

the case of primary resources and emissions). This paper presents ongoing work in the development of the database module on environmental extensions. For each category of environmental extensions, we present the number of disaggregated categories and the main data sources used. We discuss the main limitations imposed by availability of primary data and levels of disaggregation, when applying the data in an input-output framework. We discuss how primary data is transformed into a sectoral matrix structure and how data is integrated into the overall EXIOPOL database. Finally, we provide an outlook towards how the created EE I-O database can be applied in the future to calculate environmental indicators in a world-wide context, including, among others, indicators on global warming, acidification, nitrification, and indicators on the use of materials, energy, land and water.

Keywords: environmentally extended input-output analysis, emissions, energy use, land appropriation, material flows, water.

1. Introduction

The overall objective of WPIII.2.b and WPIII.3.b is to gather and process environmental data so as to build up the environmental extensions modules to the monetary EXIOPOL IO- framework.

There are several conceptual possibilities to link environmental extensions to the overall EXIOPOL Input-Output framework (see also deliverable DIII.1.a-2).

Basic conceptual choices related to EE-conceptions were taken particularly at the Leiden workshop of the Cluster III team:

- Supply-Use Tables (SUT) are to be used as the overall concept of the EXIOPOL IO-framework (=> EE-SUT)
- EE are to be linked to the SUT-framework in form of satellite accounts

2. The SUT framework (as applied in EXIOPOL)

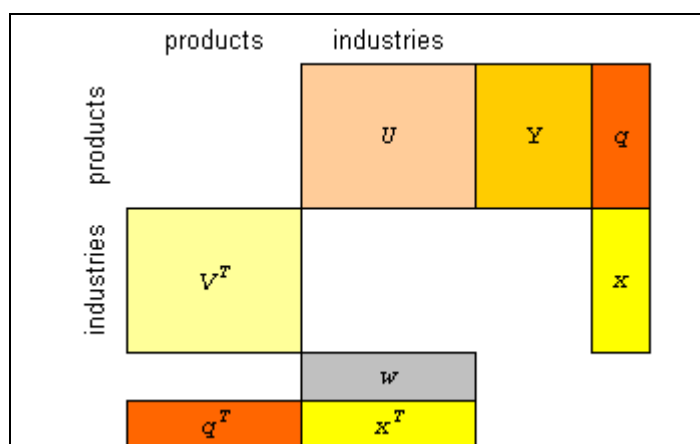
Figure 1 shows a simplified scheme of the monetary (in basic prices) SUT-framework as applied by EXIOPOL (see also Table 2.3 in Scoping document DIII.1.a-5, pp. 13-22). The scheme combines and integrates supply and use tables.

The original supply table – which needs to be rotated by 90° in such a combined SUT scheme – is mainly to be found along the first column of Figure 1. Here, VT is the transposed central element of the supply table, sometimes referred to as production matrix. An element V_{ij} indicates the supply of product i from domestic production by industry j . The vector mT is the transposed vector of imported products i . The vector qT is the transposed total supply by products i (either domestically produced by industries or through imports). The vector x is the output by industries (domestic production).

The original use table is mainly to be found along the first row of the combined SUT-scheme. Here, the matrix U denotes the inter-industry part of the use table, the so-called intermediate consumption matrix. An element of U_{ij} indicates the use of product

i by industry j (including imported intermediate goods). The matrix Y denotes the second part of the use matrix – the final demand matrix. It shows the use of product i by several components of final demand (e.g. consumption by private households and government, gross fixed capital formation, exports). Vector q shows the total of products used by industries and components of final demand. The vector w denotes the gross value added by industries (comprising several factor inputs such as wages, depreciation, surplus etc.). Finally, the transposed vector x^T shows all inputs (intermediate products and value-added) to industries.

Figure 1: General SUT-framework



There are two basic identities inherent to the SUT-scheme presented in Figure 1. First, the total use of products (q) is equal to the total supply of products (q^T). Secondly, the total input to industries (x^T) is equal to the total output of industries (x). For a mathematical formalisation of this, see EXIOPOL-deliverable DIII.1.a-5, pages 15-16.

The SUT-scheme serves as the data-wise point of departure for econometric model calculations. Common to those calculations is that the final use is usually the independent variable. In general, the type of question is: what are the consequences of changes in final demand? For instance, how much needs to be produced additionally in order to enable an increase in final demand for product i ? Model calculations based on the SUT-scheme allow answering such kind of questions in terms of industry production outputs and/or products. Thereby, several assumptions are being made (see EXIOPOL-deliverable DIII.1.a-5, pp. 17-19).

3. Environmental Extensions (EE-SUT) - framework

Environmental Extensions (EE) are certain environmentally relevant parameters in physical units which are to be linked to the monetary SUT-scheme (shown in Figure 1) in order to enable integrated environmental and economic model calculations. The objective is to quantify environmental consequences of changes in final demand. An increase in final demand will cause – likewise the additional production and product output – also additional environmental factor inputs.

Likewise gross value added, environmental variables can be regarded as kind of factor input to production. Whereas value added represents monetarily valued factor inputs to the production processes, the utilisation of the natural environment can be regarded as physical factor inputs to production.

The utilisation of the natural environment as a factor input to production can have various forms. It relates to the natural environment's service function as a source as well as a sink. The source function comprises the provision of resources such as raw materials, land water etc. The sink function comprises the assimilation (take up) of emissions from economic processes and activities.

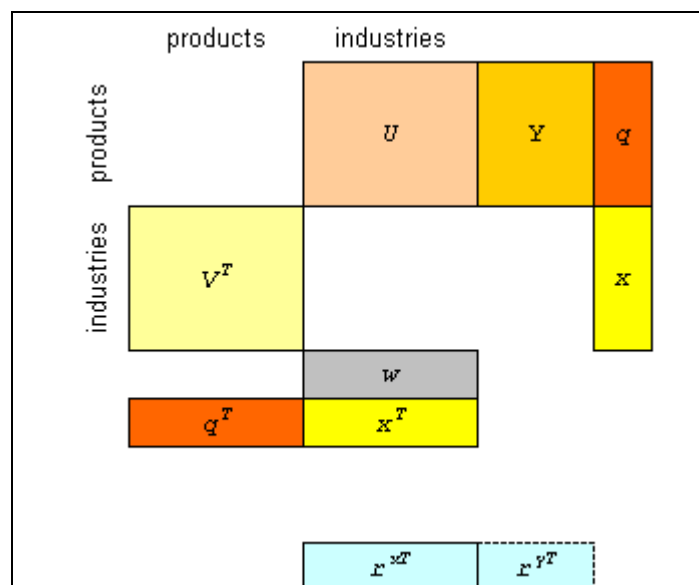
The SUT-scheme in Figure 1 is a closed system as it is expressed solely in monetary units. The monetary input to industries equals the monetary output of industries and the product supply in monetary units equals the product use in monetary units. These identities are an important prerequisite for the mathematical Leontief-type models.

Hence, it is reasonable to arrange the physical factor inputs (i.e. environmental extension parameters) external to the closed monetary SUT-scheme. This is done via so-called satellite accounts. They form a simple possibility for adding physical factor inputs (i.e. environmental extension parameters but also other physical representations of factor inputs, such as e.g. labour in working hours or number of occupied persons) to the monetary SUT-scheme.

Satellite accounts are external vectors and/or matrices which are simply added to the monetary core SUT-scheme, arranged in a compatible way to the SUT column and row headings.

The most common way is to arrange the environmental factor inputs to the use table part, likewise the value added. Figure 2 shows how a single environmental extension (e.g. CO₂-emissions) vector can be externally added to the SUT-scheme. Actually, this environmental factor input vector comprises two parts, one related to industries and another to the several components of final use. The vector x shows the direct environmental factor input (e.g. CO₂-emissions) by industries j . The vector r shows the environmental factor input to components of final use, basically private households.

Figure 2: General SUT scheme extended by one single external environmental factor input vector



Obviously, one can also add more than one environmental variable leading to matrices of environmental factor inputs R .

4. Environmental Extensions (EE-SUT) - mathematics

The SUT-scheme (as shown in Fehler! Verweisquelle konnte nicht gefunden werden.) can be put into a mathematical SUT-model (see EXIOPOL-deliverable

DIII.1.a-5, pp. 15-19). This section outlines how environmental extensions can be linked to and integrated into this mathematical SUT model.

