CREEA - Compiling and Refining Environmental and Economic Accounts

Report D7.2

Update EXIOBASE with WP3-6 input

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CREEA is a Collaborative project funded by the EU's
Seventh Framework Program – Theme ENV.2010.4.2.2-1
Grant agreement no: 265134

Deliverable number:	**D7.2**
Revision number:	**1.0**
Date of current draft:	**30 June 2013**
Due date of deliverable:	**M 24 (31 March 2013)**
Actual submission date:	**30 June 2013**
Dissemination level:	**PU**

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Grant agreement no: 265134
Start date of the project: 1 April 2011, Duration: 36 Months

About CREEA

The main goal of CREEA is to refine and elaborate economic and environmental accounting principles as discussed in the London Group and consolidated in the future SEEA 2012, to test them in practical data gathering, to troubleshoot and refine approaches, and show added value of having such harmonized data available via case studies. This will be done in priority areas mentioned in the call, i.e. waste and resources, water, forest and climate change / Kyoto accounting. In this, the project will include work and experiences from major previous projects focused on developing harmonized data sets for integrated economic and environmental accounting (most notably EXIOPOL, FORWAST and a series of Eurostat projects in Environmental Accounting). Most data gathered in CREEA will be consolidated in the form of Environmentally Extended Supply and Use tables (EE SUT) and update and expand the EXIOPOL database. In this way, CREEA will produce a global Multi-Regional EE SUT with a unique detail of 130 sectors and products, 30 emissions, 80 resources, and 43 countries plus a rest of world. A unique contribution of CREEA is that also SUT in physical terms will be created. Partners are:

1. Nederlandse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek (TNO), Netherlands (co-ordinator)
2. JRC -Joint Research Centre- European Commission (DG JRC IPTS), Belgium /Spain
3. Universiteit Leiden (Unileiden), Netherlands
4. Centraal Bureau voor de Statistiek (CBS), Netherlands
5. Norges Teknisk-Naturvitenskapelige Universitet (NTNU), Norway
6. Statistiska Centralbyran (SCB), Sweden
7. Universiteit Twente (TU Twente), Netherlands
8. Eidgenössische Technische Hochschule Zürich (ETH) Switzerland
9. 2.-0 LCA Consultants Aps (2.-0 LCA), Denmark
10. Wuppertal Institut Fur Klima, Umwelt, Energie Gmbh. (WI), Germany
11. SERI - Nachhaltigkeitsforschungs Und –Kommunikations Gmbh (SERI) Austria
12. European Forest Institute (EFI), Finland / Spain

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Executive Summary

This report covers the preparation of harmonized MR MSUT tables including labour and environmental extensions (WP7). The report covers the full data processing from preparation of source data to producing final MR EE SUT tables. The main goal of the development of the EXIOBASE database within CREEA is to operationalize the economic and environmental accounting principles as discussed in the London Group and consolidated in the future SEEA 2012. The focus is on practicalities of implementing SEEA guidelines with respect to data gathering, the refinement of approaches for allocating supply-chain impacts, and the demonstration of global impacts across the production-consumption perspectives. Most data gathered in CREEA will be consolidated in the form of Environmentally Extended Supply and Use tables (EE SUT). The work of WP 7 is to integrate the outputs on the environmental extensions of WP3-6 with a harmonized, trade-balanced and disaggregated system of Supply and Use Tables, in a global context. This thus provides a basis for later MRIO analysis. This document describes the process of arriving at such an integrated database. Whilst deliverable 7.1 described only as far as the economic component concerns (i.e. construction of an MR MSUT), this deliverable (Task 7.2) also includes description of how the full database including production of environmental extensions is undertaken. As most environmental extensions were produced under methodologies explored in WP3-6, only the summary of data taken into EXIOBASE is included here. Further reading of the WP3-6 deliverables give full details on methodologies. As the land use data was produced wholly in WP7, an annex is given to this report with the full documentation of the land use construction.

Aspects addressed in this report that push forward the state of the art in the field of MRIO include: Increased country detail; increased product/industry detail; Rectangular instead of square (EE) SUT; Expanding Monetary SUT to Physical SUT(the latter described in WP4). In CREEA SUTs are used as the basic building blocks for the database. Significant auxiliary data was utilized in the creation of a harmonized and disaggregated MRSUT. The summary of the steps towards making a full MRIO system for CREEA is as follows: Harmonizing and detailing SUT; Harmonizing and estimating extensions; Linking the country SUT via trade; Importing all data in EXIOBASE.

1 Introduction

The main goal of the development of the EXIOBASE database within CREEA is to operationalize the economic and environmental accounting principles as discussed in the London Group and consolidated in the future SEEA 2012. The focus is on practicalities of implementing SEEA guidelines with respect to data gathering, the refinement of approaches for allocating supply-chain impacts, and the demonstration of global impacts across the production-consumption perspectives. Most data gathered in CREEA will be consolidated in the form of Environmentally Extended Supply and Use tables (EE SUT). The work of WP 7 is to integrate the outputs on the environmental extensions of WP3-6 with a harmonized, trade-balanced and disaggregated system of Supply and Use Tables, in a global context. This thus provides a basis for later MRIO analysis. This document describes the process of arriving at such an integrated database (i.e. construction of an MR EE SUT).

1.1 Backgrounds on EE SUT and IOT

Multi-regional input-output (MRIO) analysis has come a long way in the last decade (Tukker and Dietzenbacher 2013). Whilst MRIO at the global scale started with exploration in the early 2000's (Munksgaard and Pedersen 2001; Lenzen, Pade, and Munksgaard 2004), the use of it for addressing issues of carbon leakage related to limiting greenhouse gas emissions (Hertwich and Peters 2009; Peters 2008; Davis and Caldeira 2010) has advanced development significantly. Now a considerable number of environmental issues congruent with "footprint" approaches use MRIO in order to fully account for life-cycle impacts of consumption (Lenzen et al. 2012; Ewing et al. 2012; Wiedmann et al. 2011; Daniels, Lenzen, and Kenway 2011; Tukker et al. 2013).

The input-output framework as exemplified by the European System of Accounts (ESA95) consists of three types of table: supply and use tables (SUT) and symmetric input-output tables (IOT)(European Communities 1996; compare UN, 1993 and UN et al.,2003).

The supply table shows the supply of goods and services, both domestic and imported, by product and type of supplier in basic prices, while the use table shows the use of goods and services by product and type of use in purchase prices, i.e. as intermediate consumption by industries, final use (consumption, gross capital formation) and exports. The use table also contains the components of the value added by industry, i.e. compensation of employees, other taxes less subsidies on production and gross

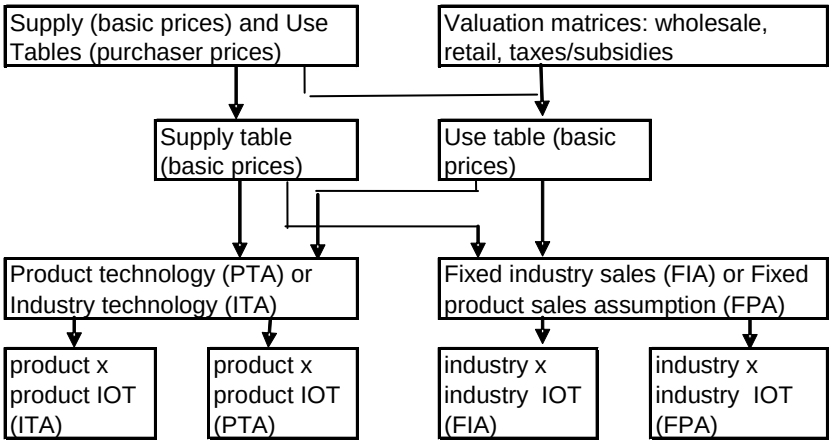

Figure 1.1: Simplified input-output framework (modified from Rueda-Cantuche et al., 2007)

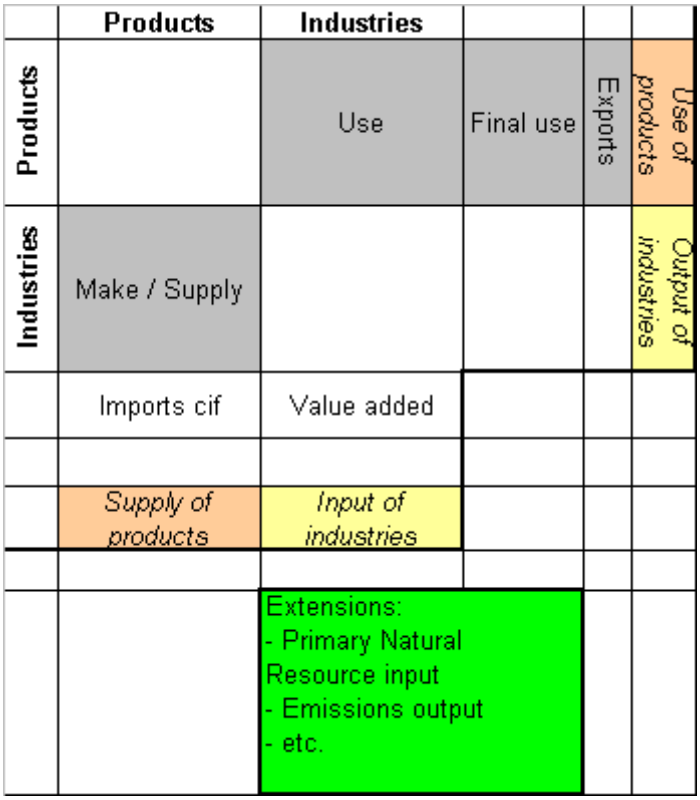

Figure 1.2: Schematic SUT with environmental extensions

operating surplus. The use table can be converted to basic prices with the help of valuation matrices reflecting retail, wholesale and taxes/subsidies per product used per industry. If necessary, the SUT can be broken down into a domestic and import (use) and an export (supply) part.

Most analytical applications and models used (e.g. CGE) are based on IOTs rather than SUT (for an exception, see e.g. ten Raa and Rueda Cantuche 2007b). Using various assumptions about technology, IOTs can be derived from the SUT in basic prices. The tables can be of a product by product type or an industry by industry type (see figure 1.1). Box 1.1 gives an example of how IOT can be constructed from SUT. We further refer to references such as Miller and Blair (1985), Ten Raa, (2005) and Eurostat, 2008b, as well as Ten Raa and Rueda-Cantuche (2003 and 2007a).

SUT and IOT can be expanded with satellite accounts to indicate an industry's resource inputs from and emission outputs to the environment (see figure 1.2.)

