considerably higher but only 3 tons per capita of upstream material inputs are consumed. The higher level of material use is especially due to the higher use of non-metallic minerals. These materials are mainly used for construction purposes (buildings and transport infrastructure). Austria recently adopted a new method for calculating construction minerals (see Milota et al. 2011)

[5] Source: Weinzettel and Kovanda 2009

[6] Sources: Buyny et al. 2009, Buyny and Lauber 2010

because significant amounts of resource extraction in the construction sector were previously not reported by standard statistics.[7] The new calculation method improved data coverage of physical data and in consequence increased total material use from previously 19 tons per capita to 23 t/cap in 2003.

Figure 24: Per Capita RMC in the Czech Republic, Germany, and Austria, 2003



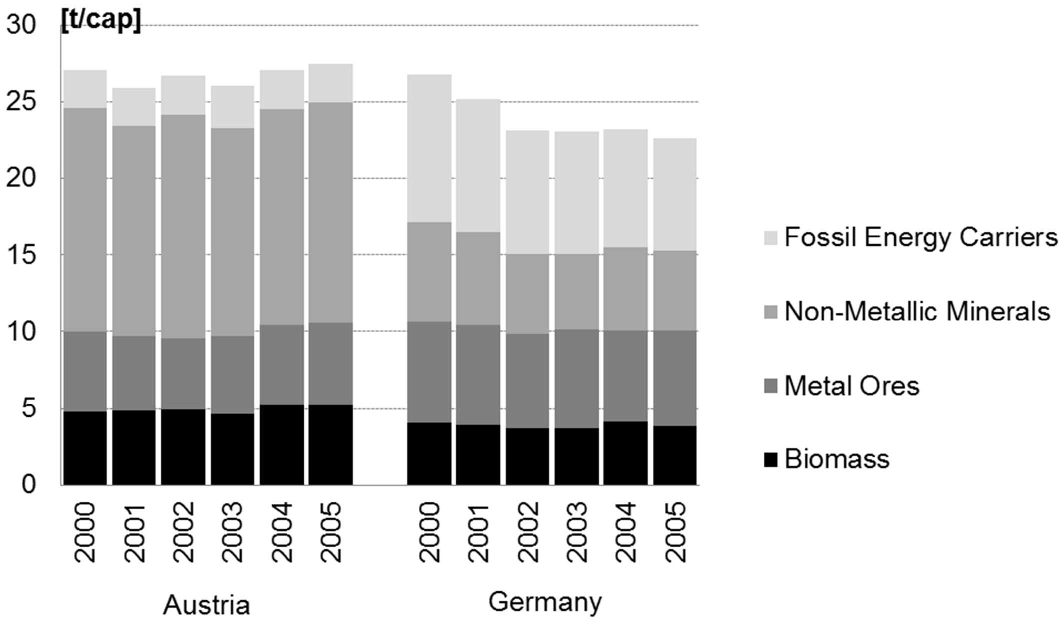
Please note: On the right-hand side of the figure, non-metallic minerals have been omitted to allow for better comparability of the other material categories.

Sources: Buyny et al. 2009, Buyny and Lauber 2010 (DE), Weinzettel and Kovanda 2009 (CZ)

Figure 24 presents RMC for the three countries disaggregated by the four material categories (biomass, fossil energy carriers, metal ores, and non-metallic minerals). In the diagram on the right-hand side, the non-metallic minerals were not included in order to make the other material categories more readily visible. Among the three material categories biomass, fossil fuels, and metals, high similarities between Germany and the Czech Republic can be observed: About one quarter of use is biotic materials (at 20%, the Czech Republic uses slightly less), 45% are fossil fuels, and 33-37% of raw material use are metallic minerals. Austria has a significantly higher share of biomass (37%), a slightly higher share of metal ores (40%), and a significantly lower share of fossil energy carriers (22%). The higher Austrian raw material use in the category of metals can be explained by the high importance of the domestic steel industry which requires high foreign and domestic raw material inputs for domestic production. The lower requirements of fossil fuels might be the result of the comparatively high significance of renewable energy (mainly hydro power and biomass) in Austria.

[7] Underestimations were due to (1) confidential data, (2) reporting procedures i.e. enterprises below 20 employees have no reporting obligation, and (3) non-characteristic production in the construction sectors which is not reported as domestic extraction and thus was not included in MF accounts.

Figure 25: per capita RMC in Germany and Austria, 2000-2005



Sources: Buyny et al. 2009, Buyny and Lauber 2010

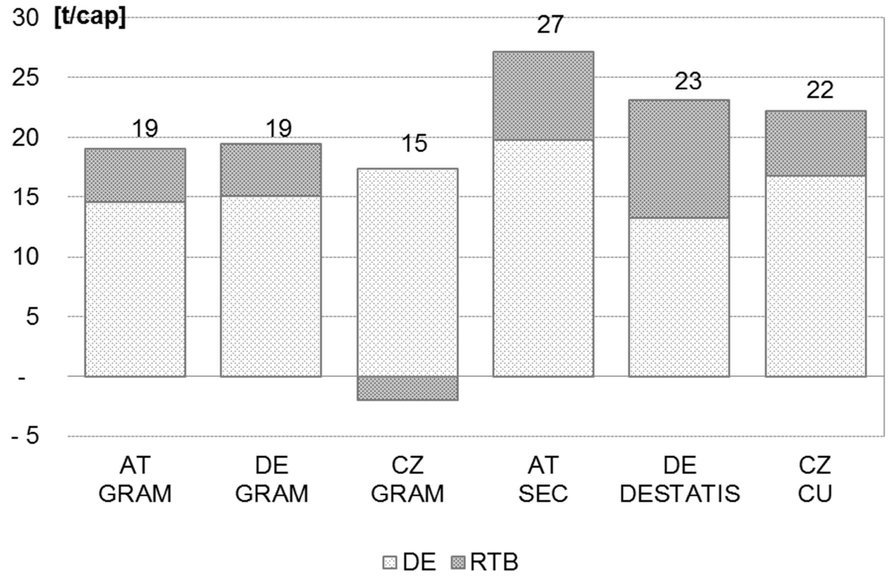
German RME accounts are available in time series (2000-2005, and until 2007 at the aggregate level, see Figure 25). A comparison of trends in RMC shows that Germany decreased its raw material consumption from 27 t/cap in 2000 to 23 t/cap in 2005 (and 22 t/cap in 2007). Austria's RMC, on the other hand, stagnated between 26 and 27 t/cap between 2000 and 2004 and increased to 28 t/cap by 2005 (remaining at this level until 2007). The decreasing German RMC is mainly the result of a decreasing DMC. The latter is driven by a reduction of use of metals and non-metallic minerals which occurred between 2000 and 2003. Use of biomass and fossil fuels more or less remained constant.

Comparison with Results from the GRAM Calculation

The Sustainable Europe Research Institute (SERI) published first results of RME at the global level based on their "Global Resource Accounting Model (GRAM)" (Giljum et al. 2008). The calculation uses IO tables for 52 countries and world regions, disaggregated by 48 sectors, and linked via OECD bilateral trade data for the year 2000. SERI's material flow data (see www.materialflows.net) were then linked to the IO model.

Figure 26 illustrates the comparison of the results from the GRAM calculation with the three case studies on the Czech Republic (Charles University CU), Germany (German Federal Statistical Office DESTATIS), and Austria (Institute of Social Ecology SEC). The data on the Czech Republic was only available for the year 2003; for the other countries, all data refer to the year 2000. RMC as calculated in the national case studies are higher than the results from the global GRAM study for all three countries. The biggest difference in the results for RMC occurs for Austria where RMC from the national study (27 t/cap) is higher than RMC as calculated in GRAM (19 t/cap) by a factor of 1.4. For Germany and the Czech Republic, the result from the respective national study is 1.2 times higher than the result from GRAM.

Figure 26: DE, RTB, and RMC: Comparison of GRAM Estimates and Country Studies



RMC is indicated by the numbers above the columns.