The environmental factor input vector is related to industries as shown in the scheme of **Fehler! Verweisquelle konnte nicht gefunden werden.**. A simple linear relationship is assumed between the production output x_j of a given industry j and its environmental factor input r_j^x leading to the intensity s_j^x for this particular industry j :

$$s_j^x = r_j^x / x_j \quad (1)$$

The intensity represents the amount of environmental factor input per unit monetary production output. All elements of s_j^x together form the vector of environmental intensities s^x .

$$s^{xT} = [s_1^x \ s_2^x \ s_3^x \ \dots \ s_j^x] \quad (2)$$

In matrix notation the derivation of the vector of environmental intensities by industries reads like:

$$s^{xT} = r^{xT} \cdot \langle x \rangle^{-1} \quad (3)$$

with:

r^x : environmental factor input vector by industries

x : production output by industries

s^x : vector of environmental intensities by industries

Note: the subscript T denotes the transposed of a vector or matrix; the signs $\langle \rangle$ denote that the respective vector is diagonalized.

In addition to the vector of environmental intensities by industries, the various SUT-models also require knowing the environmental factor input and respective vector of environmental intensities broken down by products. r_j^q denotes the environmental factor input by products and it represents the directly utilised environmental factor input to all production processes producing product q_j .

Accordingly, s_j^q denotes the environmental intensity of product q_j . We derive this vector of environmental intensities by products s^q through multiplying the inverse of the transposed production matrix V^T from left with the environmental factor input vector by industries r^x :

$$s^q = V^{-T} \cdot r^x \quad (4)$$

Accordingly, the corresponding factor input vector by product can be obtained through multiplying the product output q with the previously obtained environmental intensity of products s^q :

$$r^{qT} = q^T \cdot \langle s^q \rangle \quad (5)$$

with:

s^q : environmental intensities by products

V : production matrix

r^q : environmental factor input vector by products

q : product output

Several mathematical Input-Output models based on a Supply-Use-framework are presented in the EXIOPOL-deliverable DIII.1.a-5 (pp. 15-19). The different models differ with regards to two technology assumptions:

- Industry-technology assumption (ITA) assumes that all industries have the same input structure (technology) regardless of the product they produce. For instance, assume the car manufacturing industry is producing cars as a principal output and electricity as a secondary output. Under the ITA, it is assumed that both products, i.e. the cars and the electricity, are produced with the same technology and respective recipe of inputs.
- Commodity-technology assumption (CPA) assumes that all products have the same input structure (technology) regardless of the industry that produces it. For instance, assuming again that the car manufacturing industry is producing both,

cars and electricity. Under the CTA it is assumed that the latter electricity by the car industry is produced with the input structure (technology) as observed in the electricity industry.

Industry-technology assumption (ITA)

The system of equations related to the ITA – two equations in two unknowns – can be represented in the following supply-use block (eq.[16] in EXIOPOL scoping report DIII.1.a-5):

$$\begin{pmatrix} q \\ x \end{pmatrix} = \begin{pmatrix} 0 & U \langle x \rangle^{-1} \\ V^T \langle q \rangle^{-1} & 0 \end{pmatrix} \begin{pmatrix} q \\ x \end{pmatrix} + \begin{pmatrix} y \\ 0 \end{pmatrix} \quad (6)$$

Solving this system for industry output gives the industry-by-industry requirement matrix, i.e. the central block in an industry-by-industry IOT. The related Leontief-type model reads like following:

$$x = (I - A^x)^{-1} \cdot y^x \quad (7)$$

where

$$A^x = V^T \cdot \langle q \rangle^{-1} \cdot U \cdot \langle x \rangle^{-1} \quad (8)$$

and

$$y^x = V^T \cdot \langle q \rangle^{-1} \cdot y \quad (9)$$

The environmental factor input is integrated by adding s^q , the environmental intensities by industries, to the right side of the equation:

$$R^x = \langle s^x \rangle \cdot (I - A^x)^{-1} \cdot \langle y^x \rangle \quad (10)$$

Each element R^x_{ij} of this resulting physical industry by industry matrix shows, how much environmental factor input is used by industry i to produce intermediate goods for industry j in order to enable the latter to produce its goods for final demand. The row totals show the direct environmental factor inputs by industries i , i.e. the original environmental factor input vector by industries (r^x).

The column totals show the direct and indirect environmental factor inputs activated by the final demand of industry outputs j .

Solving the above ITA system for product outputs gives the product-by-product requirements matrix, the central block of a product-by-products IOT. The related Leontief-type model is:

$$\mathbf{q} = (\mathbf{I} - \mathbf{A}^q)^{-1} \cdot \mathbf{y} \quad (11)$$

where

$$\mathbf{A}^q = \mathbf{U} \cdot \langle \mathbf{x} \rangle^{-1} \cdot \mathbf{V}^T \cdot \langle \mathbf{q} \rangle^{-1} \quad (12)$$

Again, the environmental factor input is integrated by adding the vector of environmental intensities to the model equation; however, this time the intensities-vector is by products, i.e. \mathbf{s}^q :

$$\mathbf{R}^q = \langle \mathbf{s}^q \rangle \cdot (\mathbf{I} - \mathbf{A}^q)^{-1} \cdot \langle \mathbf{y} \rangle \quad (13)$$

Each element \mathbf{R}_{ij}^q of this product by product matrix shows, how much environmental factor input is directly used for the production of product i to be delivered as intermediate good for the production of final demand of product j . The row totals show the direct environmental factor inputs needed for total output of product i , i.e. the vector of environmental factor inputs broken down by products (\mathbf{r}^q).

The column totals show the direct and indirect environmental factor inputs activated by the final demand of product j .

Finally, a mixed system can be derived that takes the final demand in products and returns the industry output which probably constitutes the most typical research question. The related Leontief-type model reads:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A}^x)^{-1} \cdot \mathbf{V}^T \cdot \langle \mathbf{q} \rangle^{-1} \cdot \mathbf{y} \quad (14)$$

Alternatively, this can be solved as:

$$\mathbf{x} = \mathbf{V}^T \cdot \langle \mathbf{q} \rangle^{-1} \cdot (\mathbf{I} - \mathbf{A}^q)^{-1} \cdot \mathbf{y} \quad (15)$$

Both Leontief-type models can be extended by the physical factor input leading to:

$$R^x = \langle s^x \rangle \cdot (I - A^x)^{-1} \cdot V^T \cdot \langle q \rangle^{-1} \cdot y \quad (16)$$

$$R^x = \langle s^x \rangle \cdot V^T \cdot \langle q \rangle^{-1} \cdot (I - A^q)^{-1} \cdot y \quad (17)$$

For both cases, each element R^x_{ij} of the resulting physical industry by product matrix shows, how much environmental factor input is used by industry i to produce intermediate goods for the production of final demand of product j . The row totals show the direct environmental factor inputs by industries i , that is the original environmental factor input vector by industries (r^x).

The column totals show the direct and indirect environmental factor input activated by the final demand for product j .

Commodity-technology assumption (CTA)

The system of equations related to the CTA – two equations in two unknowns – can be represented in the following supply-use block (eq.[25] in EXIOPOL scoping report DIII.1.a-5):

$$\begin{pmatrix} q \\ x \end{pmatrix} = \begin{pmatrix} 0 & U \langle x \rangle^{-1} \\ \langle x \rangle V^{-1} & 0 \end{pmatrix} \begin{pmatrix} q \\ x \end{pmatrix} + \begin{pmatrix} y \\ 0 \end{pmatrix} \quad (18)$$

As for ITA, the CTA leads to either a product or industry system. Solving the system for industry output gives the industry-by-industry requirement matrix and the related Leontief-type model is:

$$x = (I - A^x)^{-1} \cdot y^x \quad (19)$$

where

$$A^x = \langle x \rangle \cdot V^{-1} \cdot U \cdot \langle x \rangle^{-1} \quad (20)$$

and

$$y^x = \langle x \rangle \cdot V^{-1} \cdot y \quad (21)$$

As previously, the vector of environmental intensities is added to the model equation leading to:

$$R^x = \langle s^x \rangle \cdot (I - A^x)^{-1} \cdot \langle y^x \rangle \quad (22)$$

Also for the CTA case, each element R^x_{ij} of this resulting physical industry by industry matrix shows, how much environmental factor input is used by industry i to produce intermediate goods for industry j in order to enable the latter to produce its goods for final demand. The row totals show the direct environmental factor inputs by industries i , i.e. the original environmental factor input vector by industries (r^x).

The column totals show the direct and indirect environmental factor inputs activated by the final demand of industry outputs j .