Box 1.1: Mathematical formulation of the industry technology assumption (Model B)

Adapted from *Eurostat Manual of Supply, Use and Input-Output Tables*

In the case of the industry technology, the transformation matrix is:

$T = (diag(g))^{-1} V$

Hence intermediates, value added and environmental extensions of the product-by-product input-output table are:

$S = UT$

$S^W = WT$

$S^R = RT$

Input coefficient matrices can be derived from those by dividing the columns by the total domestic output of products.

$A = S(diag(q-m))^{-1} = U(diag(g))^{-1} V(diag(q-m))^{-1}$

$A^w = S^W (diag(q-m))^{-1} = W(diag(g))^{-1} V(diag(q-m))^{-1}$

$A^R = S^R(diag(q-m))^{-1} = R(diag(g))^{-1} V(diag(q-m))^{-1}$

Note that Fig. 1.2 shows an EE SUT for a single country. This leads to the problem of how to deal with imports and exports. In some cases, apparent decoupling of CO_2 emissions or primary material use from GDP growth is in fact the result of the relocation of material and energy-intensive production to other countries (Giljum et al., 2008b; Wiedmann et al., 2008). Practitioners have sought to resolve this problem by using a multi-regional approach, in which different country EE SUT or EE IOT are linked via trade to a multi-regional SUT or IOT with environmental extensions (MR EE SUT or MR EE IOT). Figure 1.3 visualizes an MR EE SUT.

		Industries				$Y_{*,A}$	$Y_{*,B}$	$Y_{*,C}$	$Y_{*,D}$	q
Products		$Z_{A,A}$	$Z_{A,B}$	$Z_{A,C}$	$Z_{A,D}$	$Y_{A,A}$	$Y_{A,B}$	$Y_{A,C}$	$Y_{A,D}$	q_A
		$Z_{B,A}$	$Z_{B,B}$	$Z_{B,C}$	$Z_{B,D}$	$Y_{B,A}$	$Y_{B,B}$	$Y_{B,C}$	$Y_{B,D}$	q_D
		$Z_{C,A}$	$Z_{C,B}$	$Z_{C,C}$	$Z_{C,D}$	$Y_{C,A}$	$Y_{C,B}$	$Y_{C,C}$	$Y_{C,D}$	q_C
		$Z_{D,A}$	$Z_{D,B}$	$Z_{D,C}$	$Z_{D,D}$	$Y_{D,A}$	$Y_{D,B}$	$Y_{D,C}$	$Y_{D,D}$	q_D
W		W_A	W_B	W_C	W_D					
g		g_A	g_B	g_C	g_D					
C & L		$Capital_A$	C_B	C_C	C_D					
		$Labor_A$	L_B	L_C	L_D					
Environ Ext		$NAMEA_A$	$NAMEA_B$	$NAMEA_C$	$NAMEA_D$					
		$Agric_A$	$Agric_B$	$Agric_C$	$Agric_D$					
		$Energy_A$	$Energy_B$	$Energy_C$	$Energy_D$					
		$Metal_A$	$Metal_B$	$Metal_C$	$Metal_D$					
		$Mineral_A$	$Mineral_B$	$Mineral_C$	$Mineral_D$					
		$Land_A$	$Land_B$	$Land_C$	$Land_D$					

Figure 1.3: Example of a MR EE SUT for 4 countries

1.2 Overview of MR EE SUT and MR EE IOT developed in CREEA

In CREEA SUTs are used as the basic building blocks for the database. Using SUTs as basis for building up an IO framework accommodates both flexibility of modelling in terms of both products as well as industries; whilst keeping tractability of data – which is usually collected for supply and use of products, by industries or activities. As such, modelling and data inventory can be kept separate.

There are several caveats to use SUTs as basic building blocks for the IO database, though. The supply of products is published in basic prices, whilst the use of products is published in purchasers' prices. In order to produce an IOT, both tables need to be in the same valuation. For this reason, valuation matrices giving taxes less subsidies and trade- and transport margins are needed to convert the use table from purchasers' prices into basic prices. Once the basic SUTs are in the right prices, transformations to the desired IOT via one of the common technology assumptions (i.e. industry technology, commodity technology, fixed industry sales structure, or fixed product sales structure assumption) is straightforward (Box 1.1).

To provide the environmental detail desired in the EXIOBASE model and to maintain consistency across nations included in the dataset we use a standard set of industries and products. The sectoral structure of the EXIOPOL database loosely follows the NACE revision 1.1 industry classifications or CPA product classification. All sectors present in the standardized Eurostat tables are also present in the EXIOBASE database. In addition, details have been added to sectors of particular importance to SEEA. The following are categories of industries for which additional details are provided in EXIOBASE:

a) Agriculture and food
b) Mining and raw materials
c) Energy intensive metals production
d) Electricity
e) Transport
f) Re-processing of secondary material
g) Waste

Furthermore, significant extra detail is provided on energy products in a first step to harmonizing MRIO work with the IEA energy balances.

1.2.1 MRIO Advances

Aspects addressed in CREEA that push forward the state of the art

1. **Increased country detail**. EXIOBASE 1.0 contains 43 countries and a Rest of World. The world has over 200 countries, whereas in future for analytical purposes it could be helpful to split the bigger countries in regions. Computational limitations have previously prevented highly detailed models being operational. With advances in computational power, there is less reason to aggregate trading partners. The implication is that CREEA now includes 5 regions to describe the rest of the rest of the world, disaggregating by continental aggregates the one region of EXIOBASE 1.0. This provides a compromise for explicitly separating out different regional production practices, whilst not overloading the model with data.
2. **Increased product/industry detail**. To harmonise with the material balances of waste accounts being derived elsewhere in the project, additional detail was put into both the product and industry classification, resulting in some 200 products and 163 industries. In addition, previously artificially split processes such as refining were aggregated.
3. **Rectangular instead of square (EE) SUT**. An implication of point 2 is that we now work with a rectangular instead of square (EE) SUT. Again, EXIOBASE is fully flexible with regard to product/sector structures by country, trade linking is done via products and hence not influenced by the fact if the SUT is square or rectangular. The final transformation to IOT can then be programmed to handle rectangular SUT.
4. **Expanding Monetary SUT to Physical SUT**. An exercise undertaken in the physical accounting of this project is to expand the monetary SUT to physical SUT. The result is to express all product flows also in mass terms (dry weight). This implies that from a product perspective, the mass balance principle Supply = Use will hold. CREEA also requires a consistent mass balance from an industry perspective (i.e. by industry the Supply of products + Outputs to Nature = Use of products + Inputs from Nature).

The last point, whilst integral to the design of work flows in WP7 is not covered here, as it forms the major work effort of WP4.

1.2.2 EXIIOBASE Work flow summary

The summary of the steps towards making a full MRIO system for CREEA is as follows:

1. **Harmonizing and detailing SUT**
    a. Gathering SUT from the EU27 via Eurostat, and other SUT and IOT from 16 other countries (covering in total 90% of the global GDP).
    b. Harmonizing and detailing SUT with auxiliary data from FAO and a European AgriSAMS for agriculture, the IEA database for energy carriers and electricity, various resource databases for resources, etc.
2. **Harmonizing and estimating extensions (described in D7.2)**
    a. Allocating available resource extraction data (e.g. FAOSTAT, Aquastat) to industry sectors
    b. Allocating the International Energy Agency database for 60 energy carriers to sectors of use. Estimating emissions on the basis of energy and other activity data and TNOs TEAM model
3. **Linking the country SUT via trade**
    a. Splitting of Import Use tables and allocating imports to countries of exports using UN COMTRADE trade shares
    b. Confronting the resulting implicit exports with exports in the SUT, adjusting differences and rebalancing.
4. **Estimation and allocation of environmental extensions**
    a. Water, Material, Land, Emissions extensions are estimated by various groups and allocated to the industry classification of EXIOBASE.
5. **Importing all data in EXIOBASE**

    Exiobase, developed by CML, is a specially constructed database system with extensive reporting on errors and inconsistencies allowing for iterative improvement of the database.

1.3 Scope of this report

This report covers the preparation of harmonized MR MSUT tables including labour and environmental extensions. The physical SUT and energy SUT layers are documented in other work package reports. Other environmental extensions include material extraction, land use, water use, water emissions and air emissions. Detailed documentation of material extraction, water use and emissions and air emissions are reported in other work package reports. This report hence describes the addition of extensions on the basis of deliverables from WP3-6, and the land use documentation is included as a separate annex.

2 MSUT Data Flow

CREEA follows the approach in EXIOPOL of utilising the individual country SUTs as benchmark data to which all other data is reconciled to. Exceptions to this only occur where there is necessary work on harmonisation of the tables (See section 4.1). Behind the aggregate SUTs, the general data flow is designed to maximise use of high quality auxiliary data in the disaggregation of the aggregate MSUT. As per EXIOPOL, no changes were made to the aggregate MSUT unless obvious errors were encountered (negatives in the wrong place, totals not adding up. These are reviewed in Section 3). As such, auxiliary data was chosen in order to help disaggregate the MSUT to an environmentally important industry classification, to increase consistency with the ESUT, and to allow for the harmonisation of the PSUT.