Sources: Giljum et al. 2008 (GRAM), Buyny et al. 2009, Buyny and Lauber 2010 (Germany: DE DESTATIS), Weinzettel and Kovanda 2009 (Czech Republic: CZ CU)

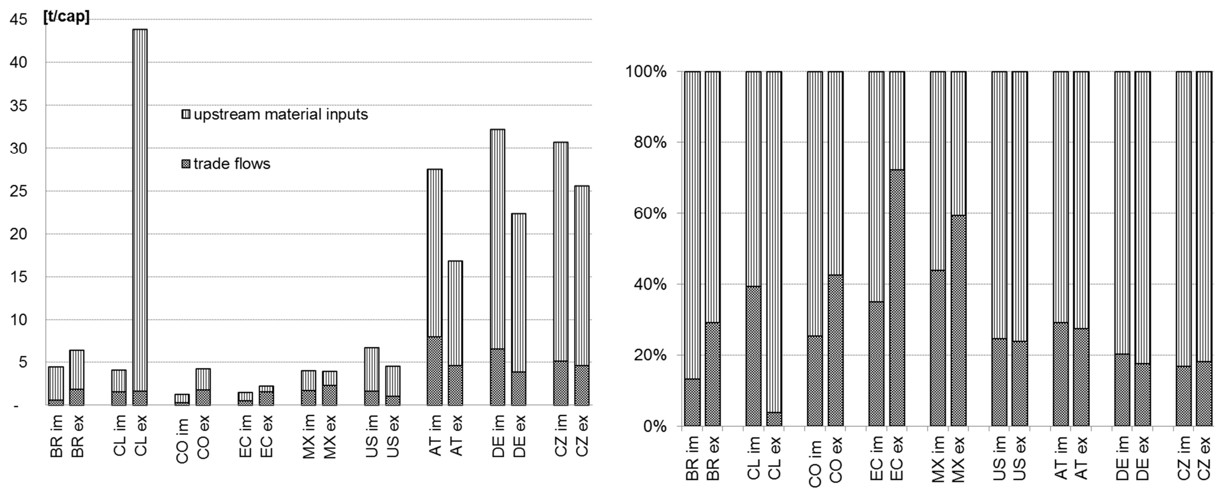
The lightly shaded areas in Figure 26 show the underlying values for domestic extraction (DE) used in the respective studies. Austria's per capita DE as used in our study (SEC) is the highest out of all the DE values and 1.4 times higher than the DE value assumed for the GRAM calculation due to the improved representation of construction minerals (Milota et al. 2011). The German DE from the national study is slightly lower than the one used for GRAM (factor 0.9) and the Czech DE in 2003 is almost identical to the value assumed for the year 2000 in GRAM. Hence, the difference in RMC results is mainly due to differences in the calculated RTB. RTB corresponds to the RIM minus REX and DE + RTB = RMC. For Austria, the RTB as calculated within the national study is 1.7 times larger than the RTB calculated in GRAM; for Germany, it is 2.3 times larger. The results for the Czech Republic can only be compared with caution since the national study is based on the year 2003 while the GRAM calculations were made for the year 2000. However the stark difference between the negative RTB calculated in GRAM and the 7 t/cap larger positive RTB calculated in the national study indicates that the difference in time alone cannot explain the discrepancy of the results.

The national and the global studies are contrasted here to illustrate the difficulty in developing a globally applicable approach to RME calculation that is sufficiently accurate at the national level. The results show the challenges that the research field of RME is still facing and that the theoretically more sophisticated method does not necessarily lead to more plausible results. A deeper understanding of advantages but also of problems of the different methodological approaches is still needed.

International Comparison across World Regions and Development Statuses

Muñoz et al. (2009) provide RME accounts for five Latin American countries (Brazil, Chile, Colombia, Ecuador, Mexico) as well as the USA. The authors applied a single-region IO (SRIO) approach which is expected to result in underestimations for the RME of non-competitive imports. However, for big economies active in all sectors (like the United States) the approximation can be expected to be within reasonable margins. In the following, the RME accounts of Muñoz et al. (2009) are compared with the national case studies for Austria, Germany, and the Czech Republic. Figure 27 shows trade flows, RIM, and REX in tons per capita. Because the overall magnitude of RME results does differ greatly, we will focus on general trends only.

Figure 27: Trade Flows and Upstream Material Inputs for Selected Countries



Countries are Brazil (BR), Chile (CL), Colombia (CO), Ecuador (EC), Mexico, United States (US), Austria (AT), Germany (DE), and the Czech Republic (CZ).

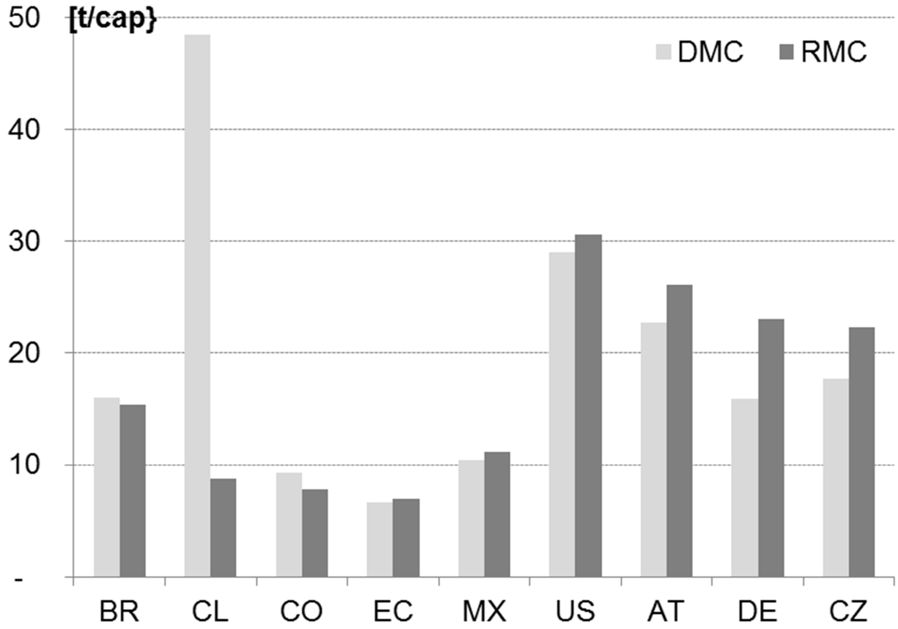
Flows are imports (im) and exports (ex).

Sources: Muñoz et al. 2009 (BR, CL, CO, EC, US), Buyny et al. 2009, Buyny and Lauber 2010 (DE), Weinzettel and Kovanda 2009 (CZ)

All industrialized countries (US, AT, DE, CZ) are characterized by comparable ratios between upstream material inputs and imports and exports. With the exception of Brazil, the Latin American countries featured here export goods that require more upstream material inputs than is the case in the industrialized countries. The high ratio of upstream inputs to exports in Chile are a result of the large quantities of waste rock that are extracted in copper mining but are not included in copper exports. In the production of Ecuador's exports, the mobilization of materials not included in the exports themselves and remaining in the country as waste or emissions is much smaller. This is most likely due to the fact that Ecuador exports large quantities of fossil fuels in the production of which the required upstream inputs are significantly lower than in the case of metals extraction and production. Mexico shows a similar pattern and is also a large exporter of fossil fuels.

For imports, the ratio of upstream material inputs to trade flows is much more similar for the different countries than for exports. While the Latin American countries seem to export very material-intensive goods, their imports are of a similar intensity as those of the industrialized countries.

Figure 28: International Comparison of DMC and RMC



Brazil (BR), Chile (CL), Colombia (CO), Ecuador (EC), Mexico, United States (US), Austria (AT), Germany (DE), and the Czech Republic (CZ)

Sources: Muñoz et al. 2009 (BR, CL, CO, EC, US), Buyny et al. 2009, Buyny and Lauber 2010 (DE), Weinzettel and Kovanda 2009 (CZ)

Figure 28 compares DMC and RMC for the selected 9 countries. For all industrialized countries, RMC is higher than DMC. This means, they depend on raw material inputs in other economies in order meet their domestic final demand. Mexico's and Ecuador's RMC is also slightly higher than their DMC. The other countries – Brazil, Colombia, and most notably Chile (due to the specific case of copper production discussed above) – exhibit lower RMC than DMC. In the case of Chile, the outstandingly high DMC (48 t/cap) translates into an RMC per capita that, at 9 t/cap, is comparable to that of other Latin American countries.