Solving the above CTA system for product outputs gives the product-by-product requirements matrix, the central block of a product-by-products IOT. The related Leontief-type model is:

$$q = (I - A^q)^{-1} \cdot y \quad (23)$$

where

$$A^q = U \cdot V^{-1} \quad (24)$$

The environmental factor input is integrated by adding the vector of environmental intensities to the model equation; note, this time the intensities-vector is by products, i.e. s^q :

$$R^q = \langle s^q \rangle \cdot (I - A^q)^{-1} \cdot \langle y \rangle \quad (25)$$

Also for the CTA case, each element R^q_{ij} of this product by product matrix shows, how much environmental factor input is directly used for the production of product i to be delivered as intermediate good for the production of final demand of product j . The row totals show the direct environmental factor inputs needed for total output of product i , that is the vector of environmental factor inputs broken down by products (r^q).

The column totals show the direct and indirect factor inputs activated by the final demand of product j .

Also in the CTA case, a mixed system can be derived that takes the final demand in products and returns the industry output. The related Leontief-type model reads:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A}^x)^{-1} \cdot \langle \mathbf{x} \rangle \cdot \mathbf{V}^I \cdot \mathbf{y} \quad (26)$$

The environmental factor input is added to the model resulting in a physical matrix as:

$$\mathbf{R}^x = \langle \mathbf{s}^x \rangle \cdot (\mathbf{I} - \mathbf{A}^x)^{-1} \cdot \langle \mathbf{x} \rangle \cdot \mathbf{V}^I \cdot \mathbf{y} \quad (27)$$

Each element R^x_{ij} of the resulting physical industry by product matrix shows, how much environmental factor input is used by industry i to produce intermediate goods for the production of final demand of product j . The row totals show the direct environmental factor inputs by industries i , that is the original environmental factor input vector by industries (\mathbf{r}^x).

The column totals show the direct and indirect environmental factor input activated by the final demand for products j .

An example with numbers

This section presents an illustrative example with number for the mathematics of the different EE-SUT models as theoretically introduced in the previous section.

The EE-SUT scheme as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** shall be represented with the following numbers:

(Style "Heading")

		products			industries							
products					5	15	5	10	5	40		
					15	15	20	80	50	180		
					5	25	45	100	55	230		
industries		30	5	0						35		
		10	175	0						185		
		0	0	230						230		
					10	130	160					
					40	180	230	35	185	230		
								30	530	230	5	0

The vector of environmental intensities by industries is calculated using equation (3), leading to:

$$s^{i^T} = r^{i^T} \cdot \langle X \rangle^{-1}$$

0.9	2.9	1.0
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The vector of environmental intensities by products can be derived with equation (4):

$$s^{q^T} = V^{-T} \cdot r^{i^T}$$

(4)

0.5
3
1.0

And the environmental factor input vector by products is obtained backwards by applying equation (5):

$$r^{q^T} = q^T \cdot \langle s^{q^T} \rangle$$

20	540	230
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Industry-technology assumption (ITA)

The industry-by-industry Leontief-type model under the ITA-assumption is as follows:

$$x = (I - A^x)^{-1} \cdot Y^x \quad A^x = V^T \cdot \langle q \rangle^{-1} \cdot U \cdot \langle x \rangle^{-1} \quad Y^x = V^T \cdot \langle q \rangle^{-1}$$

(7) <table border="1" style="border-collapse: collapse; margin: auto;"> <tr><td style="background-color: yellow;">35</td></tr> <tr><td style="background-color: yellow;">185</td></tr> <tr><td style="background-color: yellow;">230</td></tr> </table>	35	185	230	(8) <table border="1" style="border-collapse: collapse; margin: auto;"> <tr><td>0.1</td><td>0.1</td><td>0.0</td></tr> <tr><td>0.5</td><td>0.1</td><td>0.1</td></tr> <tr><td>0.1</td><td>0.1</td><td>0.2</td></tr> </table>	0.1	0.1	0.0	0.5	0.1	0.1	0.1	0.1	0.2	(9) <table border="1" style="border-collapse: collapse; margin: auto;"> <tr><td style="background-color: yellow;">15</td></tr> <tr><td style="background-color: yellow;">130</td></tr> <tr><td style="background-color: yellow;">155</td></tr> </table>	15	130	155
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185																	
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0.1	0.1	0.0															
0.5	0.1	0.1															
0.1	0.1	0.2															
15																	
130																	
155																	

Integrating the environmental extension leads to the following physical matrix:

$$R^x = \langle s^x \rangle \cdot (I - A^x)^{-1} \cdot \langle Y^x \rangle$$

(10)	<table border="1" style="border-collapse: collapse; margin: auto;"> <tr><td>15</td><td>9.9</td><td>5</td><td>30</td></tr> <tr><td>27</td><td>438</td><td>65</td><td>530</td></tr> <tr><td>4.7</td><td>28</td><td>198</td><td>230</td></tr> <tr><td>47</td><td>476</td><td>267</td><td>790</td></tr> </table>	15	9.9	5	30	27	438	65	530	4.7	28	198	230	47	476	267	790
15	9.9	5	30														
27	438	65	530														
4.7	28	198	230														
47	476	267	790														

The product-by-product model under the ITA is:

$$q = (I - A^q)^{-1} \cdot Y \quad A^q = U \cdot \langle x \rangle^{-1} \cdot V^T \cdot \langle q \rangle^{-1}$$

(11) <table border="1" style="border-collapse: collapse; margin: auto;"> <tr><td style="background-color: orange;">40</td></tr> <tr><td style="background-color: orange;">180</td></tr> <tr><td style="background-color: orange;">230</td></tr> </table>	40	180	230	(12) <table border="1" style="border-collapse: collapse; margin: auto;"> <tr><td>0.1</td><td>0.1</td><td>0.0</td></tr> <tr><td>0.3</td><td>0.1</td><td>0.1</td></tr> <tr><td>0.1</td><td>0.1</td><td>0.2</td></tr> </table>	0.1	0.1	0.0	0.3	0.1	0.1	0.1	0.1	0.2
40													
180													
230													
0.1	0.1	0.0											
0.3	0.1	0.1											
0.1	0.1	0.2											

Extending this model leads to the physical matrix:

$$R^q = \langle s^q \rangle \cdot (I - A^q)^{-1} \cdot \langle Y \rangle$$

(13)	<table border="1" style="border-collapse: collapse; margin: auto;"> <tr><td>9</td><td>7.5</td><td>3.5</td><td>20</td></tr> <tr><td>22</td><td>454</td><td>65</td><td>540</td></tr> <tr><td>4.4</td><td>28</td><td>198</td><td>230</td></tr> <tr><td>35</td><td>490</td><td>266</td><td>790</td></tr> </table>	9	7.5	3.5	20	22	454	65	540	4.4	28	198	230	35	490	266	790
9	7.5	3.5	20														
22	454	65	540														
4.4	28	198	230														
35	490	266	790														

The two mixed industry-by-product model under the ITA assumption are:

$$x = (I - A^x)^{-1} \cdot V^T \cdot \langle q \rangle^{-1} \cdot Y \quad x = V^T \cdot \langle q \rangle^{-1} \cdot (I - A^q)^{-1} \cdot Y$$

(14) <table border="1" style="border-collapse: collapse; margin: auto;"> <tr><td style="background-color: yellow;">35</td></tr> <tr><td style="background-color: yellow;">185</td></tr> <tr><td style="background-color: yellow;">230</td></tr> </table>	35	185	230	(15) <table border="1" style="border-collapse: collapse; margin: auto;"> <tr><td style="background-color: yellow;">35</td></tr> <tr><td style="background-color: yellow;">185</td></tr> <tr><td style="background-color: yellow;">230</td></tr> </table>	35	185	230
35							
185							
230							
35							
185							
230							

Both models can be extended leading to physical matrices like the following:

$$R^x = \langle s^x \rangle \cdot (I - A^x)^{-1} \cdot V^T \cdot \langle q \rangle^{-1} \cdot \langle Y \rangle$$

(16)

12	13	5	30
33	432	65	530
4.4	28	198	230
49	474	267	790

$$R^x = \langle s^x \rangle \cdot V^T \cdot \langle q \rangle^{-1} \cdot (I - A^x)^{-1} \cdot \langle Y \rangle$$

(17)

12	13	5	30
33	432	65	530
4.4	28	198	230
49	474	267	790

Industry-technology assumption (ITA)