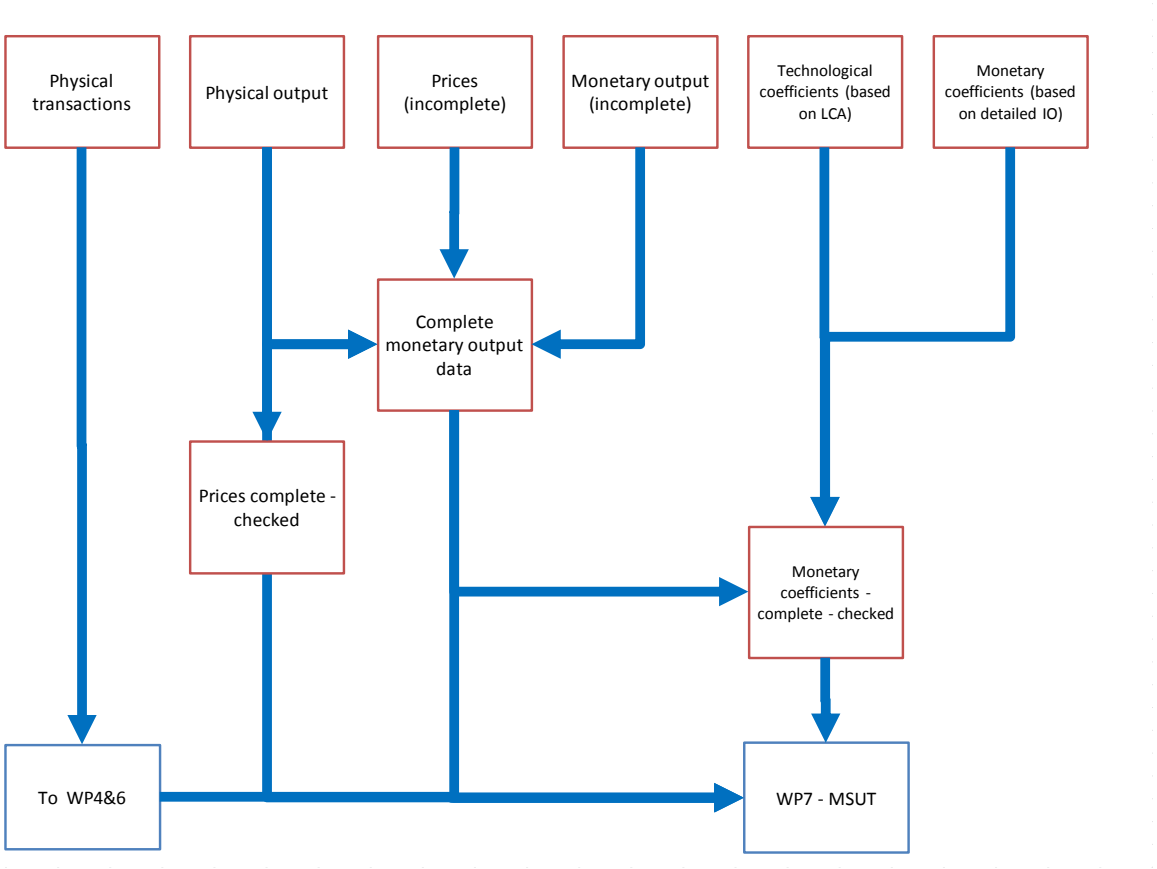

Figure 2.1: Data flow in CREEA

One challenge of the work is the large lack of consistency in source data. Even large international databases show big structural differences in them. This is complicated by the choice of maintaining connection to aggregate MSUT – which themselves embody errors. The benefit that we have in working with a full global MR SUT is that by definition, all flows must balance. Hence we are generally always working on improving source data, rather than being hamstrung by it.

The general approach integrates as much monetary data on production values in either product or industry classification as possible with physical and price data. This production data is then coupled with coefficient data in order to give first estimates on expected product-industry flows in each country. This estimate along with coefficient data from AgroSAMs and flow data from the IEA is then used to do a prior splitting of the aggregate MSUT data. The splitting is done at the cell by cell level, meaning that production balances across supply, use and auxiliary data are no longer met. This discrepancy, at least between supply and use is then resolved through mathematical programming.

3 MSUT Data sources

3.1 Aggregate MSUT

Data description

In the following table detailed information about data availability on systems of monetary supply and use tables is presented. The column of notes is mostly concerned with data on various valuation layers, but other important points could also be mentioned there. For a number of countries (China, Indonesia, India, Japan and South Korea) a lot of manual changes of original data were required, and, therefore, the description of the carried out transformation is given after the table.

All the original data, which was originally in national currency and/or for a year other than 2007, was scaled to the required year using GDP growth and converted into millions of Euros prior to disaggregation procedure.

Countries	Available raw data	Notes
EU-27		
Austria	Supply and use in purchasers' prices till 2007 in Euros (Eurostat); valuation layers of net taxes and total margins, use in basic prices for year 2006 (eeSUIOT project)	Valuation layers were provided by Isabelle Rémond-Tiedrez (Eurostat) only for confidential use
Belgium	Supply and use in purchasers' prices till 2007 in Euros (Eurostat); valuation layers of net taxes and total margins, use in basic prices for year 2004 (eeSUIOT project)	Valuation layers were provided by Isabelle Rémond-Tiedrez (Eurostat) only for confidential use
Bulgaria	Supply and use in purchasers' prices till 2005 in national currency (Eurostat); valuation layers of net taxes and total margins for year 2003 (eeSUIOT project)	Valuation layers were provided by Isabelle Rémond-Tiedrez (Eurostat) only for confidential use
Cyprus	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Italy are taken as proxy
Czech Republic	Supply and use in purchasers' prices till 2007 in national currency (Eurostat); use in basic prices for year 2007 (eeSUIOT project)	Use in basic prices was provided by Isabelle Rémond-Tiedrez (Eurostat) only for confidential use; for valuation layers rates of Romania are taken as proxy
Germany	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Austria are taken as proxy

Countries	Available raw data	Notes
Denmark	Supply and use in purchasers' prices till 2007 in Euros (Eurostat); valuation layers of net taxes and total margins, use in basic prices for year 2007 (eeSUIOT project)	In use table for 2007 there are negatives in the intermediate part, so for now year 2006 is used
Estonia	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Romania are taken as proxy
Spain	Supply and use in purchasers' prices till 2007 in Euros (Eurostat); use in basic prices for year 2006 (eeSUIOT project)	Use in basic prices was provided by Isabelle Rémond-Tiedrez (Eurostat) only for confidential use; for valuation layers rates of Italy are taken as proxy
Finland	Supply and use in purchasers' prices till 2007 in Euros (Eurostat); valuation layers of net taxes and total margins, use in basic prices for year 2006 (eeSUIOT project)	Valuation layers were provided by Isabelle Rémond-Tiedrez (Eurostat) only for confidential use
France	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Austria are taken as proxy
Greece	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Italy are taken as proxy
Hungary	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Romania are taken as proxy
Ireland	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Denmark are taken as proxy
Italy	Supply and use in purchasers' prices till 2007 in Euros (Eurostat); valuation layers of net taxes and total margins, use in basic prices for year 2007 (eeSUIOT project)	Valuation layers were provided by Isabelle Rémond-Tiedrez (Eurostat) only for confidential use
Lithuania	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Romania are taken as proxy
Luxembourg	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Austria are taken as proxy
Latvia	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Romania are taken as proxy
Malta	Supply and use in purchasers' prices till 2004 in Euros (Eurostat)	For valuation layers rates of Romania are taken as proxy

Countries	Available raw data	Notes
Netherlands	Supply and use in purchasers' prices till 2007 in Euros (Eurostat); valuation layers of net taxes and total margins, use in basic prices for year 2007 (eeSUIOT project)	Valuation layers were provided by Isabelle Rémond-Tiedrez (Eurostat) only for confidential use
Poland	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Romania are taken as proxy
Portugal	Supply and use in purchasers' prices till 2006 in Euros (Eurostat)	For valuation layers rates of Italy are taken as proxy
Romania	Supply and use in purchasers' prices till 2007 in national currency (Eurostat); valuation layers of net taxes and total margins for year 2005 (eeSUIOT project)	Valuation layers were provided by Isabelle Rémond-Tiedrez (Eurostat) only for confidential use
Sweden	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Finland are taken as proxy
Slovenia	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Romania are taken as proxy
Slovakia	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Romania are taken as proxy
United Kingdom	Supply and use in purchasers' prices till 2007 in Euros (Eurostat)	For valuation layers rates of Denmark are taken as proxy
Non EU-27		
Australia	For 2006-07 year in national currency: supply, total use in basic prices, use of imported products in basic prices, valuation layers of taxes and subsidies (4 types), trade margins (2 types), transport margins (6 types) and other margins (4 types) (ABS)	In the use table data was missing (n.p.) for the sector Water, Pipelines and Other Transport and the sector Air and Space Transport in the final demand categories. Also the concerning rows/columns didn't add up to the total. The missing amounts were estimated to achieve balance with total numbers. Use in purchasers' prices and use of domestic products in basic prices were derived from available tables.

Countries	Available raw data	Notes
Brazil	Supply and use in purchasers' prices for 2007 in national currency; supply, use in purchasers' prices, use of domestic products in basic prices and use of imported products in basic prices for 2005 in national currency (IBGE)	In 2005 tables activities 'Services to families and associations' and 'Domestic services' were aggregated; the split was done to gain consistency with 2007 tables. For 2005 split between margins and net taxes valuation layers was done based on EXIOPOL rates.
Canada	For 2007 in national currency: supply, use in purchasers' prices, valuation layers of trade margins (2 types), transport margins (4 types), taxes (1 type) and total use in basic prices (Statistics Canada)	A lot of confidential values are forced to zero, therefore could not be differentiated from real zero transactions. According to a contact person in NSI "All column and row totals shown in the tables, however, are accurate". Use in purchasers' price has non-zero row of subsidies on products and valuation layer of taxes includes only taxes but no subsidies. This implies that the layer of subsidies should be estimated and added to the available use table.
Switzerland	Supply and use in producers' prices for 2008 in national currency (ETH Zurich)	Vector of total margins was missing from supply table. Valuation layers of total margins and net taxes were estimated based on EXIOPOL rates. Subsequently, use in purchasers' prices and in basic prices were calculated based on available use and estimated values. Vector of total margins was calculated based on corresponding estimation of valuation layer.
China	Input-output table in producers' prices for 2007 in national currency (GTAP)	See description after the table

Countries	Available raw data	Notes
Indonesia	For year 2005 in national currency: input-output table in purchasers' prices, total input-output table in producers' prices and domestic input-output table in producers' prices (BADAN PUSAT STATISTIK)	See description after the table
India	Use table in factor prices and product mix table for 2004 in national currency (CENTRAL STATISTICAL ORGANISATION)	See description after the table
Japan	Input-output table for 2005 in national currencies in the following valuations: total producers' prices, imported products, trade margins (2 types), transport margins (7 types) and purchasers' prices (http://www.stat.go.jp/english/index.htm)	See description after the table
South Korea	For year 2007 total, domestic and import input-output tables in producers' prices in national currency; for year 2005 input-output table in national currency in the following valuations: basic prices, producers' prices and purchasers' prices (Bank of Korea)	See description after the table
Mexico	For year 2003 in national currency: supply, use in purchasers' prices, total use in basic prices, use of domestic products in basic prices, use of imported products in basic prices, valuation layers of taxes, subsidies, trade margins and transport margins (National Institute for Statistics and Geography)	Data is taken from EXIOPOL raw files. Availability of more recent data was checked, but nothing was available
Norway	Supply and use in purchasers' prices till 2007 in national currency (Eurostat)	For valuation layers rates of Finland are taken as proxy