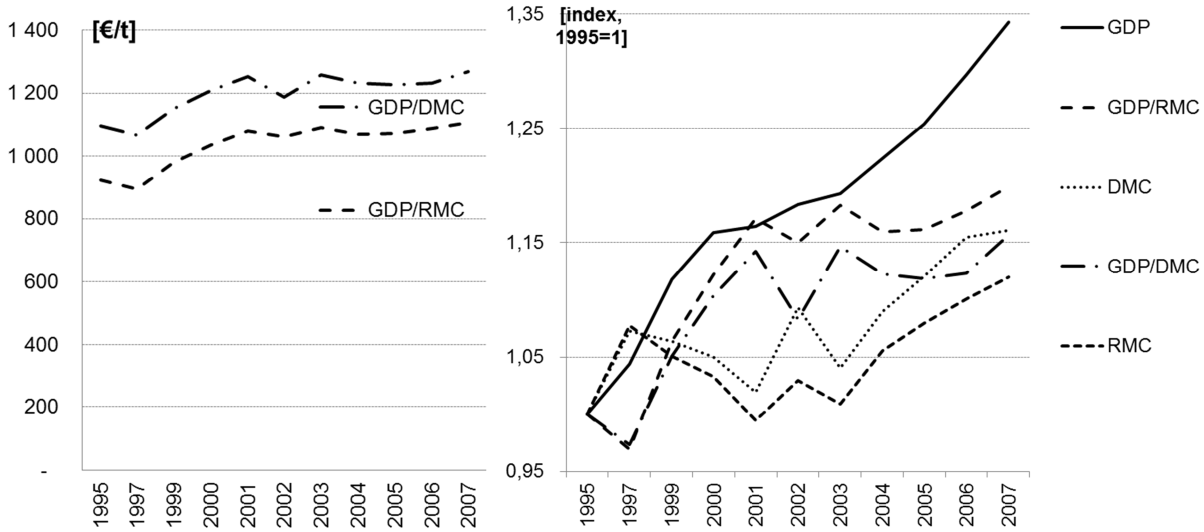
Outsourcing and Resource Productivity

According to our calculations, domestic material consumption (DMC) and raw material consumption (RMC) largely follow the same trends over time but on considerably different levels. RMC is somewhat larger than DMC by a factor of 1.2 to

1.1 (see left diagram in Figure 29) and both indicators, DMC and RMC, grow at a similar rate, i.e. by a factor of 1.1 and 1.2 (see right diagram in Figure 29).

We initially expected to see evidence of Austria improving its resource productivity through outsourcing of material-intensive production steps into other countries; in which case the stagnating DMC would be accompanied by a rising RMC. In this case, resource productivity measured using the DMC would have slightly improved while resource productivity measured using the RMC would have declined. Instead, however, the results do not indicate that Austria is achieving improvements in resource productivity by outsourcing material intensive production. DMC and RMC are both stagnating so that the development of resource productivity is very similar for both indicators. Even though for the development of resource productivity based on the RMC is very similar to that based on DMC, the level of resource productivity is somewhat different. In 2007, the Austrian economy was able to generate 1268 Euros of GDP per tonne of DMC but only 1004 Euros of GDP per tonne of RMC.

Figure 29: Trends in Austrian Resource Productivity and Its Components, 1995-2007



Resource productivity is calculated as the economic output per unit of material use (Euro per ton). Between 1995 and 2007 in Austria GDP[8] grew by a factor of 1.3 while material use grew a little more slowly; DMC grew by factor 1.2 while RMC grew by factor 1.1. Resource productivity improved by a factor of approximately 1.2 for GDP/DMC (1.16) and GDP/RMC (1.20). The increasing resource productivity indicates that the Austrian economy is dematerializing. However, only relative dematerialization could be achieved because in absolute terms material use is still increasing. In order to get on a path of absolute dematerialization, Austria has to decrease its material use and achieve resource productivity rates which exhibit stronger growth than GDP.

[8] GDP is reported in real terms, chain volumes, based on the year 2005 (Havel et al. 2010).

Figure 30: Trend in Austrian Resource Productivity by Material Category, 1995-2007

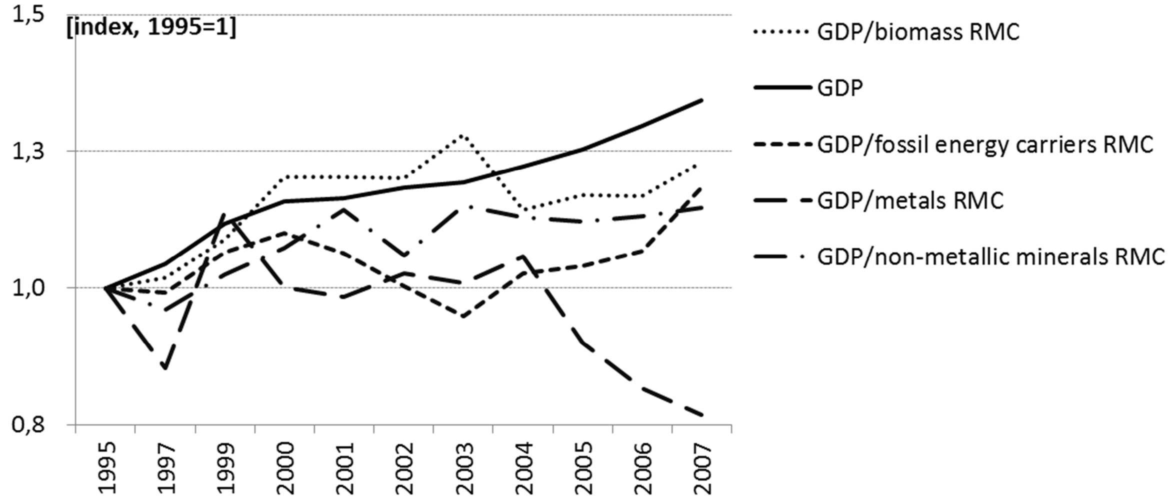
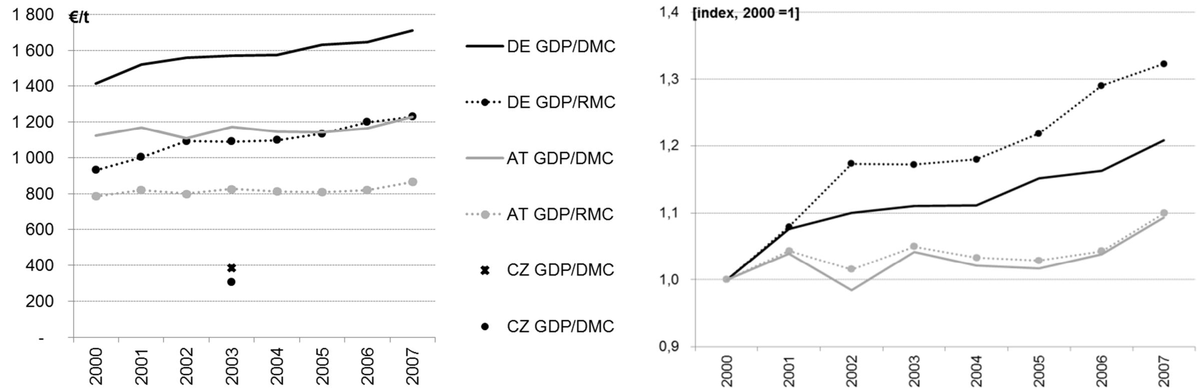


Figure 30 shows the trend in resource productivity measured as GDP/RMC by the four material categories biomass, fossil fuel energy carriers, metals, and non-metallic minerals as well as the trend in GDP growth. The strongest improvement in resource productivity can be observed for raw material use of biomass and fossil energy carriers: Between 1995 and 2007, the GDP/RMC for these material categories grew by a factor of 1.2 which is almost as high as GDP growth (factor 1.3). For the decrease in biomass RMC productivity between 2003 and 2004, no single cause could be identified. Increasing productivity seems to have been due to both changes in domestic extraction (crops and crop residues) as well as imports (wood, crops). The GDP/RMC for non-metallic minerals grew by a factor of 1.2 until 2003 and then decreased again so that a factor 1.1 can be determined between the 1995 and the 2007 level.