The industry-by-industry Leontief-type model under the CTA-assumption is obtained by equations (19 to 21), as follows:

$$x = (I - A^x)^{-1} \cdot Y^x$$

(19)

35
185
230

$$A^x = \langle x \rangle V^{-1} \cdot U \langle x \rangle^{-1}$$

(20)

0.1	0.1	0.0
0.4	0.1	0.1
0.1	0.1	0.2

$$Y^x = \langle x \rangle V^{-1} \cdot$$

(21)

8.9
136
155

The corresponding environmentally extended model yields the following physical matrix:

$$R^x = \langle s^x \rangle \cdot (I - A^x)^{-1} \cdot \langle Y^x \rangle$$

(22)

9.4	15	5.9	30
15	451	63	530
2.9	30	198	230
28	495	267	790

The product-by-product model under the CTA-assumption looks like:

$$q = (I - A^q)^{-1} \cdot y \quad (23)$$

40
180
230

$$A^q = U \cdot V^{-1} \quad (24)$$

0.2	0.1	0.0
0.5	0.1	0.1
0.1	0.1	0.2

The extended version reveals the following physical matrix:

$$R^q = \langle s^q \rangle \cdot (I - A^q)^{-1} \cdot \langle y \rangle \quad (25)$$

9.4	7.1	3.5	20
31	444	66	540
5.1	27	198	230
45	478	267	790

Finally, the mixed industry-by-product Leontief-model under the CTA-assumption yields the following:

$$x = (I - A^x)^{-1} \cdot \langle x \rangle \cdot V^{-1} \cdot y \quad (26)$$

35
185
230

The related environmentally extended model results into the following physical matrix:

$$R^x = \langle s^x \rangle \cdot (I - A^x)^{-1} \cdot \langle x \rangle \cdot V^{-1} \cdot \langle y \rangle \quad (27)$$

18	5.7	5.9	30
22	445	63	530
5.1	27	198	230
45	478	267	790

The following overview presents the six different results for the physical models, here only the vector of column-totals is compared as this is the most interesting outcome as it re-attributes the initial environmental factor inputs to the final demand:

Comparative overview of results for EE re-attributed to final demand		
	ITA	CTA
industry-by-industry	47 476 267	28 495 267
product-by product	35 490 266	45 478 267
industry-by-product	49 474 267	45 478 267

The re-attribution model results differ quite substantially between ITA and CTA for two first models (industry-by-industry and product-by-product).

For the mixed model (industry-by-product) the differences between ITA and CTA are less pronounced, actually, the outcomes are quite close.

5. Resources

Materials

Used extraction of materials

Global economic growth – accelerated by one of its driving motors, global trade – is steadily increasing the extraction and consumption of natural resources and materials. Empiric trends show clearly a growing demand on resources – especially in the Global North and in the emerging countries (like China or India) –and a rising orientation on resource exports in the resource-rich country of the Global South (Behrens et al., 2007).

Hence, in order to reconcile further economic growth, environmental quality and sustainable development, a sophisticated and efficient management of natural resources and materials is crucial, especially regarding negative environmental impacts associated with the production, consumption and disposal of natural resources as well as the issue of long-term security of supply and rising resource prices. The supply and use of natural resources is particularly influenced by their rising prices. This development of the last years increasingly supports the demand for a decrease in the use of natural resources, especially through an improvement in the efficiency in material use, a topic picked up by international organisations as the OECD (2008).

With regard to materials, in the EXIOPOL project we follow the accounting standards adhering to the EUROSTAT MFA guidelines, elaborated in 2001

(EUROSTAT, 2001) and further refined in 2007 (Weisz et al., 2007b). This means that the set of environmental extensions is also compatible with the respective MFA guide published by the OECD (2008).

The material section encompasses the aggregated material categories 'Fossil Fuels', 'Metals', 'Construction and Industrial Minerals', and 'Biomass'. Within these categories the materials are divided into various sub-categories. In total, the data base comprises 267 different material commodities with data series available from 1980-2005.

In the following, we provide a short description of the primary data sources and the related calculation factors used for each of the aggregated material categories.

Fossil Fuels:

Data for this section was taken from IEA's energy statistics (IEA, 2007a,b). This compilation of fuel as well as energy use data is the most comprehensive currently available data set. Data can be easily compiled and retrieved with a Pivot-type tool provided by IEA. In the EXIOPOL project – on the basis of the EU-FP6 MOSUS project (www.mosus.org) - the category 'Fossil Fuels' has been divided into the sub-categories of hard coal, lignite/brown coal, crude oil, natural gas, natural gas liquids, and peat for energy use.

Metals:

Almost all the data for the metals section was taken from the data base developed by British Geological Survey (BGS, 2007). Although BGS provides an exhaustive collection of data on extraction of metals and minerals, in quite a number of cases the time series contained gaps. These gaps can be the result of, for instance, non-reported or confidential data, or just data management errors. Therefore, we completed the BGS data set by using data of the 'World Mining Data' (WMD) base of the Austrian Ministry for Economy and Labour (Weber and Zsak, 2007), on the one hand, and with UNSTATS data, on the other hand (United Nations, 2005). These data bases were also used to check the plausibility of the BGS data. As the BGS data series start only in the

year 1986 and in quite a number of cases are incomplete, we applied a set of principles to complement the BGS data, which are listed in Annex 1.

Concerning the data on metal extraction, BGS reports the majority of the different metal types in metal content contained in an extracted ore. In these cases, we used factors, in order to calculate the corresponding gross extraction (run of mine). Information on concentrations of metals in crude ores was obtained through interviews with experts and a literature survey of more than 300 publications, in particular country and metal reports from the German Federal Geological Institute and the US Geological Survey (a more detailed list is provided in Annex 2).

Industrial and Construction Minerals:

For the allocation of minerals to the categories Industrial Minerals and Construction Minerals we adhered to the handbook for economy-wide material flow accounting published by the Statistical Office of the European Union (EUROSTAT, 2001). In cases where certain types of minerals (as for instance limestone, sandstone, etc) are used for construction as well as for industrial purposes, an allocation as presented in Annex 3 was developed, based on estimations on the primary purpose of use of the different materials.

Also for the section of Industrial Minerals primary data was available from BGS, WMD, and UNSTATS, and gaps were filled with complementing data or estimations. In contrast to the necessary conversion of reported metal extraction, industrial minerals generally are reported as concentrated products, and as such do not have to be converted (exception: diamonds).

In general, coverage of Construction Minerals in official statistics is still unsatisfactory, even in industrialised countries (see also Bringezu and Schütz, 2001b; see also EUROSTAT, 2002; Weisz et al., 2006), but in particular with regard to non-OECD countries, where huge data gaps were identified (in many cases, no data at all was available from published statistics).

For the EU-15, for the years 1990-2004 we used aggregated data published by EUROSTAT (Weisz et al., 2007a). USGS provides a solid data base for the USA, so

USGS data were applied in this case. Additionally, BGS reports on some of the construction minerals commodities for various countries (especially: gypsum, sand and gravel).

For all countries, except the EU-15 and the USA, we applied an estimation procedure (developed in the MOSUS project), in order to obtain a level of per capita extraction of construction minerals, which – according to interviewed experts in this field and information from other sources such as geological institutes – can be assumed as realistic in different world regions.

Biomass:

The category ‘Biomass’ has a multitude of sub-categories: Agriculture, By-products of harvest, Grazing, Forestry, Fishing, Hunting, Other biomass. The main data source for these sub-categories was the data base of the Food and Agriculture Organisation of the United Nations (FAO, 2007). Necessary conversion factors were taken mainly from EUROSTAT studies – as to calculate, for instance, amounts of by-products of harvest (EUROSTAT, 2002), biomass uptake from grazing (Weisz et al., 2007b), etc.

Unused extraction of materials

In the MFA methodology, some material categories, such as overburden for mining activities or unused residuals of biomass extraction are defined as ‘unused extraction’ (OECD, 2008). Data availability and quality is still unsatisfying for many countries (in particular, non-OECD countries) and improvement of UDE estimates would require significant resources. Therefore, in EXIOPOL we focus on the improvement and update of data on used extraction. However, data on unused domestic extraction (UDE) is also included in the EXIOPOL data base. UDE was estimated by multiplying used extraction with factors expressing amounts of unused materials per used materials (in ton/ton). Therefore, factors and data sources were cross-checked and harmonized with the database on unused material extraction developed by the Wuppertal Institute. In order to be able to calculate unused values for all commodities in all countries the availability in Germany of the following types of factors was checked, and the respective factors allocated:

National factor → continental average factor → world average factor

Annex 4 shows the main sources ordered by material category.