Countries	Available raw data	Notes
Russia	For year 2003 in national currency: supply, use in purchasers' prices, total use in basic prices, use of domestic products in basic prices, use of imported products in basic prices, valuation layers of net taxes, trade margins and transport margins (GKS)	Original tables have significant imbalances
Turkey	Supply and use in purchasers' prices for 2002 in national currency (Eurostat)	For valuation layers rates of Romania are taken as proxy
Taiwan	Input-output table for 2006 in national currency in the following valuations: total producers' prices (2 types: with and without import duties), domestic products, imported products (2 types: with and without import duties), trade margins (2 types), transport margins (7 types) and purchasers' prices (National statistics)	IO in purchasers' prices is taken as use table and supply was assumed diagonal. Since IO in producers' prices had non-zero row of product taxes it was assumed that this table can be taken as use in basic prices with exception that VAT and net import duties moved from the value-added block to the row 'Net taxes on products' (VA block in basic prices should be the same as in purchasers' prices). Valuation layer of net taxes was calculated as difference between use in purchasers' prices and sum of use in basic prices and total margins
United States	For year 2002 in national currency: supply, use in purchasers' prices, total use in basic prices, use of domestic products in basic prices, use of imported products in basic prices, valuation layers of taxes (2 types), subsidies, trade margins (2 types), transport margins (6 types)	Data is taken from EXIOPOL raw files. Availability of more recent data was checked, but nothing was available
South Africa	Supply and use in purchasers' prices for 2005 in national currency (Statistics South Africa)	For valuation layers rates of EXIOPOL are taken as proxy

China:
Since only an input-output table was available, it was taken as use table and supply was assumed diagonal. Original data was only available in producer's prices. Therefore the valuation layer of net taxes had to be estimated based on tax rates available from EXIOPOL. Then the table of net taxes was subtracted from the original data, the table in basic prices was the result. However, in some transactions the tax rates from EXIOPOL were too high (60-390%). These tax rates were replaced by the tax rate of a comparable transaction. This was the case for most transactions from the products Wholesale and retail trade. Also this was the case for the transactions: transport storage - petroleum processing and transport storage - GFCF. Valuation layer of total margins was estimated based on rates from EXIOPOL. Then the table of total margins was added to the original data, the table in purchasers' prices was the result. In the original table the vector of net taxes on products was missing, it was taken as a sum from net taxes valuation layer. Net taxes on production (from value added block) were adjusted in such a way that all tables were in balance.

Indonesia:
Since only input-output tables are available, supply table was assumed to be diagonal and IO in purchasers' prices was taken as use in purchasers' prices. In IO in purchasers' prices only taxes (duty and sales) on imported products are given. Taxes on domestic output were estimated using rate on VAT (10%) for most products and zero rate for some specific products. Tax rates were applied only on value added for each product (possible to do since supply is diagonal). Zero tax rate was used for the following products: paddy, beans, maize, 'coal and metal ore mining', 'crude oil, natural gas and geothermal mining', 'other mining and quarrying', 'restaurant and hotel', railway, road, water and air transport, financial intermediaries, 'general government and defense', 'social and community services'. Rate of 9% was used for manufactured cigarettes. The rates were based on Indonesian Tax Guide 2010 from Deloitte. Application of other types of product taxes was very difficult because their rates could vary significantly between specific products within 65 products groups available in IO tables. Vector of total use in purchasers' prices was kept as in original tables and operational surplus in use table was used to keep balance between columns of supply and use tables. Valuation layer of total margins was calculated as IO in purchasers' prices minus IO in producers' prices. Small imbalances were removed using RAS procedure. Valuation layer of net taxes is based on EXIOPOL rates.

India:
In order to get supply table column totals from available use tables were distributed accordingly with the product mix table. Import vector was already given as part of use table. Factor prices were assumed to be similar to basic prices. Valuation layer of total margins was estimated based on EXIOPOL rates. From available use table net indirect taxes per industry were already known. In order to estimate the net taxes valuation layer initial guess was estimated based on EXIOPOL rates and further balanced using minimum entropy taken total taxes from use table as a constraint. For some industries the mathematical problem could not be solved (because of negatives) and the gross value added was adjusted in such a way that total industry output would remain unchanged. This occurred with the industries: paddy, wheat, gram, sugarcane, groundnut, coconut, tea, tobacco, other crops, milk and milk products, egg and poultry, other livestock products, electricity, railway transport services and communication.

Tax rates, calculated based on EXIOPOL, data were for some transactions extremely high (70-200%). To correct for this either the average of the product category was taken or, when this option would still not give an acceptable tax rate, the tax rates of a comparable product category was copied. In the list below the specifications are given:

- Product: Industrial machinery (others) - tax rates were copied from industrial machinery (F&T);
- Product: Other transport equipment - tax rates were copied from motor vehicles;
- Activity: Tea and coffee processing (col) - tax rates were copied from miscellaneous food products;
- Transactions: Industrial machinery (F&T) (row) & Tobacco manufacturing - average of product category was taken;
- Activity: Beverages manufacturing (col) - tax rates were copied from miscellaneous food products;
- Transactions: Organic heavy chemicals (row) & Computer related services - tax rates from product category were taken;
- Transactions: Organic heavy chemicals (row) & Plastic products - tax rates from product category were taken.

Japan:
In the original data each transaction is marked by one of the following types: standard input, scrap input, scrap output, by-product input, by-product output, trade margins, transport margins. Original input and output of scrap, as well as by-products, are balanced between each other. The products which had scrap input/output transactions were split into two types: virgin and recycled. Firstly use table was estimated using following assumptions:

- Intermediate block: standard input + scrap input + scrap output;
- Value added block: standard input;
- Final demand block: standard input + scrap input + scrap output + by-product input (since scrap output should be added with minus sign some of the final demand entries are negative, e.g. used paper, recycled glass product, etc.).

In the IO table only commodity taxes and duties on imported product were given. In order to estimate taxes on domestic products the tax rate of commodity taxes on imported products were use with the following exceptions:

- 5% rate for the products where import rate was not available (5% is an estimate of average commodity tax rate);
- Zero rate on certain products and public services: pork (bone meat), school lunch, private power generation, waste management services, self-transportation by private cars, airport and traffic control, public administration, school education, social education, research institutes, health and hygiene, social insurance, social welfare, office supplies;
- Zero rate on recycled products.

In order to estimate intermediate part of the supply table, total domestic output per product was calculated as total use in purchasers' prices minus total margins minus total product taxes and minus imports. Then scrap output and by-product output were placed in the intermediate part and all the rest domestic output were put on the diagonal.

Since additional taxes on commodities were estimated, operating surplus in use table was used to keep balance between columns of supply and use tables. Valuation layer of net taxes is based on EXIOPOL rates.

South Korea:
Since only input-output table was available, it was taken as use table and supply was assumed diagonal.
The problem with using original IO table for 2007 was that certain products had negatives due positive output of scraped materials during production process. The table for 2005 had the following properties:

- Purchasers' prices: no negatives, because output of scraped materials is given in a separate row and total use of scraped materials is given in a separate column;
- Producers' prices: negatives due positive output of scraped materials during production process; negatives are only in total and domestic tables, import table was without scrap;
- Basic prices: negatives due positive output of scraped materials during production process. Value added differs from other valuations. Probably this adjustment by the value of net taxes on products was made by the statistical office in order to keep row-column balance (in purchasers' and producers' prices there are only columns with commodity taxes on imported products).

Firstly, valuation layer of total margins for year 2005 and output of scraped materials by each production activity for year 2005 were estimated using minimum entropy problem. Restrictions used in the estimation:

- Total margins + scrap output = IO in purchasers' prices - IO in producers' prices;
- Each column of margins sums up to zero (positives and negatives are allowed only in specific places);
- Each row of margins sums up to the corresponding value from IO in purchasers' prices;
- Each column of scrap output sums up to the scrap output from IO in purchasers' prices;
- Each row of scrap output sums up to the scrap input from IO in purchasers' prices;

Secondly, IO in producers' prices for year 2005 without negatives was calculated as a difference between IO in purchasers' prices and estimated valuation layer of total margins. Thirdly, scrap output for year 2007 was estimated using the assumption that it equals a certain share of total intermediate inputs. Shares were assumed the same as in year 2005. Scrap output of dummy sector row was set to zero. Next, total scrap was distributed between users. It was assumed that the total amount of a certain scraped material is used only by one sector. This sector was defined as a maximum user or taken the same as in Japan data. Next, IO in producers' prices for year 2007 without negatives (in intermediate part) was calculated as a sum of original IO in producers' prices and scrap output. All input of scraped products was put into new product 'Recycled materials'. Negatives in final consumption reflect output of recycled materials by households and GFCF (this output cannot be put into supply table). Next, valuation layer of total margins for year 2007 was estimated using the margins rates from year 2005. The table was balanced to sum up to zero using the minimum entropy problem approch. Next, IO in purchasers' prices for year 2007 without negatives (in intermediate part) is calculated as a sum of IO in producers' price without negatives and estimated valuation layer of total

margins. Next, net taxes on products for year 2007 are estimated using the tax rates from year 2005. For year 2005 net taxes valuation layer is calculated as IO in producers' prices - IO in basic prices. Next, IO in basic prices for year 2007 without negatives (in intermediate part) is calculated as a difference between IO in producers' price without negatives and estimated net taxes. Value added decreased (through taxes on production) by the amount on net taxes on products in order to keep row-column balance. Next, domestic IO in producers' prices for year 2007 is calculated as difference between IO in producers' prices without negatives and original import IO in producers' prices. Supply table was estimated at the last step with total values on diagonal and all output of scraped materials put into new product 'Recycled materials'. Column of other net taxes on products includes net taxes on domestic products and was calculated as difference between total net taxes from corresponding valuation layer and taxes on imported products (custom duties plus commodity taxes).

3.2 Auxiliary Data

3.2.1 Agriculture Social Accounting Matrices for European Countries (AgroSAM)

A set of Social Accounting Matrices for the EU27 were developed as part of the AgroSAM project at the Institute for Prosepective Technological Studies (Müller, Pérez Domínguez et al. 2009). These tables follow the standard Eurostat format of supply use tables in purchaser prices, but extended for feedbacks of primary inputs into final demand (not used in this project). In addition, the project provided disaggregated agricultural data for 30 primary agricultural sectors and 11 food processing sectors. Such detail allowed the direct mapping of the AgroSAM database to the EXIOBASE classification for all sectors except one – this being processing of fish products which was aggregated with food products nec. As the AgroSAM data is only for 2000, the structure of inputs and sales were taken for the agricultural and food sectors, and applied as coefficients to the disaggregation of the 2007 tables.