In comparison to the resource productivity (GDP/RMC) of the Czech Republic and Germany, the Austrian values ranged above these two countries. In 2003 in the Czech Republic, 307 € of GDP were generated for each ton of raw material (RMC) used and Germany generated 1089 €/t. At 1091 €/t, Austria's productivity was highly comparable to Germany's.

Figure 31: Resource Productivity in the Czech Republic, Germany, and Austria, Values and Trends



Sources: Buyny et al. 2009, Buyny and Lauber 2010 (DE), Weinzettel and Kovanda 2009 (CZ)

Between 2000 and 2005, both the RMC and the DMC of the German economy decreased. Since this development was accompanied by continuous GDP growth, it resulted in improvements in resource productivity as illustrated in Figure 31. GDP/RMC of Germany increased by a factor of 1.3 (GDP/DMC by 1.2) whereas Austrian GDP/RMC only improved very slightly by a factor of 1.2 (for RP_{DMC} as well). In 2003, the only year for which Czech RME data are currently available, the economy's resource productivity was significantly lower than that of the other two countries.

Conclusion

Austria is a small, open economy that heavily relies on international trade. Exports contributed 59% to GDP in 2007 and growth in exports surpassed GDP growth by a factor of 1.6 between 1980 and 2010 (Statistik Austria 2012b). Trade plays an increasingly important role in meeting the economy's resource demand and in maintaining its economic dynamic. One of the main issues that drove us to examine the raw material equivalents of trade was the question whether productivity gains in industrialized economies may in fact be due to outsourcing of material consumption (Weisz et al. 2008). We have been able to show that Austria's RMC is higher than its DMC (30 million tons or factor 1.1 in 2007), i.e. that a share of the material consumption related to Austria's final demand occurs in other economies. We have also found that the dynamics of increasing dependence on resource imports from other economies do not translate into an equally dynamic growth of RMC. Instead, the latter figure stagnates across the period of investigation, exhibiting similar behaviour as the DMC. This means that the trend in Austria's resource productivity measured using the RMC is very similar to the trend based on the DMC. Like other industrialized countries, Austria is a net-importer of biomass, metals, fossil energy carriers, and non-metallic minerals; these imports play an increasingly important role in meeting the economy's resource demand. Yet not all of these imports are consumed within Austria. Instead, they also serve as inputs into the production of the goods which Austria then exports. The materials which Austria indirectly requires from other economies (upstream inputs into imported goods) and the materials the country indirectly provides to other economies (upstream inputs into exported goods) are not yet included in standard material flow accounting. Trade flows including their upstream inputs, i.e. imports and exports expressed in raw material equivalents, are of great importance in understanding global resource use.

Strategies for sustainable resource use which set targets for improvements in material productivity or reductions in material use like those currently developed in the European Union need to take the impact of production for trade into account. To this end, robust indicators and data are required. Only then will it be possible to monitor whether gains in resource productivity or reductions in material consumption could be due to leakage effects. The pattern of outsourcing is not simply bilateral but forms an intricate global web which becomes increasingly complex with the deeper integration of all economies into the global market. RME data and indicators are also relevant in addressing environmentally unequal exchange and the outsourcing of environmental burdens in the context of policies on sustainable trade relations.

In order for RME indicators to contribute to a better understanding of trade relations, a method for their calculation must be found which is internationally implementable and can be incorporated into the annual reporting of the national statistical institutes. We have presented the calculation of the raw material equivalents of Austria's trade using a hybrid approach based on both input-output calculation and LCA coefficients. Compared to the much more data-intensive multi-region input-output (MRIO) and the far less exact single-region input-output (SRIO) approach, this hybrid approach provides an approximation of the raw material equivalents of trade based on a reasonable amount of data. It can also be applied to different points in time as we have shown in this study as well as to different economies as the comparison between Austria, Germany, and the Czech Republic illustrates.

Further assessing the respective advantages and disadvantages of the approaches to RME calculation currently under development will allow us to contribute to an eventual methodological harmonization. Taking the growing importance of trade into account, this is a prerequisite to evaluating both an economy's performance with regard to its environmental impact as well as in terms of its resource efficiency.

References: Data and Literature

Bruckner, M., Giljum, S., Lutz, C., Wiebe, K.S. (2012). Materials embodied in international trade: Global material extraction and consumption between 1995 and 2005. Global Environmental Change, 22(3), 568-576.

Bullard, C. and R. A. Herendeen (1975). The Energy Costs of Goods and Services. Energy Policy 3(4): 268-278.

Buyny, Šárka, Klink, Steffen, and Lauber, Ursula (2009). Verbesserung von Rohstoffproduktivität und Ressourcenschonung - Weiterentwicklung des direkten Materialinputindikators. Endbericht. Statistisches Bundesamt (DESTATIS), Wiesbaden.

Buyny, Šárka and Lauber, Ursula (2010). Environmental-Economic Accoutning (EEA). Further development of the indicator “Raw material productivity” in the National Strategy for Sustainable Development Calculating imports and exports in raw material equivalents. Federal Statistical Office Germany, Wiesbaden.

Chapagain, Ashok and Hoekstra, Arjen (2008). The global component of freshwater demand and supply: an assessment of virtual water flows between nations as a result of trade in agricultural and industrial products. Water International, 33(1): 19-32.

Chapman, P. F. (1974). The energy costs of producing copper and aluminium from primary sources. Metals and Materials, 8, 107–111.

Dittrich, Monika, Bringezu, Stefan, and Schütz, Helmut (2012). The physical dimension of international trade, part 2: Indirect global resource flows between 1962 and 2005. Ecological Economics, 79, 32-43.

Eurostat (2001). Economy-wide Material Flow Accounts and Derived Indicators. A methodological guide. Eurostat, European Commission, Office for Official Publications of the European Communities, Luxembourg.

Eurostat (2009). Economy Wide Material Flow Accounts. Compilation Guidelines for Reporting to the 2009 Eurostat Questionnaire (Version 01 – June 2009). European Statistical Office, Luxembourg.

Fachverband der Mineralölindustrie Österreichs (2010). The Austrian Petroleum Industry in 2009. English Summary. Fachverband der Mineralölindustrie Österreichs, Vienna.

Giljum, Stefan, Christian Lutz, Ariane Jungnitz, Martin Bruckner, Friedrich Hinterberger (2008). Global dimensions of European natural resource use. First results from the Global Resource Accounting Model (GRAM). SERI Working Paper No. 7. Vienna.

Havel, Ursula et al. (2010). Volkswirtschaftliche Gesamtrechnungen 1978–2009, Hauptergebnisse. Statistik Austria, Vienna.

Kolleritsch, Erwin (2004). Input-Output Multiplikatoren 2000. Statistik Austria, Wien.

Lenzen, Manfred. (2001). A generalized Input-Output Multiplier Calculus for Australia. Economic Systems Research, 13, 65-92.

Lenzen M, Kanemoto K, Moran D, and Geschke A (2012). Mapping the structure of the world economy, Environmental Science & Technology, 46(15), 8374-8381.

Leontief, Wassily. (1936) Quantitative input-output relations in the economic system. Review of Economics and Statistics, 18, 105-125.

Leontief, Wassily. (1941) The Structure of the American Economy. Oxford University Press, New York.

Miller, Ronald E. and Blair, Peter D. (2009). Input-Output Analysis: Foundations and Extensions. Cambridge University Press, Cambridge.

Milota, Eva, Schaffartzik, Anke, and Eisenmenger, Nina (2011). Ressourcendaten - Verbesserung des statistischen Datenmaterials im Bereich natürliche Ressourcen. Projektbericht. Statistik Austria, Vienna.

Muñoz, Pablo, Giljum, Stefan, and Roca, Jordi (2009). The Raw Material Equivalents of International Trade. Journal of Industrial Ecology, 13(6), 881-898.