Land

Land is a natural resource different from materials. Whereas the latter constitute flows of natural materials that are physically processed into goods, land constitutes a natural asset that is utilised but not as such physically incorporated into products. Land area can be regarded as a natural stock providing various services to human activities, such as construction territory, fixation of contaminants, biotope function, etc. (United Nations, 2003).

Yet, land area is an important production factor although it is in most of the cases fixed and not increasable. Agriculture and forestry are the most important economic activities using one particular service function of land. Those economic activities utilise land area to grow biomass; a renewable material resource which is further economically used for processing of goods. The global land area available for growing biomass is limited. This implies that the total amount of biomass material that can be grown for use in economic processing is also limited. Basically, there are two means to increase the amount of biomass produced in agriculture:

(1) Increasing the land area utilised to grow biomass through land use changes from e.g. natural forest area (e.g. rainforests) into arable land.

(2) Increasing the hectare productivity or yields through e.g. technological progress; i.e. increasing the amount of biomass harvested per hectare (expressed in tonnes per hectare).

There are indications that the EU economy is already using more biomass as they grow on their own land area. Through net-imports of biomass-based products, the EU is indirectly utilising land area in other world regions to meet its consumption needs. The global land use of the EU15 exceeds the domestic agricultural area by about one fifth (Bringezu, 2007; Steger, 2005).

Recording land area which is used to generate biomass for economic processing in the EXIOPOL database seems of high policy relevance. Recent EU policy efforts, such as e.g. the increased use of biofuel, will have implications on land use in Europe and beyond.

Built-up area denotes land use for settlements and infrastructures. Unlike land use for biomass growing, built-up area provides no direct physical inputs to the economy. It provides rather a service of "hosting capital goods" and it is hence not directly linked to flows of materials into the economy. International data sets on built-up land are currently only under development. The most important initiative on the EU level is the establishment of "Land and Ecosystem Accounts (LEAC)" at the European Environment Agency (EEA, 2006). LEAC includes the Corine data set on land cover, a standardized land cover inventory derived from satellite image, using a 100 m x 100 m grid. Within Corine, several categories cover artificial surfaces, of which three can be allocated to transport (road/rail, ports, airports) and three others to mines, dump and construction. For the whole category of Industry and Commerce, only one aggregated number is provided for each country. This level of aggregation does not allow a proper allocation to the large number of non-primary sectors in the EXIOPOL data base. It has therefore be decided that built-up land will not be considered in EXIOPOL.

Originally, it was intended to consider the Ecological Footprint (WWF, 2006) in the environmental extensions of the EXIOPOL IO framework. The idea was to link the Ecological Footprint data to land use and to collect at least those land use data which are related to the composition of Ecological Footprint accounts, namely land providing renewable resources and assimilating emissions. Basically, this is agricultural land and forestry.

An important feature of the original Ecological Footprint accounts is that its start of departure is 'net consumption' volumes of a single good. However, relating natural resource items to consumption does not make sense in an environmentally extended Input-Output framework such as the EXIOPOL database. In the EXIOPOL framework environmental extensions are in general linked to the production activities and the re-attribution to consumption is done in a later analytical step. In the multi-regional IO framework it will be able to specify land areas in foreign countries re-

attributed to the consumption of a certain good in another country (e.g. how much Brazilian land area is 'embodied' in the Dutch consumption of cheese?) which is not the case with the traditional EF.

The Ecological Footprint is a composite indicator expressed in artificial land-use units global hectares; e.g.: hectares with global average productivity). Its accounting procedure is not based on actual land uses but starts with material consumption data (biotic resources) and CO₂ emissions. As the EF operates with artificial land use units (global hectares), data-wise EF accounts are hence not based on and linkable to 'real' land use data. Therefore, in EXIOPOL a direct linkage to the standard EF calculation has not been established.

Land area which is used to generate biomass for economic processing was included in the EXIOPOL database using the categories 'Arable Land', 'Pasture', and 'Forest':

Water

Freshwater is no longer taken for granted as a plentiful and always available resource. More and more people in an increasing number of countries, among which EU is not an exception, are experiencing water shortages or even droughts – as individuals in their day-to-day lives as well as communities and nations. In addition to drought impacts, overexploitation of water, especially for agriculture, increases the risk of water deficit (lowering of groundwater tables).

The problem of water deficit resulting from resource overexploitation is further exacerbated by global warming which is likely to increase the variability of precipitation patterns, thereby changing the patterns of water availability on a quantitative, temporal and/or regional basis (UNEP, 2007). Therefore, the upper most level of water management is supposedly the global responsibility for shifts in the water distribution on a worldwide level.

Against this background various studies and approaches have emerged which try to quantify water consumption and the water content of different products. Among these, the concepts of virtual water, virtual water trade, and the water footprint have

gained more and more importance as a strategic instrument in water policy. Virtual water is defined as the volume of water required to produce a commodity or service, and the water footprint of e.g. a country is the total volume of water contained by all the products and services consumed by a country (Chapagain and Hoekstra, 2004).

The main data source for water use for the incorporation in the EXIOPOL data base was identified as the study "Water Footprints of Nations" by UNESCO-IHE Institute for Water Education (Chapagain and Hoekstra, 2004), based widely on the FAO-AQUASTAT database where the water use data are given in yearly average numbers for 5-year periods (e.g. 1999-2003). Country coverage is fairly complete, although some single countries might be missing or contain extrapolated data from previous years.

It is important to note that no data is available for cooling water (which could be attributed to electricity generation) for the EXIOPOL database, the three categories of water use need to be allocated to economic entities of direct use (industries/products; households). While for the agriculture water use this allocation is straightforward, the allocation of domestic water and industrial water is less straightforward and the availability of data restricted.

Concerning the agricultural sectors, it has to be stated that the reported values are retrieved using only parameters referring to climate and crop and soil properties - irrigation patterns are not incorporated. Nonetheless, this concept allows for a direct comparison of the different countries. Hence, this data has been aggregated to NACE/GTAP classification structures of the SUT.

6. Energy

Objective

The objective is to generate energy extensions to the SUT framework describing the physical flow (supply and use) of energy by economic activities (131 industries) and final use categories (households, stock changes, exports etc.). This is based on IEA Energy Statistics.

Typical analytical requirements for energy extensions are:

- Representation of emission-relevant energy use by industries and households, broken down by energy carriers
- Representation of the share of renewable energy use/supply in total energy use/supply
- Providing a breakdown of prominent national-level energy indicators (such as e.g. primary energy supply PES) by economic activities

Definitions/Terminology

Energy Energy is often defined as the capacity to do work. Several different forms of energy, such as kinetic, potential, thermal, electromagnetic, chemical, nuclear, and mass have been defined to explain all known natural phenomena. Energy is converted from one form to another, but it is never created or destroyed. This principle, the conservation of energy, was first postulated in the early 19th century, and applies to any isolated system.

Energy Accounts: Representation of physical energy flows (supply and use) according to the rules/frameworks of National Accounts (SNA/ESA) – SUT scheme

Energy Statistics: Representations of physical energy flows (supply and use) according to the rules/frameworks of IEA/OECD-Eurostat
Energy Statistics comprise two main forms of representation:
(1) Commodity Balances show the supply and use of energy commodities in *natural units* (e.g. tonnes, cubic metres)
(2) Energy Balances present supply and use in *energy units* (mainly Joule)

There are a number of differences in the concepts and definitions as applied by Energy Accounts (SNA/ESA) in comparison to Energy Statistics (IEA/OECD-Eurostat).