3.2.2 Agricultural outputs

FAOSTAT data was used for estimates of production values in 2007 dollars for the agricultural sector directly. This output data was coupled with the AgroSAM data on coefficients. Some adjustments were made to FAOSTAT data where there was a discrepancy between non-zero physical reported values and zero monetary reported values. Export prices were applied to the domestic physical production as a proxy.

3.2.3 PRODCOM

Manufacturing output for European countries is obtained from the PRODCOM database (Eurostat 2012a). Whilst this database is highly detailed, it often does not cover small producers and contains quite some confidential information. As a result, a number of quality checks were introduced in order to filter out suspect data. These checks included cross-checking to export data (if domestic production added up to more than exports), checking endogenous prices, checking the scaling of a product group to the aggregate MSUT data. If large discrepancies were found, the data was disregarded.

3.2.4 Energy Products

The IEA Energy Balances was used as the source of disaggregation for the energy sectors (International Energy Agency 2012a). Energy data was mapped to specific EXIOBASE sectors with prices applied (see below).

3.2.4.1 Electricity – distribution and transmission

In order to be able to disaggregate the electricity costs the data sheets have been filled with information for industry and households, respectively, stemming from work done in EXIOPOL reconciled to Eurostat statistics for the EU (Eurostat 2012b). The data have been made comparable by transforming them into a common unit, i.e. Euros/MWh. Some countries report the relative proportion of distribution and transmission (Australia and Canada) in the SUTs, and these values were confronted with aggregate country specific data where available. Similar treatment was done for distribution of Natural Gas.

3.2.4.2 Energy – price information

For most carriers/products the data are directly taken from the IEA source (in $ per toe) (International Energy Agency 2012b). These data pertain only to selected OECD countries. As for non-OECD countries covered by the IEA, the data are calculated using the original price data ($ per Unit) and suitable conversion factors (toe per Unit). For some carriers/products prices per unit of calorific content are not provided by the IEA, so they are calculated even for OECD countries.

For every product the missing data for a country was calculated using the average product price of other countries from the same geographical region. We distinguish between seven regions:

1. Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Switzerland, UK
2. Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic
3. Finland, Sweden, Norway
4. Bulgaria, Cyprus, Greece, Malta, Romania, Slovenia, Turkey
5. China, India, Indonesia
6. Korea, Taiwan
7. Brazil, Canada, Mexico, USA.

Prices for Japan were usually too high and apparently independent from other Asian countries, so it wasn't assigned to any region. Because of geographic uncertainty Australia, Russia and South Africa weren't assigned as well. For these countries, as well as the RoW, the average price of already determined prices was taken.

4 MSUT Data Harmonisation

4.1 SUT Pre-processing

The first stage in the SUT harmonisation and detailing regards the inventory and quality check of original aggregate SUT data. In essence this implies gathering:

- For EU27: ESA95 tables discerning 59 sectors and products
- For the 16 non EU countries: SUT and/or IOT in all kinds of classifications

SUT data is not always consistent across countries, and need adjustment for the MRIO context. Tables can be found that show negative values at unexpected places, are not properly balanced, etc. Hence as a first stage of the data harmonization concordances of classification are prepared and cursory checks on validity of data us performed. Secondly, the consistency of the data is checked and detected errors in original tables are corrected. Harmonization across different accounting conventions is done in this step. Key aspects include the treatment of FISIM; the handling of purchasers by residents abroad; the handling of purchases on the domestic territory by non-residents; the conversion or estimation of data to enable the estimation of basic price tables (price harmonization); the preliminary balancing of tables; and the re-basing of tables to a common base year. The final files are exported as cleaned files. An automated approach allows for creating datasets for multiple years and easy update of the data in the future.

4.1.1 Purchasers by residents abroad; Purchases on the domestic territory by non-residents

As we follow the residential principle in the construction of MRIO tables, purchasers abroad must be treated as imports, and purchases on the domestic territory by non-residents are treated as exports. As most countries only report total purchasers abroad and non-resident purchasers, these must be allocated to product type. The allocation is done in a two-step process to estimate a representative import mix of households from the aggregate purchaser prices SUT data:

1) proportionally allocating imports vector across different uses to give a crude estimate of imports by households, then
2) using this estimate to re-allocate the purchasers abroad.

Check	Description	Comments
1	Total industry output = intermediate block + value added	Accounting
2	Total product supply = total product use	Accounting
3	Total product supply = domestic supply + imports	Accounting
4	Sum over rows of taxes=taxes in use table	Accounting
5	Sum over columns of taxes =taxes in supply table	Accounting
6	Sum over columns of margins=margins in supply table	Accounting
7	Sum over rows of margins =0	Accounting
8	Sum over columns of imports= imports in supply table	Accounting
9	Industry Supply check (% on diagonal)	Defined as *potential problem* if any value < 40% as this means the reference product of the industry is not correct.
10	Negatives in wrong place	Check on Supply and Use table for negative values where positive only allowable (e.g. intermediate inputs, final consumption, gross fixed capital formation)
11	Margins do not exist	Check on tables for existence of all margins (all types of trade and transport)
12	Aggregation of data	Check if any (original) ESA95 Supply Use IO table includes aggregated data for any industry/product
13	FISIM (Financial Intermediation Services Indirectly Measured)	Check on need for re-allocation of FISIM
14	Zero main product from the industry	Zero own production i.e. zero diagonal supply. This may indicate classification problem.
15	Negative value added	The sum of intermediate inputs is greater than total output. *(Indication of coefficients >0)*
16	Other net taxes on production are missing from value added	
17	Confidentiality	Highlight countries with confidential data in tables
18	Taxes and subsidies cannot be reconciled	Taxes less subsidies row cannot be disaggregated given purchaser price table and Taxes less subsidies column
19	Margins cannot be reconciled	Margins column cannot be disaggregated given purchaser price table.

Table 4.1: List of checks applied to SUTs in aggregate and disaggregate form

4.2 Disaggregating product and industry totals

Because of the changing classifications of individual countries, and because of the changing data availability for each country, product and industry totals were generated for each country that respect the aggregate SUT totals, but that embody as much auxiliary data as possible.
As product totals detail is higher than industry detail, product detail is generated first. Most auxiliary data is in the form of products as well. The basic order of usage of auxiliary is given in table 4.2:

Order	Dataset Name
1	Selected mining and mineral data*price
2	FAO Monetary data
3	PRODCOM, Quality checked data
4	IEA energy balance data*energy prices
5	Structural Business Statistics (SBS) of Eurostat
6	Trade data (BACI)
7	Zero price assumptions on waste flows
8	Representative country data

Table 4.2: Basic order of usage of auxiliary data.

The full list of final data used for each product is listed in the appendix. A recursive routine was utilized to add detail to the aggregate classification so that if, for example, the SBS data gave higher quality data on a two sub-groups of products (e.g. electricity generation and transmission/distribution) then the SBS data would be used to do a first split before IEA or other data is used to split the electricity generators individually.
Industry total disaggregation is done in the same method as per product total disaggregation, but utilizing different datasets (Table 4.3). Further, where industry specific data is not available, the product totals are used to give shares to the industry totals. As a final check for consistency, where industry totals derived from UNIDO and SBS data does not reasonably well match estimated product totals (+/-50% to account for off-diagonal supply) the UNIDO/SBS data is ignored. As SBS data is for a more restricted set of industries, and as it is also used to inform product disaggregation, in reality, this mainly means leaving out use of UNIDO data, which is known to be somewhat incomplete.

Order	Dataset Name
1	UNIDO
2	Structural Business Statistics (SBS) of Eurostat
3	Product total estimates

Table 4.3: Basic order of industry total disaggregation.

4.3 Generation of ideal coefficients

To complement the product and industry outputs, a set of ideal coefficients are constructed in the final classification of EXIOBASE from a range of sources. The coefficients are the expected technology employed in each industry, and are used only to give resolution below the aggregate supply and use tables. Both Supply and Use ideal coefficients are generated, in order to capture the occurrences of by-production and joint-production.

The source of the ideal coefficients is mainly the most disaggregated IOTs. This is then complemented with specific coefficient data for the electricity sectors, energy products, agricultural products, and a range of cross-checks and refinements in order to ensure that the coefficient set is reasonably unbiased. The summary of IOTs used in the ideal coefficients is given in table 4.4.

Country	Product detail	Sector detail	Year	Availability	Notes
Japan	>500	>400	2005	online[1]	Very good
US	429	426	2002	Used in Exiopol	No IOT, only SUTs. Not so good, new table will be released probably in 2012 for 2007, high level of detail on services
Canada	322	129	2000	Used in Exiopol	
Australia	123	111	2007-2008	onliine[2]	Not so much detail

Table 4.4: IOTs used in the ideal coefficients

Additional detail was included for the electricity sector using GEM-E3[3]; for the aluminium sector using industry data[4]; for natural and manufactured gas from the detailed Australian SUTs (Australian Bureau of Statistics 2012). Coefficients for some agriculture, some energy and some manufacturing flows were taken from WP4 (physical LCI coefficients multiplied by prices).

4.4 Generation of country specific coefficients

Country specific coefficients were generated from the ideal coefficients in order to capture the potential substitution of energy carriers, and the joint production in the use-coefficients. As such, supply coefficients were reconciled to the aggregate MSUT supply table to provide a first estimate of country specific joint production. In the end, for reasons of expediency, for the intermediate block:

- For originally diagonal elements off-diagonals distribution weight are set to zero and diagonal ones are based on total output of a specific activity.

[1] http://www.e-stat.go.jp/SG1/estat/ListE.do?bid=000001019588&cycode=0
[2] http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5209.0.55.0012007-08%20Preliminary?OpenDocument
[3] http://www.ecmodels.eu/index_files/MODELS%20Description%20of%20GEM-E3%20Developments.pdf
[4] http://agmetalminer.com/2009/02/27/cost-build-up-model-for-primary-aluminum-ingot-production/

- For originally off-diagonal elements distribution weights are based on multiplication of share of total output of a specific activity and of a specific product.

The market shares were then multiplied by the product-specific use coefficients in order to get country specific use coefficients for each industry.

4.5 MSUTs disaggregation approach

4.5.1 Estimation of updated 'initial estimate' of disaggregated supply and use in purchasers' prices tables

The first step to disaggregated and balanced system of supply and use tables (big tables) is to estimate their draft versions based on original tables (aggregate tables) and auxiliary data (Fig 4.1). The 'initial estimates' are estimated in such a way that their aggregation yields back original aggregate tables. Using a schematic example we can see that three types of disaggregation will be present: from cell to row-vector (blue), from cell to column-vector (green) and from cell to matrix (yellow). We use auxiliary data to get relative distribution weights for each of the orange cells. Distribution weights are set in such a way that the sum of three blue cells in the first row equals orange cell in the first row and so on. The grey cells remain as in the small original table.