Narayanan, Badri, Aguiar, Angel, and McDougall, Robert (eds.) (2012). Global Trade, Assistance, and Production: The GTAP 8 Data Base, Center for Global Trade Analysis, Purdue University. http://www.gtap.agecon.purdue.edu/databases/v8/v8_doco.asp.

Öko-Institut (2009). Globales Emissions-Modell Integrierter Systeme (GEMIS) 4.5. Öko-Institut, Darmstadt.

ÖSTAT (1994). Input.Output-Tabelle 1983. Band 2: Technologiematrizen. Beiträge zur österreichischen Statistik. Österreichisches Statistisches Zentralamt, Vienna.

Ritthoff, Michael, Rohn, Holger, and Liedtke, Christa (2002). Calculating MIPS: Resource Productivity of Products and Services. Wuppertal Institute, Wuppertal.

Schoer, Karl, Jürgen Giegrich, Jan Kovanda, Christoph Lauwigi, Axel Liebich, Sarka Buyny, Josefine Matthias (2012). Conversion of European Product Flows Into Raw Material Equivalents. ifeu - Institut für Energie- und Umweltforschung, Heidelberg.

Statistik Austria (2011a). Input-Output-Statistik: Aufkommens- und Verwendungstabellen. Statistik Austria, Vienna.

Statistik Austria (2011b). Materialflussrechnung ab 1995: Inländische Entnahme und Importe Gesamt. Statistik Austria, Vienna.

Statistik Austria (2011c). Materialflussrechnung. http://www.statistik.at/web_de/statistiken/energie_und_umwelt/umwelt/materialflussrechnung/index.html. Statistik Austria, Vienna.

Statistik Austria (2012a). HVPI (Basis 2005) monatliche Werte und Inflationsraten von 1995 bis 2011. Statistik Austria, Vienna.

Statistik Austria (2012b). STATcube Statistical Database. http://www.statistik.at/web_de/services/datenbank_superstar/index.html. Statistik Austria, Vienna.

Suh, S., M. Lenzen, G. J. Treloar, H. Hondo, A. Horvath, G. Huppes, O. Jolliet, U. Klann, W. Krewitt, Y. Moriguchi, J. Munksgaard, G. Norris (2003). System boundary selection in life-cycle inventories using hybrid approaches. Environmental Science & Technology. 38(3): 657-664.

Timmer, Marcel (ed.) (2012). The World Input-Output Database (WIOD): Contents, Sources and Methods. http://www.wiod.org/publications/source_docs/WIOD_sources.pdf.

Tukker A, Poliakov E, Heijungs R, Hawkins T, Neuwahl F, Rueda-Cantouche J, Giljum S, Moll S, Oosterhaven J, Bouwmeester M (2009). Towards a global multiregional environmentally-extended input-output database. Ecological Economics 68(7): 1928-1937.

UN Comtrade (2011). United Nations Commodity Trade Statistics Database. United Nations.

Weinzettel, Jan and Kovanda, Jan (2009). Assessing Socioeconomic Metabolism Through Hybrid Life Cycle Assessment - The Case of the Czech Republic. Journal of Industrial Ecology, 13, 607-621.

Weisz, Helga (2006). Accounting for raw material equivalents of traded goods. A comparison of input-output approaches in physical, monetary, and mixed units. Social Ecology Working Paper 87. Institute of Social Ecology, Vienna.

Weisz, Helga and Duchin, Faye (2006). Physical and monetary input-output analysis: What makes the difference? Ecological Economics, 57(3), 534-541.

Weisz, Helga, Eisenmenger, Nina, and Schaffartzik, Anke (2008). Methodische Weiterentwicklung der Berechnung des Rohmaterialbedarfes im Außenhandel. Endbericht an das BMLFUW zum Vertrag GZ: BMLFUW-UW.1.4.18/0028-V/10/2007, September 2008. 2008. Wien, IFF Soziale Ökologie.

Weizsäcker,E.U.v., Hargroves,K., Smith,M.H., Desha,C. & Stasinopoulos,P. (2009). Factor Five. Transforming the Global Economy through 80% Improvements in Resource Productivity. Earthscan, London.

Wiebe, K.S., Bruckner, M., Giljum, S., Lutz, C., Polzin, C. (2012). Carbon and Materials Embodied in the International Trade of Emerging Economies. Journal of Industrial Ecology, 16(4), 636-646.

Wilting, H. C. (1996). An energy perspective on economic activities, University of Groningen, Groningen.

Annex 1: Allocation of MFA Domestic Extraction to Sectors (2007)

Allocation of MFA Domestic Extraction to Economic Activities 2007									
		Sectors (CPA)							
MFA Code	MFA Name	1	2	5	10	11	13	14	45
1.1.1.	Cereals	1,0							
1.1.10.	Other crops	1,0							
1.1.2.	Roots, tubers	1,0							
1.1.3.	Sugar crops	1,0							
1.1.4.	Pulses	1,0							
1.1.5.	Nuts	1,0							
1.1.6.	Oil bearing crops	1,0							
1.1.7.	Vegetables	1,0							
1.1.8.	Fruits	1,0							
1.1.9.	Fibres	1,0							
1.2.1.	Crop residues (used)	1,0							
1.2.2.	Fodder crops and grazed biomass	1,0							
1.3.1.	Timber (industrial roundwood)		1,0						
1.3.2.	Wood fuel and other extraction		1,0						
1.4.1.	Fish catch			1,0					
1.5.	Hunting and gathering	1,0							
2.1.	Iron ores						1,0		
2.2.1.	Copper ores						1,0		
2.2.2.	Nickel ores						1,0		
2.2.3.	Lead ores						1,0		
2.2.4.	Zinc ores						1,0		
2.2.5.	Tin ores						1,0		
2.2.6.	Gold, silver, platinum, and other precious metal ores						1,0		
2.2.7.	Bauxite and other aluminum ores						1,0		
2.2.9.	Other metal ores						1,0		
3.1.1.	Ornamental or building stone							1,0	
3.1.2.	Chalk and dolomite							1,0	
3.1.3.	Slate							1,0	
3.1.4.	Chemical and fertilizer minerals							1,0	
3.1.5.	Salt							1,0	
3.1.6.	Other mining and quarrying products							1,0	
3.2.1.	Limestone and gypsum							0,5	0,5
3.2.2.	Gravel and sand							0,5	0,5
3.2.3.	Clays and kaolin							0,5	0,5
4.1.1.	Brown coal				1,0				
4.1.2.	Hard coal				1,0				
4.1.4.	Peat				1,0				
4.2.1.1.	Crude Oil					1,0			
4.2.2.	Natural gas					1,0			

Annex 2: Allocation of MFA Imports to Sectors (2007)