Primary data source

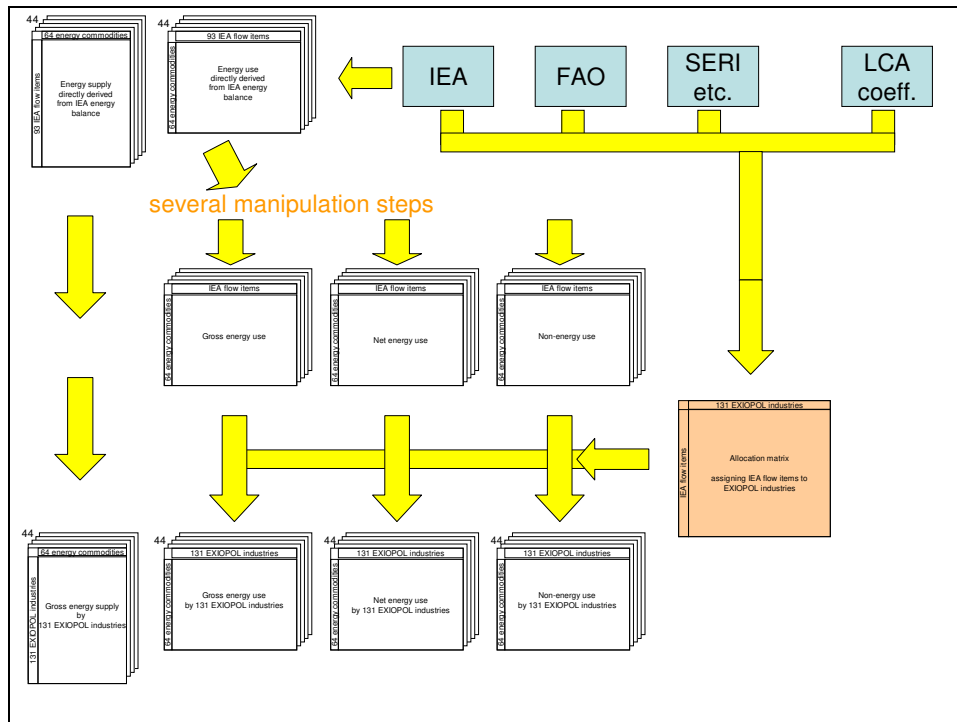
IEA Energy Statistics form the primary data source. The IEA World Energy Statistics CD-ROM (version 2007) provides several data bases of which "extended energy balances" is the type used. The latter is provided for OECD countries (OECDBIG.IVT) and Non-OECD countries (WED_BBAL.IVT) in separate files.

The IEA energy balance is a kind of commodity balance. The balance for each of the 64 energy commodities – i.e. supply, transformation, use – is shown in one single column. The so-called flow-dimension of such a single-column-balance comprises 93 items. Hence, the point of departure is a 93 flow-items by 64 energy commodities matrix.

Transformation procedure

The IEA commodity balances need to be transformed into a format compatible with the conventions of National Accounts and the EXIOPOL framework of Supply- and Use Tables (SUT). The initial IEA 93-by-64 matrix needs to be manipulated so as to derive the supply and use of energy commodities (64) by industries (131 as defined in the EXIOPOL SUT framework). In other words, the 93 flow items need to be assigned to the supply and use by 131 industries.

The following flow chart provides a brief overview of the sequence of transformation steps:



The WI developed a scheme where original IEA energy commodity balances are transformed into supply and use matrices following the EXIOPOL classification of 131 industries/products and categories of final use. The transformation (bridging) from IEA Energy Balances to energy SUTs has been performed in an EXCEL workbook comprising several sheets which are linked together via formulas. A prototype EXCEL workbook has been developed based on the World total data from IEA Energy Balances (version 2007); it has been tested with the four pilot countries as well. This prototype workbook can be used as template for all other countries. A test data set comprising the four pilot countries was finalised by 10 January 2008.

Altogether, nine transformation (bridging) steps have been distinguished and implemented in the EXCEL-workbook template:

Step 1: Loading data from IEA Energy Balances

Step 2: Transformation to Tera Joules (TJ)

Step 3: Separating 'Supply' and 'Use'

Step 4: Distribution of unclear supply/use of energy commodities

Step 5: Splitting 'Combined Heat and Power' (CHP)

Step 6: Replacing 4 IEA items with 6 EXIOPOL items

Step 7: Adjusting (gross) 'Use' from double counting (net use) and separating non-energy use

Step 8: Re-sorting of IEA items (close to NACE)

Step 9: Re-allocation to 131+ NACE/EXIOPOL items

The allocation matrix employed in the last step is of particular importance. It constitutes a country-specific correspondence-key from IEA categories of balance items to the 131 industries and categories of final use as defined in the EXIOPOL SUT-framework.

One particular challenge is the detail of 131 industries. Many IEA items relate to a grouping of many industries as defined in the EXIOPOL-industry-classification namely, agriculture, mining, food manufacturing, mineral products manufacturing, metal industry, and electricity supply. For instance, the IEA flow-item "agriculture/forestry" needs to be distributed over 16 industries as defined in the EXIOPOL-industry-classification.

Therefore, auxiliary data are needed to specify this kind of detailing. Auxiliary data are derived from FAOSTAT, the SERI data on material inputs, UNSTAT and other international data sources. In most cases, these volume data are combined with LCA-coefficients so as to derive specific allocation keys.

Resulting energy extension data

Several types of 'Use' can be distinguished. First one may distinguish between 'energy-use' and 'non-energy-use'. Another distinction relates to double-counting which occurs if all 'Supply' and 'Use' cells are added up, primary and secondary commodities are added up to a 'gross supply' and 'gross use'. This 'gross' sum bears some double-counting of energy because the primary coal as well as the secondary coke are summed together. Hence, a certain amount of the primary energy commodity (which is

incorporated in the secondary commodity) needs to be balanced out in order to arrive at a 'net' sum.

In the end, we obtain 4 types of energy extensions linkable to the SUT framework:

- Supply of energy: 64 energy commodities by 131 industries and several categories of final use
- Gross energy use: 64 energy commodities by 131 industries and several categories of final use
- Net energy use: 64 energy commodities by 131 industries and several categories of final use
- Non-energy use: 64 energy commodities by 131 industries and several categories of final use

Altogether this makes 256 vectors of energy extensions to the SUT framework.

7. Emissions

Objective

The objective is to generate environmental extensions for emissions to the SUT framework describing the physical flow of residuals emitted by economic activities (131 industries) and final use categories (households, stock changes, exports etc.). This is based on an international database set up by TNO which again utilises a number of international primary data sources.

The TNO data base

The TNO data base is a worldwide compilation of air emissions (greenhouse gases and air pollutants). Its basic approach is to calculate emissions based on the methodologies and compilation guidelines as laid down in the context of international conventions.

In general an emission data point is derived by multiplying a certain 'activity' with a specific 'emission coefficient'.

The 'activity' variables are taken from international data sources. Most 'activity' data are related to the use of energy and are taken from the IEA. Other 'activity' variables – such as e.g. number of animals or production volumes of certain products – are taken from other international statistics such as e.g. FAO.

The 'emission coefficients' are derived from international compilation guidelines in combination with country specific assumptions on the state of implementation of abatement technologies.

The TNO emission data base has many dimensions allowing manifold output formats that can be further processed and transformed for the purpose of generating environmental extension vectors linkable to the SUT framework in EXIOPOL.

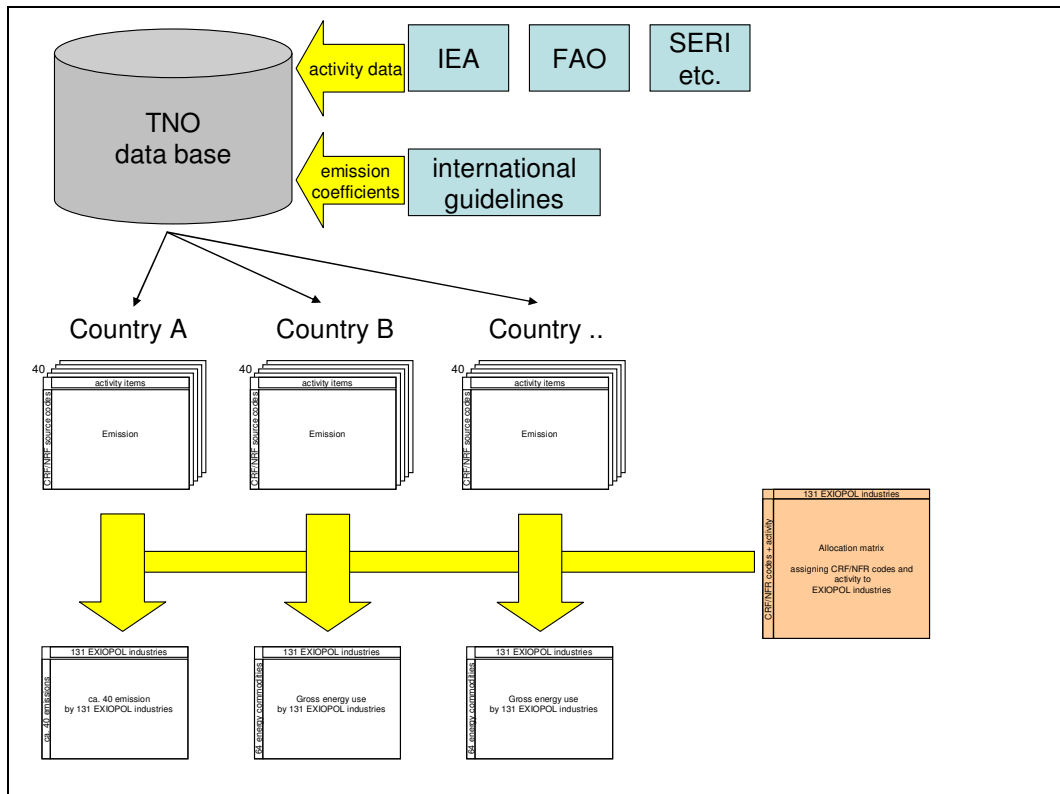
Transformation procedure

The general procedure is to take a certain output-format of the TNO data base and to adjust it to the classification used in the EXIOPOL SUT framework. That is to assign emissions to the 131 industries and final use categories as used in EXIOPOL.