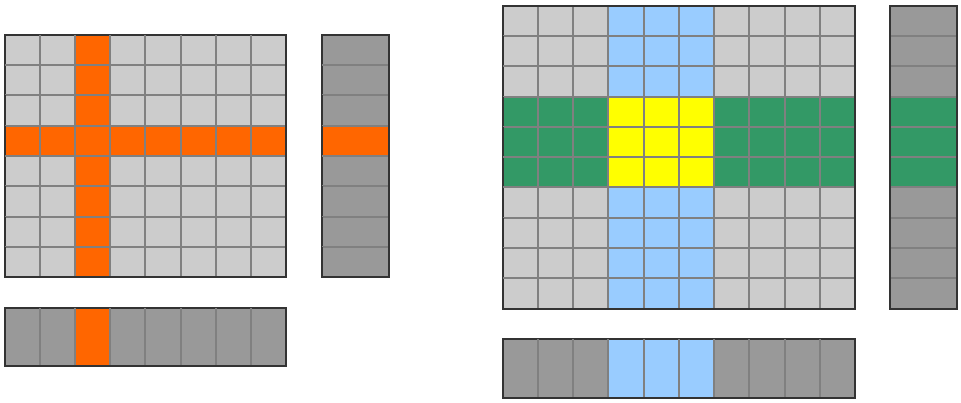

Fig 4.1: *Left*: Original aggregate table; *Right*: Draft big table

We start with estimation of 'initial estimates' for supply table and use table in purchasers' prices. Disaggregation of use table is a more difficult task and is based on the following auxiliary data:

- Intermediate block:
  - For detailed agricultural and food products and activities distribution weights are based on Social Accounting Matrices with detailed representation of agriculture and food. SAMs are available only for EU-27 countries.
  - For detailed energy products distribution weights are based on energy balances of International Energy Agency which were converted into monetary values.
  - For all other activities and products distribution weights are based on combination of 'ideal monetary coefficients' and total output of a specific activity[5].
- Value added block: distribution weights are based on total output of a specific activity. In case if the original tables don't have enough details about value added components, shares from the table of 'ideal monetary coefficients' are used.
- Final demand block:
  - For final consumption distribution shares are based on data from AgriSAMs or energy balances, if possible. For other products shares from the table of 'ideal monetary coefficients' are used.
  - For changes in inventories distribution shares are based on data from energy balances, if possible. For other products shares of domestic production are used.
  - For export column distribution shares are based on corrected BACI trade data. BACI data were corrected for energy products in order to be able to preserve global energy balance.

Disaggregation of supply table is based on the following auxiliary data:

- Country specific supply coefficients for all flows except agricultural flows from AgriSAMs.
- Import: distribution shares are based on corrected BACI trade data. BACI data were corrected for energy products in order to be able to preserve global energy balance.
- Valuation block: distribution shares are based on data from AgriSAMs, if possible. For other products total supply in basic prices are used.

[5] Data on total output are collected from various sources, including among others Structural Business Statistics, PRODCOM, Geological Surveys, FAO.

Balancing supply and use in purchasers' prices tables

After the first step we have two tables of 'initial estimates': supply in basic prices with valuation into purchasers' prices - S - and use table in purchasers' prices – U. Although the tables are in line with the original official statistical tables and preserve the structure from auxiliary data, the tables in general case would not be mutually balanced. In order to balance the system the following nonlinear problem is solved.

Tables' notation:
S, U – 'first guess' versions of disaggregated supply and use tables;
$\tilde{S}, \tilde{U}$ – mutually balanced supply and use tables (target tables).
The target tables are obtained by minimizing the distance between the draft tables and the balanced ones. Distance is approximated by the entropy function which reads:

$$e \equiv \sum_{i,j}|s_{ij}| \cdot \ln\left(\frac{s_{ij}}{\tilde{s}_{ij}}\right) + \sum_{i,j}|u_{ij}| \cdot \ln\left(\frac{u_{ij}}{\tilde{u}_{ij}}\right) \Longrightarrow_{\tilde{u}_{ij},\tilde{s}_{ij}} min \ ,$$

where the lowercase symbols are elements of the tables denoted with corresponding capital symbols.
The optimization problem is being solved subject a number of constraints:

1. Total supply equals total use: $\sum_j \tilde{s}_{ij} = \sum_j \tilde{u}_{ij}$, $\forall i$.
2. Total output equals intermediate consumption plus value added: $\sum_i \tilde{s}_{ij} = \sum_i \tilde{u}_{ij}$, $\forall j$.
3. Total output is close to total output derived from auxiliary data: $\sum_i \tilde{s}_{ij} = slack_j \cdot output_j$, $\forall j$. In most of the cases the $slack_j$ variable is kept within the range $[0.9, 1.1]$.Positive, negative and zero values are placed correctly: $sgn(\tilde{s}_{ij}) = sgn(s_{ij})$ and $sgn(\tilde{u}_{ij}) = sgn(u_{ij})$, $\forall i,j$.
4. Aggregation of $\tilde{S}$ and $\tilde{U}$ yields original small tables.

Estimation of valuation matrices and use table in basic prices

Based on information about taxes and subsidies on products and trade and transport margins for a specific country, a similar country, or from previous work within EXIOPOL project, the following steps are taken to obtain valuation layers and use table in basic prices:

1. 'Initial estimate' of net taxes table is calculated based on the structure of the total use table in purchasers' prices $\tilde{U}$, variation of net tax rates between different users (same country, similar country or EXIOPOL rates) and taking the vector of total net taxes from the supply table $\tilde{S}$ as a constraint.
2. 'Initial estimates' of trade and transport margins tables separately are compiled in three sub-steps. Firstly, total positive margin values are estimated based on the structure of the total use table in purchasers' prices $\tilde{U}$, variation of total margin rates between different users (same country, similar country or EXIOPOL rates) and taking the vector of total margins from the supply table $\tilde{S}$ as a constraint. Secondly, negative margin values are distributed column-wise using structure of margins in supply table $\tilde{S}$. And lastly the total margins table is split into separate trade and transport margins tables using proportions of trade products' and transport products' margins.
3. Final estimates of valuation matrices and use table in basic prices are derived using another balancing procedure. As in the case with supply and use in purchasers' prices tables the distance approximated by the entropy function

between the 'initial estimates' and balanced table is minimized. The following constraints are use during the optimization procedure:

a. Total taxes and total margins per product equal to the corresponding columns from the supply table $\tilde{S}$.
b. Total margins per user are equal to zero.
c. The use table in basic prices, derived as use table in purchasers' prices minus net taxes and minus margins, has negative values only in the same positions are the use table in purchasers' prices $\tilde{U}$.
d. Per user the absolute value of a negative margin cannot be greater than the sum of positive margins on products corresponding to this negative margins. For example, margins charged by retail trade services of motor fuel cannot be greater than the margins included in the purchasers' price of motor fuel products. This constrain is included in order to assure that margins charged always correspond to a physical transaction of product.

Estimation of domestic and import use tables in basic prices

There are several ways to estimate import use tables. In case of no other import information available, the imports are distributed row-wise using the vector of total import in the supply table $\tilde{S}$ and structure of total use table in basic prices.

The other option is to calculate percentage of import in each transaction from small original import and domestic use tables and apply this percentage to corresponding cells in total use table in basic price. After that each row should be adjusted so it sums up to the corresponding import value in the supply table $\tilde{S}$.

Domestic use table is calculated as a difference between total use table in basic prices and import use table.

5 Trade data and trade linking

The main trade data used in CREEA originates from the UN Comtrade database (United Nations Statistics Division 2012a) and the UN services trade database (United Nations Statistics Division 2012b). The Comtrade data whilst of reasonably high quality is not reconciled to itself, such that bilateral exports are not consistent with the mirror of bilateral imports. The BACI database (Gaulier and Zignago 2010) is based on UN Comtrade, but is reconciled, such that for a single year, every trade flow is recorded as a single bilateral trade flow in both physical units and in f.o.b. monetary valuation.

We hence start with the BACI database in both physical and monetary values and aggregate the 5000 or so products of the HS classification into the EXIOBASE2.0 classification. Whilst this is usually a simple aggregation, for energy and waste flows, the EXIOBASE 2.0 classification is more detailed than the HS classification such that disaggregation is also required. Estimated energy exports (from the IEA database) or else estimated domestic production is used to disaggregate these HS codes. A similar process is done for the UN services trade database. The services trade database is complicated by much missing data, the multiple levels of aggregation and the partial reporting of bilateral trade flows, and total import/export flows. A bottom-up process is used to utilise as much information as possible in maintaining detailed product and bilateral flows scaled to aggregate product and total import/export flows. Where the product detail is not high enough in the services trade data, the export flows are split by the shares of domestic production.

Once the bilateral commodity trade and services trade data is in the EXIOBASE2.0 classification, it then undergoes a number of pre-processing steps in order to match it to both IEA energy data and MSUT trade data (Fig. 5.1). In the first step, the bilateral trade data is reconciled to the total IEA imports and exports by country and product using mathematical programming. In a second step, the bilateral trade data is then reconciled to MSUT aggregate imports (CIF valuation) and exports (FOB) using the bilateral trade data and an estimate of margins. This provides a complete bilateral trade dataset that can then be used for estimation of the RoW and are close to final data points in the MSUT disaggregation.

The final trade linking is performed within the EXIOBASE software created in the EXIOPOL project (see Chapter 13).