		Allocation of MFA Imports to Economic Activities 2007																														
MFA Code	MFA Name	1	2	5	10	11	13	14	15	16	17	18	19	20	21	23	24	25	26	27	28	29	30	31	32	33	34	35	36	40	92	93
1.1.1.	Cereals	0,7	-	-	-	-	-	-	0,3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.10.	Other crops	0,1	-	-	-	-	-	-	0,8	0,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.2.	Roots, tubers	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.3.	Sugar crops	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.4.	Pulses	0,7	-	-	-	-	-	-	0,3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.5.	Nuts	0,6	-	-	-	-	-	-	0,4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.6.	Oil bearing crops	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.7.	Vegetables	0,7	-	-	-	-	-	-	0,3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.8.	Fruits	0,6	-	-	-	-	-	-	0,4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.9.	Fibres	0,1	-	-	-	-	-	-	0,9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.2.1.	Crop residues (used)	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.2.2.	Fodder crops and grazed biomass	0,7	-	-	-	-	-	-	0,3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.3.1.	Timber (industrial roundwood)	-	-	-	-	-	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.3.2.	Wood fuel and other extraction	0,0	0,5	-	-	-	-	-	-	-	-	-	-	0,3	-	-	-	0,2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.4.1.	Fish catch	-	-	0,4	-	-	-	-	0,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.6.1.	Live animals	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.6.2.	Meat and meat preparations	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.6.3.	Dairy products, birds' eggs, honey	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.6.4.	Other products from animals (fibres, skins, furs, leather, etc.)	0,0	-	-	-	-	-	-	0,9	-	-	0,0	0,1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.7.	Products mainly from biomass	0,0	-	-	-	-	-	-	0,2	-	-	-	-	-	0,8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,0
2.1.	Iron ores	-	-	-	-	-	0,6	-	-	-	-	-	-	-	-	-	-	-	-	0,4	-	-	-	-	-	-	-	-	-	-	-	-
2.2.1.	Copper ores	-	-	-	-	-	0,0	-	-	-	-	-	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-
2.2.2.	Nickel ores	-	-	-	-	-	0,0	-	-	-	-	-	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.	Lead ores	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-
2.2.4.	Zinc ores	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-
2.2.5.	Tin ores	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-
2.2.6.	Gold, silver, platinum, and other precious metal ores	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-
2.2.7.	Bauxite and other aluminum ores	-	-	-	-	-	0,1	-	-	-	-	-	-	-	-	-	-	-	-	0,9	-	-	-	-	-	-	-	-	-	-	-	-
2.2.9.	Other metal ores	-	-	-	-	-	0,1	-	-	-	-	-	-	-	-	-	-	-	-	0,9	-	-	-	-	-	-	-	-	-	-	-	-
2.3.	Products mainly from metals	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,0	0,3	0,3	0,0	0,1	0,0	0,0	0,3	0,1	0,0	-	-	-
3.1.1.	Ornamental or building stone	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.1.2.	Chalk and dolomite	-	-	-	-	-	-	0,3	-	-	-	-	-	-	-	-	-	-	0,7	-	-	-	-	-	-	-	-	-	-	-	-	-
3.1.3.	Slate	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.1.4.	Chemical and fertilizer minerals	-	-	-	-	-	-	0,2	-	-	-	-	-	-	-	-	0,8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.1.5.	Salt	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.1.6.	Other mining and quarrying products	-	-	0,0	-	-	-	0,2	-	-	-	-	-	-	-	0,0	0,5	-	0,2	0,1	-	-	-	-	-	-	-	-	-	-	-	-
3.2.2.	Gravel and sand	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.2.3.	Clays and kaolin	-	-	-	-	-	-	0,4	-	-	-	-	-	-	-	-	-	-	0,6	-	-	-	-	-	-	-	-	-	-	-	-	-
3.3.	Products mainly from non-metallic minerals	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-
4.1.1.	Brown coal	-	-	-	1,0	0,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.1.2.	Hard coal	-	-	-	1,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.1.4.	Peat	-	-	-	1,0	0,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.2.1.1.	Crude Oil	-	-	-	-	0,5	-	-	-	-	-	-	-	-	-	0,5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.2.2.	Natural gas	-	-	-	-	1,0	-	-	-	-	-	-	-	-	-	0,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.3.	Products mainly from petroleum products	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,3	0,6	0,1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.	Other products	-	-	-	-	-	-	-	0,0	-	0,1	0,0	0,0	0,0	0,0	-	0,4	0,1	0,0	-	-	0,0	-	0,0	-	0,0	-	-	0,2	-	0,0	-

Band 25
Informationsgrundlagen struktureller Ökologisierung. Beitrag zur Tagung "Strategien der Kreislaufwirtschaft: Ganzheitl. Umweltschutz/Integrated Environmental Protection", Graz 1992. Steurer, A., Fischer-Kowalski, M. (1992)

Band 26
Stoffstrombilanz Österreich 1988. Steurer, A. (1992)

Band 28
Naturschutzaufwendungen in Österreich. Gutachten für den WWF Österreich. Payer, H. (1992)

Band 29
Indikatoren der Nachhaltigkeit für die Volkswirtschaftliche Gesamtrechnung - angewandt auf die Region. Payer, H. (1992). In: KudlMudl SonderNr. 1992:Tagungsbericht über das Dorfsymposium "Zukunft der Region - Region der Zukunft?"

Band 31
***Leerzeichen.* Neuere Texte zur Anthropologie**. Macho, T. (1993)

Band 32
Metabolism and Colonisation. Modes of Production and the Physical Exchange between Societies and Nature. Fischer-Kowalski, M., Haberl, H. (1993)

Band 33
Theoretische Überlegungen zur ökologischen Bedeutung der menschlichen Aneignung von Nettoprimärproduktion. Haberl, H. (1993)

Band 34
Stoffstrombilanz Österreich 1970-1990 - Inputseite. Steurer, A. (1994)

Band 35
Der Gesamtenergieinput des Sozio-ökonomischen Systems in Österreich 1960-1991. Zur Erweiterung des Begriffes "Energieverbrauch". Haberl, H. (1994)

Band 36
Ökologie und Sozialpolitik. Fischer-Kowalski, M. (1994)

Band 37
Stoffströme der Chemieproduktion 1970-1990. Payer, H., unter Mitarbeit von Zangerl-Weisz, H. und Fellinger, R. (1994)

Band 38
Wasser und Wirtschaftswachstum. Untersuchung von Abhängigkeiten und Entkoppelungen, Wasserbilanz Österreich 1991. Hüttler, W., Payer, H. unter Mitarbeit von H. Schandl (1994)

Band 39
Politische Jahreszeiten. 12 Beiträge zur politischen Wende 1989 in Ostmitteleuropa. Macho, T. (1994)

Band 40
On the Cultural Evolution of Social Metabolism with Nature. Sustainability Problems Quantified. Fischer-Kowalski, M., Haberl, H. (1994)

Band 41
Weiterbildungslehrgänge für das Berufsfeld ökologischer Beratung. Erhebung u. Einschätzung der Angebote in Österreich sowie von ausgewählten Beispielen in Deutschland, der Schweiz, Frankreich, England und europaweiten Lehrgängen. Rauch, F. (1994)

Band 42
Soziale Anforderungen an eine nachhaltige Entwicklung. Fischer-Kowalski, M., Madlener, R., Payer, H., Pfeffer, T., Schandl, H. (1995)

Band 43
Menschliche Eingriffe in den natürlichen Energiefluß von Ökosystemen. Sozio-ökonomische Aneignung von Nettoprimärproduktion in den Bezirken Österreichs. Haberl, H. (1995)

Band 44
Materialfluß Österreich 1990. Hüttler, W., Payer, H.; Schandl, H. (1996)

Band 45
National Material Flow Analysis for Austria 1992. Society's Metabolism and Sustainable Development. Hüttler, W. Payer, H., Schandl, H. (1997)

Band 46
Society's Metabolism. On the Development of Concepts and Methodology of Material Flow Analysis. A Review of the Literature. Fischer-Kowalski, M. (1997)

Band 47
Materialbilanz Chemie-Methodik sektoraler Materialbilanzen. Schandl, H., Weisz, H. Wien (1997)

Band 48
Physical Flows and Moral Positions. An Essay in Memory of Wildavsky. A. Thompson, M. (1997)

Band 49
Stoffwechsel in einem indischen Dorf. Fallstudie Merkar. Mehta, L., Winiwarter, V. (1997)

Band 50+
Materialfluß Österreich- die materielle Basis der Österreichischen Gesellschaft im Zeitraum 1960-1995. Schandl, H. (1998)

Band 51+
Bodenfruchtbarkeit und Schädlinge im Kontext von Agrargesellschaften. Dirlinger, H., Fliegenschnee, M., Krausmann, F., Liska, G., Schmid, M. A. (1997)

Band 52+
Der Naturbegriff und das Gesellschaft-Natur-Verhältnis in der frühen Soziologie. Lutz, J. Wien (1998)

Band 53+
NEMO: Entwicklungsprogramm für ein Nationales Emissionsmonitoring. Bruckner, W., Fischer-Kowalski, M., Jorde, T. (1998)

Band 54+
Was ist Umweltgeschichte? Winiwarter, V. (1998)

Mit + gekennzeichnete Bände sind unter
http://www.uni-klu.ac.at/socec/inhalt/1818.htm
Im PDF-Format und in Farbe downloadbar.