The preferable output-format from the TNO data base is for each country a data set with three dimensions: emission, CRF/NFR-source code, and activity variable (e.g. energy, production volume etc.)

For each emission, a specific allocation matrix would be developed linking the CRF/NFR-code and activity variable to the 131 industries and final use categories as applied in the SUT-framework. As a result, one obtains for each country ca. 40 emission vectors by 131 industries.

The following flow chart provides a brief overview of the sequence of transformation steps:



8. Applications of the EXIOPOL database

The EE I-O work in EXIOPOL is seeking to solve the problem that no integrated EE IOT exists for Europe or the world so far. With its high resolution of 131 sectors and the large number of different environmental extensions it is possible to allocate environmental impacts in a meaningful way to sectors and products. As all national IOT are linked via international trade, these impacts can be traced along international production chains. Hence, the project's aim is to fill an essential gap in the current toolbox of environmental (and economic) accounting at the Commission's services; it is providing the EU with an exhaustive, detailed, transparent, public, global EE IOT with environmental extensions and information about externalities, allowing for numerous types of analyses for policy support.

In the following, we will present an overview in which ways the created EE I-O database can be applied in the future to get an insight in indirect resource requirements and to calculate environmental indicators in a world-wide context, including, among others, indicators on global warming, acidification, nitrification, and indicators on the use of materials, energy, land and water.

Quantification of indirect („embodied“) resource requirements of traded products

As explained above, the EXIOPOL EE IOT contains a large number of environmental extensions in the area of natural resources (material extraction, land use, water consumption), energy and emissions. This allows for the determination of indirect (“embodied”) environmental requirements of internationally traded products, necessary along the whole (international) production chain in order to produce different products and deliver them to the border of the analysed country or region (such as the EU).

Analysis of indirect („embodied“) resource requirements

An analysis of the determined indirect environmental requirements can deliver valuable information on the relations between impacts of

- different product groups and industries/sectors;
- countries of origin (imports) and destination (exports), thus illustrating the environmental dimension of different trade and economic specialisation patterns in the world economy;
- different extension categories (e.g. a specific material, specific emissions (e.g. GHG), etc).

Thereby, the advantage of the high level of disaggregation regarding sectors and extensions can be used to link the quantitative information on indirect resource flows to specific environmental impacts related to their use (e.g. implications for climate change due to fossil fuel use; implications for land use and land cover changes due to biomass extraction, etc.).

Calculation of comprehensive environmental indicators

Due to a complete balancing of the environmental performance of a country, including domestic resource use and emissions on the one hand and imports and exports and related indirect resource requirements on the other hand, comprehensive environmental indicators on the national level can be calculated. The EXIOPOL EE IO database thus

allows filling existing data gaps regarding the inclusion of international trade in national environmental indicators.

Indicators calculated with the EXIOPOL database can therefore confront indicators based on the production principle (i.e. environmental pressures and impacts are allocated to the sector and country, where they physically occur) with indicators based on the consumption principle (i.e. environmental pressures and impacts are allocated to the sector and country, where the final consumption of products takes place). The EXIOPOL database can therefore provide a key data source for further development of national environmental inventories, for example, in the light of the Post-Kyoto discussion (see, for example, Peters, 2008) .

Also comprehensive indicators of resource productivity can be calculated by combining resource use data with GDP data or data on sectoral value added. Thereby, resource productivity of a country or sector is not only expressed related to direct resource use, but including all up-stream resource requirements necessary to produce imported (and exported) products. Full consideration of international trade is essential to reflect outsourcing of environmental-intensive stages to other countries in national resource productivity indicators.

Analysis of international production chains and structural paths

Using the EXIOPOL EE IOT it is possible to analyse specific international production chains with particular importance for the country or sector of interest. This type of analysis can illustrate the number of processing steps, their geographical distribution and estimations of the transport intensity. The application of the method of „structural path analysis“ (for example, Peters and Hertwich, 2006) allows determining those chains of inter-industry deliveries, which contribute most to resource consumption and consequently to emissions of a country or sector.

Beyond the EXIOPOL project

Some applications will not be directly feasible based on the EXIOPOL database, but are of key interest for further development and extension.

- Analysis of historical trends

The EXIOPOL database will in its full first edition only comprise data for the year 2000. However, not only in the context of the Commission's aim to decouple economic growth from resource use and negative environmental impacts (compare the Thematic Strategy on the Sustainable Use of Natural Resources, European Commission, 2005) it is of great importance to dispose of a comprehensive environmentally extended IOT which not only comprises data of one year but time series of the largest possible extend. By expanding the EE IOT in this way, it would be possible to carry out analyses of interrelations between economic growth, structural changes, international trade and the distribution of environmental pressures in different world regions over time. Thereby, empirical background for debates such as the pollution haven hypothesis and the Environmental Kuznets Curve (EKC) could be provided. In the framework of the Post-Kyoto negotiations, these types of analyses could also illustrate to what extent industrialized countries have outsourced the physical basis of their economies to other world regions and which share of the total GHG emissions related to national consumption occur in other parts of the world.

- Modelling of future scenarios

The EXIOPOL database could also be linked to forecasting and simulations models (such as Duchin, 2005; Meyer et al., 2007). These models enable generating data on possible future developments of international trade, structural change and related environmental pressures and impacts (for example, material extraction or GHG emissions in different countries and world regions). These data can then be fed back into the EE IOT to calculate embodied environmental factors of trade and thus scenarios simulated with these forecasting tools could also be evaluated with regard to future global distribution of environmental pressures.

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10. Annexes

Annex 1: Procedures to close data gaps in the BGS data series (starting in the year 1986)

- For small gaps the value of a neighbouring year was used, or a value was interpolated between two points in time.
- If data before 1986 existed in the old data base of the MOSUS project, these data were used to fill the gap 1980-1985 of the new BGS data. Only in the case that differences were considerable, the trend of the former data was used for an interpolation of the 1986 value into the 1980-1985 gaps.
- Where no data existed in the old data base before 1986, the 1986 value was copied into the 1980-1985 gaps. Similarly, if the BGS data series ended before 2005 the last value was used to fill the gaps.
- In some cases data series of BGS do not appear coherent. Here, the WMD data was used and updated until 2005 – where no actual WMD data exist, the last value was copied.
- In some cases only a few data points of a whole series exist. If former data existed, the new data was only used to fill gaps, or to check the magnitude of the values. Otherwise, the new data was used and, if possible and justifiable, gaps plausibly interpolated.
- For some minerals or metals it seemed more appropriate to use WMD data, as the BGS commented difficulties in the data collection.

Annex 2: Sources for information on metal grades and overburden in metal and mineral mining

German Federal Geological Institute (www.bgr.de)

- Rohstoffwirtschaftliche Länderstudien (Raw material country studies), covering the following countries: Russia, Ukraine, Turkmenistan, Belarus, Kazakhstan, Turkmenistan, Uzbekistan, Tajikistan, Kyrgyzstan, Bulgaria, Estonia, Latvia, Lithuania, Poland, Rumania, Slovakia, Slovenia, Czech Republic, Hungary, Albania, Bosnia-Herzegovina, Yugoslavia, Croatia, Macedonia, Rumania, Brazil, Argentina, Mexico, Mongolia, China, Zimbabwe, Ethiopia, Mozambique, and New Zealand.
- Geologisches Jahrbuch – Sonderhefte zu ausgewählten Rohstoffen (Geological yearbook – special issues on selected raw materials), covering the following raw materials: iron, copper, aluminium, nickel, manganese, chromium, phosphate (and hard coal).
- Untersuchungen über Angebot und Nachfrage mineralischer Rohstoffe (Studies on supply and demand of mineral raw materials), covering the following raw materials: potash, lithium, niobium, tantalum, bauxite, zinc, molybdenum, tungsten, cobalt, vanadium, asbestos, germanium, indium, selenium, tellurium, zirconium, chromites, dolomite, diatomite, magnetite, quartzite, andalusite, and vermiculite.