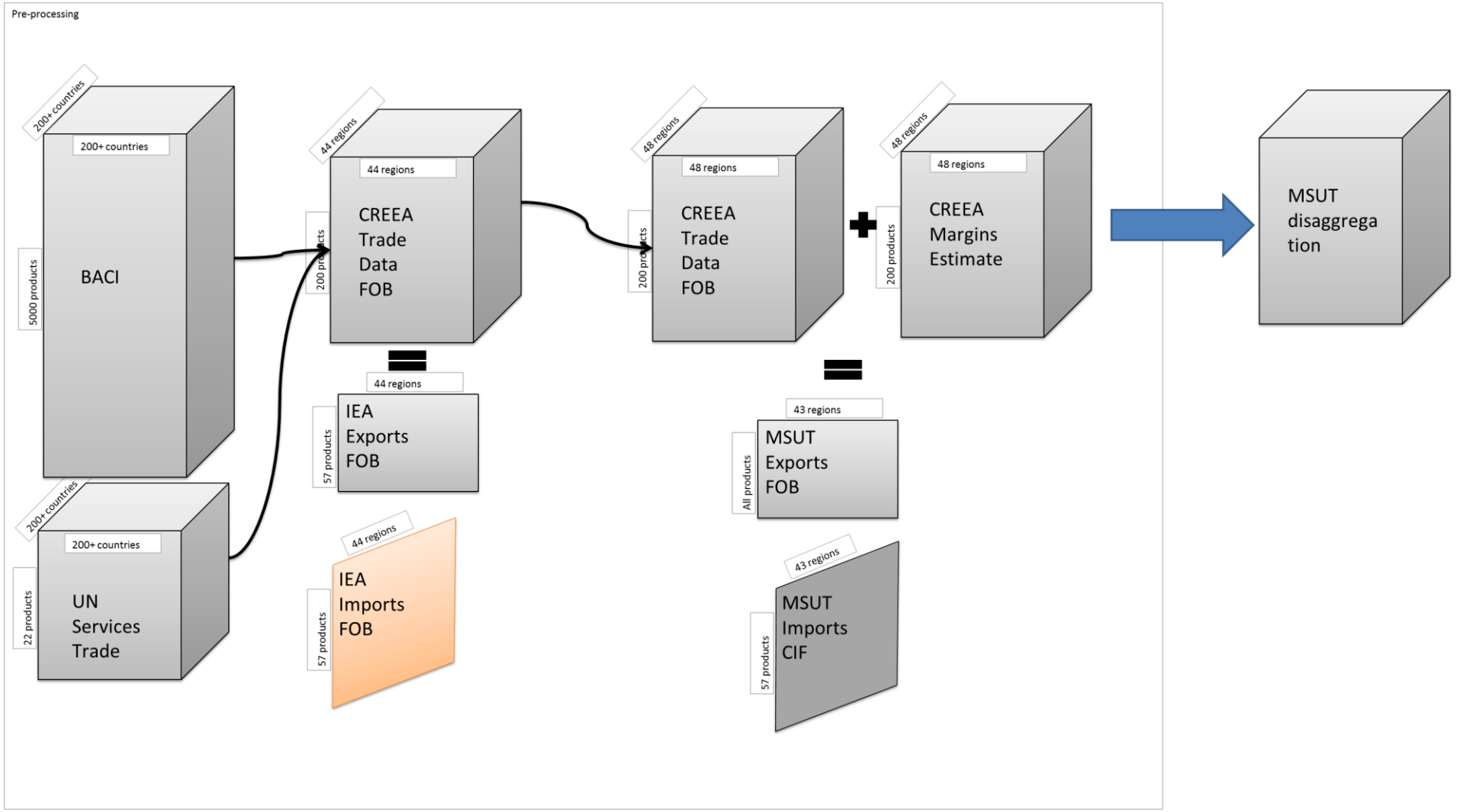

Figure 5.1 Trade pre-processing before estimation of MSUT values

6 Rest of the World

6.1 Material and Methods

The first step in building Rest of the World (RoW) Supply Use Tables (SUTs) was to estimate the RoW gross domestic product (GDP) per region (in USD, Fig. 6.1 gives an overview of the whole estimation procedure). These estimates were based on the GDP data from the The World Bank (http://www.worldbank.org/ - GDP in current US$ purchaser's prices).

GDP(RoW) = GDP(world) - sum(GDP(CREEA countries))
GDP(RoW) = sum(RoW countries)

The two approaches to estimate the GDP of the RoW resulted in minor differences: according to the first calculation the GDP of the RoW was 6.14E+12 USD versus 6.08E+12 USD for the second approach. To compensate for the differences, we scaled the GDP of the RoW countries to add up to the RoW estimated with formula 1. Subsequently the RoW countries were grouped into five regions (RoW Asia and Pacific, RoW Europe, RoW Middle East, RoW Africa, RoW America, see Table 6.1). For the RoW Middle East region we followed a traditional definition of this region (https://en.wikipedia.org/wiki/Middle_east).

In the next step we collected gross industry output and value added per broad industry sector from the UNdata (https://data.un.org/) National Accounts Official Country data ('Table 2.3 Output, gross value added, and fixed assets by industries at current prices'). For every country disaggregated sectors were deleted in case of major discrepancies (>20% between the sum of individual entries and the aggregated value) and re-disaggregated based on the average share obtained from the remaining countries.

Final demand data per category were collected from the UNdata ('Table 1.1 Gross domestic product by expenditures at current prices') and also revised in case of major discrepancies.

Values in both UN databases provide values in local currency. These were converted to USD by the exchange rate derived from:

GDP(USD)/GDP(local currency)

Industry output and final demand data were then summed per region. Due to missing country in the UNdata, the sum of the GDP per region derived from them did not add up to the GDP per region derived from the Worldbank. Therefore, we scaled all entries from the region aggregation with:

GDP(USD, region WB)/GDP(USD, region UN)

Disaggregated values in the resulting table were scaled such that all values add up to the next aggregate.

Table 6.1: RoW countries and classification

ISO3	Country	Region CREEA	Region CREEA name
AFG	Afghanistan	WA	RoW Asia and Pacific
ALB	Albania	WE	RoW Europe
DZA	Algeria	WF	RoW Africa
AND	Andorra	WE	RoW Europe
AGO	Angola	WF	RoW Africa
ATG	Antigua and Barbuda	WL	RoW America
ARG	Argentina	WL	RoW America
ARM	Armenia	WA	RoW Asia and Pacific
AZE	Azerbaijan	WA	RoW Asia and Pacific
BHS	Bahamas, The	WL	RoW America
BHR	Bahrain	WM	RoW Middle East
BGD	Bangladesh	WA	RoW Asia and Pacific
BRB	Barbados	WL	RoW America
BLR	Belarus	WE	RoW Europe
BLZ	Belize	WL	RoW America
BEN	Benin	WF	RoW Africa
BMU	Bermuda	WL	RoW America
BTN	Bhutan	WA	RoW Asia and Pacific
BOL	Bolivia	WL	RoW America
BIH	Bosnia and Herzegovina	WE	RoW Europe
BWA	Botswana	WF	RoW Africa
BRN	Brunei Darussalam	WA	RoW Asia and Pacific
BFA	Burkina Faso	WF	RoW Africa
BDI	Burundi	WF	RoW Africa
KHM	Cambodia	WA	RoW Asia and Pacific
CMR	Cameroon	WF	RoW Africa
CPV	Cape Verde	WF	RoW Africa
CAF	Central African Republic	WF	RoW Africa
TCD	Chad	WF	RoW Africa
CHI	Channel Islands	WE	RoW Europe
CHL	Chile	WL	RoW America
COL	Colombia	WL	RoW America
COM	Comoros	WF	RoW Africa
COD	Congo, Dem. Rep.	WF	RoW Africa
COG	Congo, Rep.	WF	RoW Africa
CRI	Costa Rica	WL	RoW America
CIV	Cote d'Ivoire	WF	RoW Africa
HRV	Croatia	WE	RoW Europe
CUB	Cuba	WL	RoW America
DJI	Djibouti	WF	RoW Africa
DMA	Dominica	WL	RoW America
DOM	Dominican Republic	WL	RoW America

Table 6.2 (continued): RoW countries and classification

ISO3	Country	Region CREEA	Region CREEA name
ECU	Ecuador	WL	RoW America
EGY	Egypt, Arab Rep.	WM	RoW Middle East
SLV	El Salvador	WL	RoW America
GNQ	Equatorial Guinea	WF	RoW Africa
ERI	Eritrea	WF	RoW Africa
ETH	Ethiopia	WF	RoW Africa
FRO	Faeroe Islands	WE	RoW Europe
FJI	Fiji	WP	RoW Asia and Pacific
GAB	Gabon	WF	RoW Africa
GMB	Gambia, The	WF	RoW Africa
GEO	Georgia	WA	RoW Asia and Pacific
GHA	Ghana	WF	RoW Africa
GRL	Greenland	WL	RoW America
GRD	Grenada	WL	RoW America
GTM	Guatemala	WL	RoW America
GIN	Guinea	WF	RoW Africa
GNB	Guinea-Bissau	WF	RoW Africa
GUY	Guyana	WL	RoW America
HTI	Haiti	WL	RoW America
HND	Honduras	WL	RoW America
HKG	Hong Kong SAR, China	WA	RoW Asia and Pacific
ISL	Iceland	WE	RoW Europe
IRN	Iran, Islamic Rep.	WM	RoW Middle East
IRQ	Iraq	WM	RoW Middle East
IMY	Isle of Man	WE	RoW Europe
ISR	Israel	WM	RoW Middle East
JAM	Jamaica	WL	RoW America
JOR	Jordan	WM	RoW Middle East
KAZ	Kazakhstan	WA	RoW Asia and Pacific
KEN	Kenya	WF	RoW Africa
KIR	Kiribati	WP	RoW Asia and Pacific
KSV	Kosovo	WE	RoW Europe
KWT	Kuwait	WM	RoW Middle East
KGZ	Kyrgyz Republic	WA	RoW Asia and Pacific
LAO	Lao PDR	WA	RoW Asia and Pacific
LBN	Lebanon	WM	RoW Middle East
LSO	Lesotho	WF	RoW Africa
LBR	Liberia	WF	RoW Africa
LBY	Libya	WF	RoW Africa
LIE	Liechtenstein	WE	RoW Europe
MAC	Macao SAR, China	WA	RoW Asia and Pacific
MKD	Macedonia, FYR	WE	RoW Europe