Band 55+
Agrarische Produktion als Interaktion von Natur und Gesellschaft: Fallstudie SangSaeng. Grünbühel, C. M., Schandl, H., Winiwarter, V. (1999)

Band 57+
Colonizing Landscapes: Human Appropriation of Net Primary Production and its Influence on Standing Crop and Biomass Turnover in Austria. Haberl, H., Erb, K.H., Krausmann, F., Loibl, W., Schulz, N. B., Weisz, H. (1999)

Band 58+
Die Beeinflussung des oberirdischen Standing Crop und Turnover in Österreich durch die menschliche Gesellschaft. Erb, K. H. (1999)

Band 59+
Das Leitbild "Nachhaltige Stadt". Astleithner, F. (1999)

Band 60+
Materialflüsse im Krankenhaus, Entwicklung einer Input-Output Methodik. Weisz, B. U. (2001)

Band 61+
Metabolismus der Privathaushalte am Beispiel Österreichs. Hutter, D. (2001)

Band 62+
Der ökologische Fußabdruck des österreichischen Außenhandels. Erb, K.H., Krausmann, F., Schulz, N. B. (2002)

Band 63+
Material Flow Accounting in Amazonia: A Tool for Sustainable Development. Amann, C., Bruckner, W., Fischer-Kowalski, M., Grünbühel, C. M. (2002)

Band 64+
Energieflüsse im österreichischen Landwirtschaftssektor 1950-1995, Eine humanökologische Untersuchung. Darge, E. (2002)

Band 65+
Biomasseeinsatz und Landnutzung Österreich 1995-2020. Haberl, H.; Krausmann, F.; Erb, K.H.;Schulz, N. B.; Adensam, H. (2002)

Band 66+
Der Einfluss des Menschen auf die Artenvielfalt. Gesellschaftliche Aneignung von Nettoprimärproduktion als Pressure-Indikator für den Verlust von Biodiversität. Haberl, H., Fischer-Kowalski, M., Schulz, N. B., Plutzar, C., Erb, K.H., Krausmann, F., Loibl, W., Weisz, H.; Sauberer, N., Pollheimer, M. (2002)

Band 67+
Materialflussrechnung London. Bongardt, B. (2002)

Band 68+
Gesellschaftliche Stickstoffflüsse des österreichischen Landwirtschaftssektors 1950-1995, Eine humanökologische Untersuchung. Gaube, V. (2002)

Band 69+
The transformation of society's natural relations: from the agrarian to the industrial system. Research strategy for an empirically informed approach towards a European Environmental History. Fischer-Kowalski, M., Krausmann, F., Schandl, H. (2003)

Band 70+
Long Term Industrial Transformation: A Comparative Study on the Development of Social Metabolism and Land Use in Austria and the United Kingdom 1830-2000. Krausmann, F., Schandl, H., Schulz, N. B. (2003)

Band 72+
Land Use and Socio-economic Metabolism in Pre-industrial Agricultural Systems: Four Nineteenth-century Austrain Villages in Comparison. Krausmann, F. (2008)

Band 73+
Handbook of Physical Accounting Measuring bio-physical dimensions of socio-economic activities MFA – EFA – HANPP. Schandl, H., Grünbühel, C. M., Haberl, H., Weisz, H. (2004)

Band 74+
Materialflüsse in den USA, Saudi Arabien und der Schweiz. Eisenmenger, N.; Kratochvil, R.; Krausmann, F.; Baart, I.; Colard, A.; Ehgartner, Ch.; Eichinger, M.; Hempel, G.; Lehrner, A.; Müllauer, R.; Nourbakhch-Sabet, R.; Paler, M.; Patsch, B.; Rieder, F.; Schembera, E.; Schieder, W.; Schmiedl, C.; Schwarzlmüller, E.; Stadler, W.; Wirl, C.; Zandl, S.; Zika, M. (2005)

Band 75+
Towards a model predicting freight transport from material flows. Fischer-Kowalski, M. (2004)

Band 76+
The physical economy of the European Union: Cross-country comparison and determinants of material consumption. Weisz, H., Krausmann, F., Amann, Ch., Eisenmenger, N., Erb, K.H., Hubacek, K., Fischer-Kowalski, M. (2005)

Band 77+
Arbeitszeit und Nachhaltige Entwicklung in Europa: Ausgleich von Produktivitätsgewinn in Zeit statt Geld? Proinger, J. (2005)

Band 78+
Sozial-Ökologische Charakteristika von Agrarsystemen. Ein globaler Überblick und Vergleich. Lauk, C. (2005)

Band 79+
Verbrauchsorientierte Abrechnung von Wasser als Water-Demand-Management-Strategie. Eine Analyse anhand eines Vergleichs zwischen Wien und Barcelona. Machold, P. (2005)

Band 80+
Ecology, Rituals and System-Dynamics. An attempt to model the Socio-Ecological System of Trinket Island. Wildenberg, M. (2005)

Band 81+
Southeast Asia in Transition. Socio-economic transitions, environmental impact and sustainable development. Fischer-Kowalski, M., Schandl, H., Grünbühel, C., Haas, W., Erb, K-H., Weisz, H., Haberl, H. (2004)

Band 83+
HANPP-relevante Charakteristika von Wanderfeldbau und anderen Langbrachesystemen. Lauk, C. (2006)

Band 84+
Management unternehmerischer Nachhaltigkeit mit Hilfe der Sustainability Balanced Scorecard. Zeitlhofer, M. (2006)

Band 85+
Nicht-nachhaltige Trends in Österreich: Maßnahmenvorschläge zum Ressourceneinsatz. Haberl, H., Jasch, C., Adensam, H., Gaube, V. (2006)

Band 87+
Accounting for raw material equivalents of traded goods. A comparison of input-output approaches in physical, monetary, and mixed units. Weisz, H. (2006)

Band 88+
Vom Materialfluss zum Gütertransport. Eine Analyse anhand der EU15 – Länder (1970-2000).
Rainer, G. (2006)

Band 89+
Nutzen der MFA für das Treibhausgas-Monitoring im Rahmen eines Full Carbon Accounting-Ansatzes; Feasibilitystudie; Endbericht zum Projekt BMLFUW-UW.1.4.18/0046-V/10/2005. Erb, K.-H., Kastner, T., Zandl, S., Weisz, H., Haberl, H., Jonas, M., (2006)

Band 90+
Local Material Flow Analysis in Social Context in Tat Hamelt, Northern Mountain Region, Vietnam. Hobbes, M.; Kleijn, R. (2006)

Band 91+
Auswirkungen des thailändischen logging ban auf die Wälder von Laos. Hirsch, H. (2006)

Band 92+
Human appropriation of net primary produktion (HANPP) in the Philippines 1910-2003: a socio-ecological analysis.
Kastner, T. (2007)

Band 93+
Landnutzung und landwirtschaftliche Entscheidungsstrukturen. Partizipative Entwicklung von Szenarien für das Traisental mit Hilfe eines agentenbasierten Modells.
Adensam, H., V. Gaube, H. Haberl, J. Lutz, H. Reisinger, J. Breinesberger, A. Colard, B. Aigner, R. Maier, Punz, W. (2007)

Band 94+
The Work of Konstantin G. Gofman and colleagues: An early example of Material Flow Analysis from the Soviet Union. Fischer-Kowalski, M.; Wien (2007)

Band 95+
Partizipative Modellbildung, Akteurs- und Ökosystemanalyse in Agrarintensivregionen; Schlußbericht des deutsch-österreichischen Verbundprojektes. Newig, J., Gaube, V., Berkhoff, K., Kaldrack, K., Kastens, B., Lutz, J., Schlußmeier B., Adensam, H., Haberl, H., Pahl-Wostl, C., Colard, A., Aigner, B., Maier, R., Punz, W.; Wien (2007)

Band 96+
Rekonstruktion der Arbeitszeit in der Landwirtschaft im 19. Jahrhundert am Beispiel von Theyern in Niederösterreich. Schaschl, E.; Wien (2007)

Band 98+
Local Material Flow Analysis in Social Context at the forest fringe in the Sierra Madre, the Philippines.
Hobbes, M., Kleijn, R. (Hrsg); Wien (2007)

Band 99+
Human Appropriation of Net Primary Production (HANPP) in Spain, 1955-2003: A socio-ecological analysis. Schwarzlmüller, E.; Wien (2008)