US Geological Survey (www.usgs.gov)

- Country reports: country reports are available for download almost all countries world-wide.
- Personal communications with USGS experts

Wuppertal Institute for Climate, Environment and Energy (www.wupperinst.org)

- Technical report for study "Total Material Requirement" of the EU-15" (Bringezu and Schütz, 2001b)
- Technical details of national MFA (Inputside) for Germany (Schütz, 1999)

Annex 3: Commodity allocation Industrial/Construction Minerals

Industrial Minerals	Construction Minerals
Abrasives, natural (puzzolan, pumice, volcanic cinder etc.)	Asphalt
Amber	Chert and flint
Asbestos	Common clay, clay for bricks etc.
Ball clay	Igneous rock (basalt, basaltic lava, diabase, granite, porphyry, sandstone etc.)
Barite	Ingeneous rock (basalt, basaltic lava, diabase, granite, porphyry, sandstone etc.)
Bentonite, sepiolite and attapulgite	Lavasand
Boiled salt	Limestone
Borate minerals	Loam
Calcite	Marble, travertines etc.
Chalk	Sand and gravel
Diamonds, gems	Sandstone
Diamonds, industrial	Slate (incl. roof slate)
Diatomite	Slate including fill (incl. roof slate)
Dolomite	Turfaceous rock
Feldspar	Construction Minerals nec
Fire, refractory and flint clay, Andalusite, kyanite and sillimanite (all Al-containing)	
Fluorspar	
From brine	
Fuller's earth	
Gluesand	
Graphite, natural	
Gypsum and anhydrite	
In brine, sold or used as such	
Industrial sand	
Iron pyrites	
Kaolin	
Magnesite	
Mica	
Ochre and pigment earths	
Peat for agricultural use	
Pegmatite sand	
Perlite	
Phosphate rock (natural phosphates)	
Potash	
Potter clay	
Qartz and quartzite	
Rock salt	

(Style "Heading")

Siliceous earth	
Silica sand (quartzsand)	
Slate clay	
Solar salt	
Special clay	
Strontium minerals	
Sulphur	
Sulphur as a by-product of natural gas etc.	
Sulphur from pyrites	
Talc (steatite, soapstone, pyrophyllite)	
Talcous slate	

Annex 4: Unused extraction: description of data sources and calculation methods

Fossil fuels

The following were the most important data sources for UDE factors for fossil fuels:

- Hard coal: in the special issue on hard coal of the geological yearbook (Hinrichs, 1999), the German Federal Geological Institute reports a number of country-specific factors for overburden in hard coal mining. In addition, the publications on total material requirement of the European Union prepared by the Wuppertal Institute in Germany (Bringezu and Schütz, 2001aa, 2001bb) provide numbers on UDE factors for hard coal in selected countries. If no country-specific data was available, the average factor of 0,89 tons of overburden per ton of hard coal was applied (factor taken from Bringezu and Schütz, 2001b).
- Brown coal / lignite: data on country-specific UDE factors for brown coal were taken from Bringezu and Schütz (2001bb). If no country-specific data was available, the average factor of 3,2 tons of overburden per ton of brown coal was applied (taken from the same publication).
- Crude oil: For crude oil, only one average global factor of 0,17 tons of UDE per ton of crude oil was found in the literature (Bringezu and Schütz, 2001a).
- Natural gas: in the Wuppertal publications on TMR of EU-15, several country-specific UDE factors are reported. One important source is Survey of Energy Resources by the World Energy Council (1992). If no country-specific data was available, an average factor of 0,2 tons of unused extraction per ton of natural gas was applied (Bringezu and Schütz, 2001b).

No overburden can be observed in the extraction of peat for energetic uses.

Metal ores

For UDE factors of metal ores, we used the same literature sources as described for metal ore concentrations (see also Annex II), from which a large number of country-

specific UDE factors could be extracted. If no country-specific information was available, we applied factors from neighbouring countries or continental average factors. Only if no continental information was reported, global average numbers were used.

Industrial minerals

Country-specific data on UDE factors for industrial minerals were only available for Germany and the UK, extracted from several publications of the Wuppertal Institute (Bringezu and Schütz, 2001a; 2001bb; Klinnert, 1993).

For all other countries, global average numbers were applied based on the same publications from Bringezu and Schütz.

Construction minerals

Most important data sources for UDE factors of construction minerals were the TMR studies for the EU-15 by Bringezu and Schütz (2001aa); (2001bb) and a material flow study on the European level by Mündl and Scharnagl (1998).

If no UDE factor was found in the literature, a minimum estimation of 0,05 tons UDE per ton of used construction mineral was applied.

Biomass

As stated above, UDE factors for agriculture, forestry and fishery were derived from a literature survey and all UDE factors applied in MOSUS are summarised in a separate publication (Jölli and Giljum, 2005).

In most material flow studies published so far, the category of unused biomass extractions was disregarded or calculated based on a small number of estimated factors. However, amounts of unused biomass extractions are huge and have to be considered, if the total material extraction of a national economy is assessed. Due to the fact that this issue has only recently gained more attention, only a few publications exist so far which report amounts of residues of agricultural, forestry and fishery activities.

Due to data restrictions, we were only able to provide one set of UDE factors, which we applied to all countries. Clearly, this can only give a very rough estimation of overall UDE in biomass categories, as differences in unused extraction due to different forms of cultivation, differences between social conditions of countries (which are important with regard to use and reuse of biomass residues) and differences in climate and vegetation could not be taken into account.

Agriculture

Unused biomass from agriculture can be divided into two categories: (1) parts of the plant which are retained to the field and (2) losses of parts of the plant due to harvest methods. In MOSUS, we only dealt with the first category of unused extractions of agriculture, as the second one can in general be disregarded due to small amounts of UDE. However, not all residues from agriculture are unused extractions, as unused biomass extractions are reused for a number of purposes, including energy production (biogas), forage and bio-fuels. This share has to be excluded from the calculations, as it enters the economic system for further use (see, for example, the chapter on by-products of harvest above).

For cereals, data for the ratio of the weight of the harvested product to the weight of total biomass extraction was taken from the MFA handbook by EUROSTAT (Weisz et al., 2007b), which is estimated as 1 for all cereal categories except maize (1,4).

For all other categories, data on ratios were taken from biomass energy flow accounts by Hemstock and Hall (1995) and Amoo-Gottfried and Hall (1999). Information on unused shares of residues was taken from Di Blasi et al. (1997).

Forestry

In the course our search of sources for UDE factors in forestry, we found three main studies calculating forestry residues, focusing on different countries and different years. The first study deals with the US (McKeever and Falk, 2004), the second with China (Cuiping et al., 2004) and the third study (Koopmans and Koppejan, 1997) summarises data from several sources. While the share of woody residues is quite similar in all three

publications, the results for the use of residues for other economic purposes, depending to a large extent on environmental, economic and social factors, differ considerably (between 10% and 35%).

For all country data sheets in the MOSUS project, we calculated with an average factor of 30% woody residues in total roundwood production, of which 35% were assumed to be unused.

Fishery

With regard to UDE from fishery activities, only one reliable source was identified; a study by the FAO (1994), assessing fisheries by-catch and discards on a global scale.

For marine fish, an average of 19,8 tons of every 100 tons are discarded catch (and only 80,2 tons are used catch). The discarded mortality rate of marine fishes is about 98%, i.e. 98% of the fishes which are retained to the sea do not survive due to catch, handling, etc. Consequently, the average coefficient to calculate unused marine fishes from data on used catches is 0,242.

No data were found with regard to inland fish catch. Therefore, as a first approximation, the same factor as for marine fishes was applied.

The category of "other fisheries" contains a number of very heterogeneous species: cephalopods, molluscs, sharks and marine mammals like whales, seals and other mammals, sea birds and sea turtles. Due to these differences and the lack of data we found no possibility to calculate an aggregated UDE coefficient for this category.