Band 100+
Scaling issues in long-term socio-ecological biodiversity research: A review of European cases. Dirnböck, T., Bezák, P., Dullinger S., Haberl, H., Lotze-Campen, H., Mirtl, M., Peterseil, J., Redpath, S., Singh, S., Travis, J., Wijdeven, S.M.J.; Wien (2008)

Band 101+
Human Appropriation of Net Primary Production (HANPP) in the United Kingdom, 1800-2000: A socio-ecological analysis. Musel, A.; Wien (2008)

Band 102 +
Wie kann Wissenschaft gesellschaftliche Veränderung bewirken? Eine Hommage an Alvin Gouldner, und ein Versuch, mit seinen Mitteln heutige Klimapolitik zu verstehen. Fischer-Kowalski, M.; Wien (2008)

Band 103+
Sozialökologische Dimensionen der österreichischen Ernährung – Eine Szenarienanalyse. Lackner, M.; Wien (2008)

Band 104+
Fundamentals of Complex Evolving Systems: A Primer.
Weis, E.; Wien (2008)

Band 105+
Umweltpolitische Prozesse aus diskurstheoretischer Perspektive: Eine Analyse des Südtiroler Feinstaubproblems von der Problemkonstruktion bis zur Umsetzung von Regulierungsmaßnahmen. Paler, M.; Wien (2008)

Band 106+
Ein integriertes Modell für Reichraming. Partizipative Entwicklung von Szenarien für die Gemeinde Reichraming (Eisenwurzen) mit Hilfe eines agentenbasierten Landnutzungsmodells. Gaube, V., Kaiser, C., Widenberg, M., Adensam, H., Fleissner, P., Kobler, J., Lutz, J., Smetschka, B., Wolf, A., Richter, A., Haberl, H.; Wien (2008)

Band 107+
Der soziale Metabolismus lokaler Produktionssysteme: Reichraming in der oberösterreichischen Eisenwurzen 1830-2000. Gingrich, S., Krausmann, F.; Wien (2008)

Band 108+
Akteursanalyse zum besseren Verständnis der Entwicklungsoptionen von Bioenergie in Reichraming. Eine sozialökologische Studie. Vrzak, E.; Wien (2008)

Band 109+
Direktvermarktung in Reichraming aus sozial-ökologischer Perspektive. Zeitlhofer, M.; Wien (2008)

Band 110+
CO_2-Bilanz der Tomatenproduktion: Analyse acht verschiedener Produktionssysteme in Österreich, Spanien und Italien. Theurl, M.; Wien (2008)

Band 111+
Die Rolle von Arbeitszeit und Einkommen bei Rebound-Effekten in Dematerialisierungs- und Dekarbonisierungsstrategien. Eine Literaturstudie. Bruckner, M.; Wien (2008)

Band 112+
Von Kommunikation zu materiellen Effekten - Ansatzpunkte für eine sozial-ökologische Lesart von Luhmanns Theorie Sozialer Systeme. Rieder, F.; Wien (2008)

Band 113+
(in Vorbereitung)

Band 114+
Across a Moving Threshold: energy, carbon and the efficiency of meeting global human development needs. Steinberger, J. K., Roberts, .J.T.; Wien (2008)

Band 115
Towards a low carbon society: Setting targets for a reduction of global resource use. Krausmann, F., Fischer-Kowalski, M., Steinberger, J.K., Ayres, R.U.; Wien (2010)

Band 116+
Eating the Planet: Feeding and fuelling the world sustainably, fairly and humanely - a scoping study. Erb, K-H., Haberl, H., Krausmann, F., Lauk, C., Plutzar, C., Steinberger, J.K., Müller, C., Bondeau, A., Waha, K., Pollack, G.; Wien (2009)

Band 117+
Gesellschaftliche Naturverhältnisse: Energiequellen und die globale Transformation des gesellschaftlichen Stoffwechsels. Krausmann, F., Fischer-Kowalski, M.; Wien (2010)

Band 118+
Zurück zur Fläche? Eine Untersuchung der biophysischen Ökonomie Brasiliens zwischen 1970 und 2005. Mayer, A.; Wien (2010)

Band 119+
Das nachhaltige Krankenhaus: Erprobungsphase. Weisz, U., Haas, W., Pelikan, J.M., Schmied, H., Himpelmann, M., Purzner, K., Hartl, S., David, H.; Wien (2009)

Band 120+
LOCAL STUDIES MANUAL
A researcher's guide for investigating the social metabolism of local rural systems. Singh, S.J., Ringhofer, L., Haas, W., Krausmann, F., Fischer-Kowalski, M.; Wien (2010)

Band 121+
Sociometabolic regimes in indigenous communities and the crucial role of working time: A comparison of case studies. Fischer-Kowalski, M., Singh, S.J., Ringhofer, L., Grünbühel C.M., Lauk, C., Remesch., A.; Wien (2010)

Band 122+
Klimapolitik im Bereich Gebäude und Raumwärme. Entwicklung, Problemfelder und Instrumente der Länder Österreich, Deutschland und Schweiz. Jöbstl, R.; Wien (2010)

Band 123+
Trends and Developments of the Use of Natural Resources in the European Union. Krausmann, F., Fischer-Kowalski, M., Steinberger, J.K., Schaffartzik, A., Eisenmenger, N, Weisz, U.; Wien (2011)

Band 125+
Raw Material Equivalents (RME)
of Austria's Trade. Schaffartzik, A., Eisenmenger, N., Krausmann, F., Weisz, H.; Wien (2013)

Band 126+
Masterstudium "Sozial- und Humanökologie": Selbstevaluation 2005-2010. Schmid, M., Mayer A., Miechtner, G.; Wien (2010)

Band 127 +
Bericht des Zentrums für Evaluation und Forschungsberatung (ZEF). Das Masterstudium „Sozial- und Humanökologie". Mayring, P., Fenzl, T.; Wien (2010)

Band 128+
Die langfristigen Trends der Material- und Energieflüsse in den USA in den Jahren 1850 bis 2005. Gierlinger, S.; Wien (2010)

Band 129+
Die Verzehrungssteuer 1829 – 1913 als Grundlage einer umwelthistorischen Untersuchung des Metabolismus der Stadt Wien. Hauer, F.; Wien (2010)

Band 130+
Human Appropriation of Net Primary Production in South Africa, 1961- 2006. A socio-ecological analysis. Niedertscheider, M.; Wien (2011)

Band 131+
The socio-metabolic transition.
Long term historical trends and patterns in global material and energy use. Krausmann, F. (Editor); Wien (2011)

Band 132+
„Urlaub am Bauernhof" oder „Bauernhof ohne Urlaub"? Eine sozial-ökologische Untersuchung der geschlechtsspezifischen Arbeitsteilung und Zeitverwendung auf landwirtschaftlichen Betrieben in der Gemeinde Andelsbuch, Bregenzerwald.
Winder, M.; Wien (2011)

Band 133+
Spatial and Socio-economic Drivers of Direct and Indirect Household Energy Consumption in Australia.
Wiedenhofer, D.; Wien (2011)

Band 134+
Die Wiener Verzehrungssteuer. Auswertung nach einzelnen Steuerposten (1830 – 1913). Hauer, F., Gierlinger, S., Nagele, C., Albrecht, J., Uschmann, T., Martsch, M.; Wien (2012)

Band 135+
Zeit für Veränderung? Über die geschlechtsspezifische Arbeitsteilung und Zeitverwendung in landwirtschaftlichen Betrieben und deren Auswirkungen auf Landnutzungsveränderungen in der Region „Westlicher Wienerwald". Eine sozial-ökologische Untersuchung.
Madner, V.; Wien (2012)

Band 136+
The Impact of Industrial Grain Fed Livestock Production on Food Security: an extended literature review. Erb, K-H., Mayer, A., Kastner, T., Sallet, K-E., Haberl, H.; Wien (2012)

Band 137+
Human appropriation of net primary production in Africa: Patterns, trajectories, processes and policy implications. Fetzel, T., Niedertscheider, M., Erb, K-H., Gaube, V., Gingrich, S., Haberl, H., Krausmann, F., Lauk, C., Plutzar, C.; Wien (2012)