Table 6.3 (continued): RoW countries and classification

ISO3	Country	Region CREEA	Region CREEA name
MDG	Madagascar	WF	RoW Africa
MWI	Malawi	WF	RoW Africa
MYS	Malaysia	WA	RoW Asia and Pacific
MDV	Maldives	WA	RoW Asia and Pacific
MLI	Mali	WF	RoW Africa
MHL	Marshall Islands	WP	RoW Asia and Pacific
MRT	Mauritania	WF	RoW Africa
MUS	Mauritius	WF	RoW Africa
FSM	Micronesia, Fed. Sts.	WP	RoW Asia and Pacific
MDA	Moldova	WE	RoW Europe
MCO	Monaco	WE	RoW Europe
MNG	Mongolia	WA	RoW Asia and Pacific
MNE	Montenegro	WE	RoW Europe
MAR	Morocco	WF	RoW Africa
MOZ	Mozambique	WF	RoW Africa
NAM	Namibia	WF	RoW Africa
NPL	Nepal	WA	RoW Asia and Pacific
NZL	New Zealand	WP	RoW Asia and Pacific
NIC	Nicaragua	WL	RoW America
NER	Niger	WF	RoW Africa
NGA	Nigeria	WF	RoW Africa
OMN	Oman	WM	RoW Middle East
PAK	Pakistan	WA	RoW Asia and Pacific
PLW	Palau	WP	RoW Asia and Pacific
PAN	Panama	WL	RoW America
PNG	Papua New Guinea	WP	RoW Asia and Pacific
PRY	Paraguay	WL	RoW America
PER	Peru	WL	RoW America
PHL	Philippines	WA	RoW Asia and Pacific
PRI	Puerto Rico	WL	RoW America
QAT	Qatar	WM	RoW Middle East
RWA	Rwanda	WF	RoW Africa
WSM	Samoa	WP	RoW Asia and Pacific
SMR	San Marino	WE	RoW Europe
STP	Sao Tome and Principe	WF	RoW Africa
SAU	Saudi Arabia	WM	RoW Middle East
SEN	Senegal	WF	RoW Africa
SRB	Serbia	WE	RoW Europe
SYC	Seychelles	WF	RoW Africa
SLE	Sierra Leone	WF	RoW Africa
SGP	Singapore	WA	RoW Asia and Pacific
SLB	Solomon Islands	WP	RoW Asia and Pacific

Table 6.4 (continued): RoW countries and classification

ISO3	Country	Region CREEA	Region CREEA name
LKA	Sri Lanka	WA	RoW Asia and Pacific
KNA	St. Kitts and Nevis	WL	RoW America
LCA	St. Lucia	WL	RoW America
VCT	St. Vincent and the Grenadines	WL	RoW America
SDN	Sudan	WF	RoW Africa
SUR	Suriname	WL	RoW America
SWZ	Swaziland	WF	RoW Africa
SYR	Syrian Arab Republic	WM	RoW Middle East
TJK	Tajikistan	WA	RoW Asia and Pacific
TZA	Tanzania	WF	RoW Africa
THA	Thailand	WA	RoW Asia and Pacific
TMP	Timor-Leste	WA	RoW Asia and Pacific
TGO	Togo	WF	RoW Africa
TON	Tonga	WP	RoW Asia and Pacific
TTO	Trinidad and Tobago	WL	RoW America
TUN	Tunisia	WF	RoW Africa
TKM	Turkmenistan	WA	RoW Asia and Pacific
TUV	Tuvalu	WP	RoW Asia and Pacific
UGA	Uganda	WF	RoW Africa
UKR	Ukraine	WE	RoW Europe
ARE	United Arab Emirates	WM	RoW Middle East
URY	Uruguay	WL	RoW America
UZB	Uzbekistan	WA	RoW Asia and Pacific
VUT	Vanuatu	WP	RoW Asia and Pacific
VEN	Venezuela, RB	WL	RoW America
VNM	Vietnam	WA	RoW Asia and Pacific
YEM	Yemen, Rep.	WM	RoW Middle East
ZMB	Zambia	WF	RoW Africa
ZWE	Zimbabwe	WF	RoW Africa

Average weighted shares for the disaggregation of the broad industry sectors of the UN database to the CREEA classification were obtained by aggregating sample country industry output to the UN broad sectors. The sample countries consisted of CREEA countries within the specific RoW region or of the world sum in case of too few country data (Table 6.2).

Region	Industry Output Disaggregation Sample
RoW Asia and Pacific	All Asian countries within CREEA (Japan, China, South Korea, India, Taiwan, Indonesia)
RoW America	All American countries (USA, Canada, Brazil, Mexico)
RoW Europe	All European countries within CREEA
RoW Africa	All CREEA countries
RoW Middle East	All CREEA countries

Table 6.2: Sample countries for the disaggregation of the broad industry output of the UNdata to the CREEA classification.

Energy related industry output per broad industry output as provided by the UNdata were redistributed based on shares obtained from the IEA data (see Section 3.2.4).

In the next step, preliminary product output was calculated using the ideal supply coefficient (see section 4.3). Region specific SUT coefficients were then constructed based on ideal coefficient tables which were reconciled for (a) the estimated product and industry output (b) joint production (c) region specific energy use.

To obtain a consistent trade link between the RoW regions and the other CREEA countries, imports and exports were exchanged by the estimates obtained the trade balancing routine (see section 5).

At this point, a fully disaggregated SUT for every RoW region existed. As these tables were derived based on different sources, the systems is most likely unbalanced.

We used a mathematical programming approach as per the individual country MSUTs to balance the system with minimized information gain. The objective value was calculated by weighted squared differences between the initial and calculated table. Weights were defined as reciprocal values of the initial table entries for values larger than 1E-3 or otherwise set to 1000. For every region, imports and exports as well as overall GDP and industry output were set as constrains.

The final tables were converted from USD to Euros with a conversion factor of 1.3704 (Eurostat 2012c). Finally, domestic and imported use was calculated by the share of import to total supply.

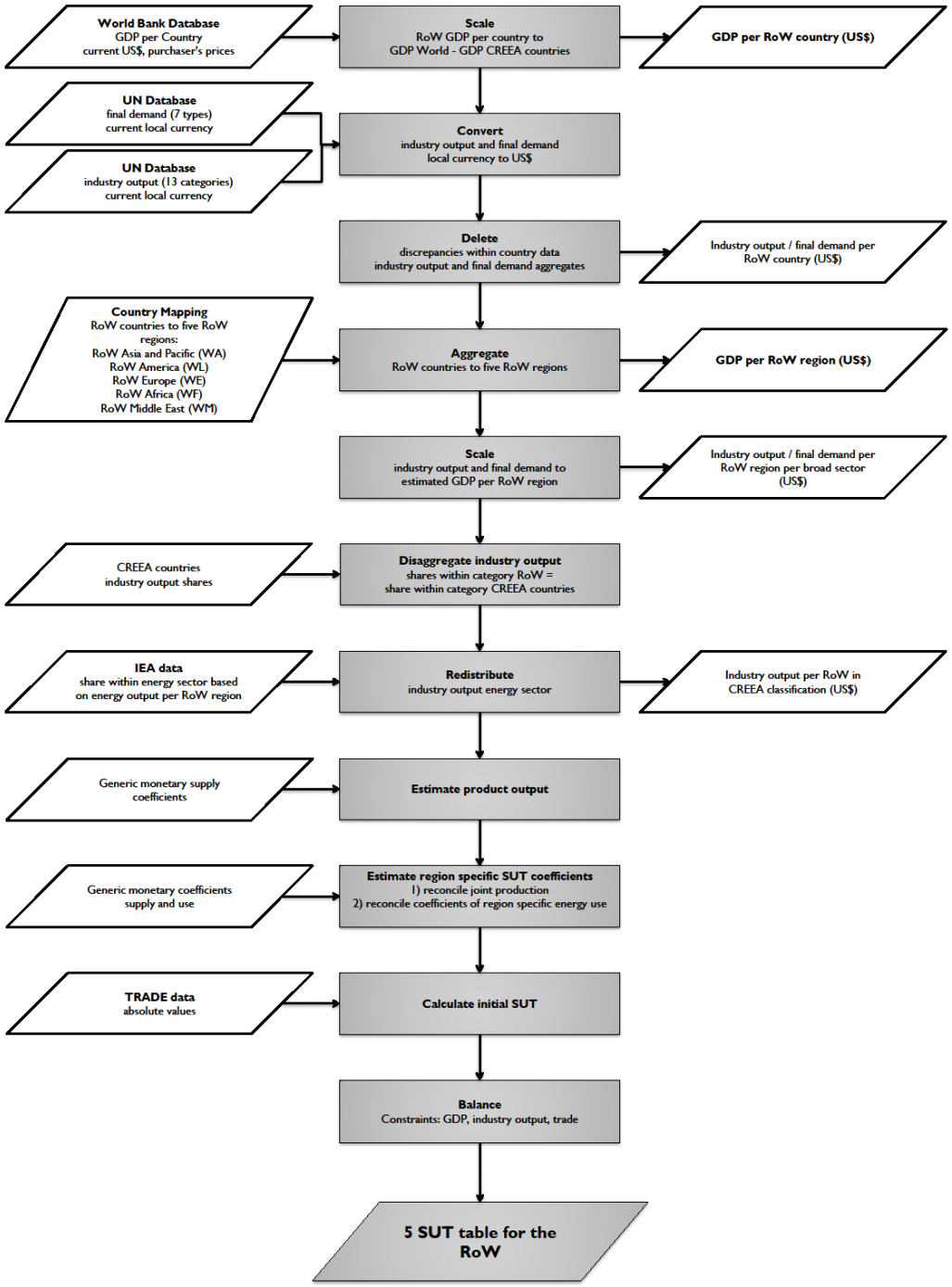

Figure 6.1: Estimation of the RoW

6.2 Results

6.2.1 Macroeconomic data

In 2007, the RoW compromised 11 % of the global GDP (4.48E6 Million Euro out of 4.07E7 Million Euro). Within the RoW the Asian/Pacific and the Middle East regions play the most important part (Table 6.3).

Region	GDP	Industry output
RoW Asia and Pacific	1.25E+06 (28 %)	2.21E+06 (28 %)
RoW America	1.06E+06 (24 %)	1.92E+06 (24 %)
RoW Europe	2.85E+05 (6 %)	6.71E+05 (9 %)
RoW Africa	6.74E+05 (15 %)	1.05E+06 (13 %)
RoW Middle East	1.21E+06 (27 %)	2.00E+06 (25 %)
RoW Sum	4.48E+06 (100 %)	7.86E+06 (100 %)

Table 6.3: Macroeconomic data for the RoW regions, values are given in million Euro.

6.2.2 Differences in technical coefficients

The following two figures highlight the differences in the regions specific SUTs showing the intensity of every product for every industry. Product and industry classification follows the structure given in the Appendix.

Supply Tables

A clear diagonal production structure characterizes the supply tables, followed by the import column vector. Major divergence from the diagonal (steps) occur (1) at the beginning for i10 (Mining of coal and lignite; extraction of peat) which provide different coal products and (2) for i23.2 (Petroleum Refinery) which manufacture different fuel products. (3) A high coproduction is typical for the manufacturing sector which appears as a blue cloud in the middle of the tables. The RoW Middle East shows a distinct coproduction also within the mining sector in the upper left part of the table.

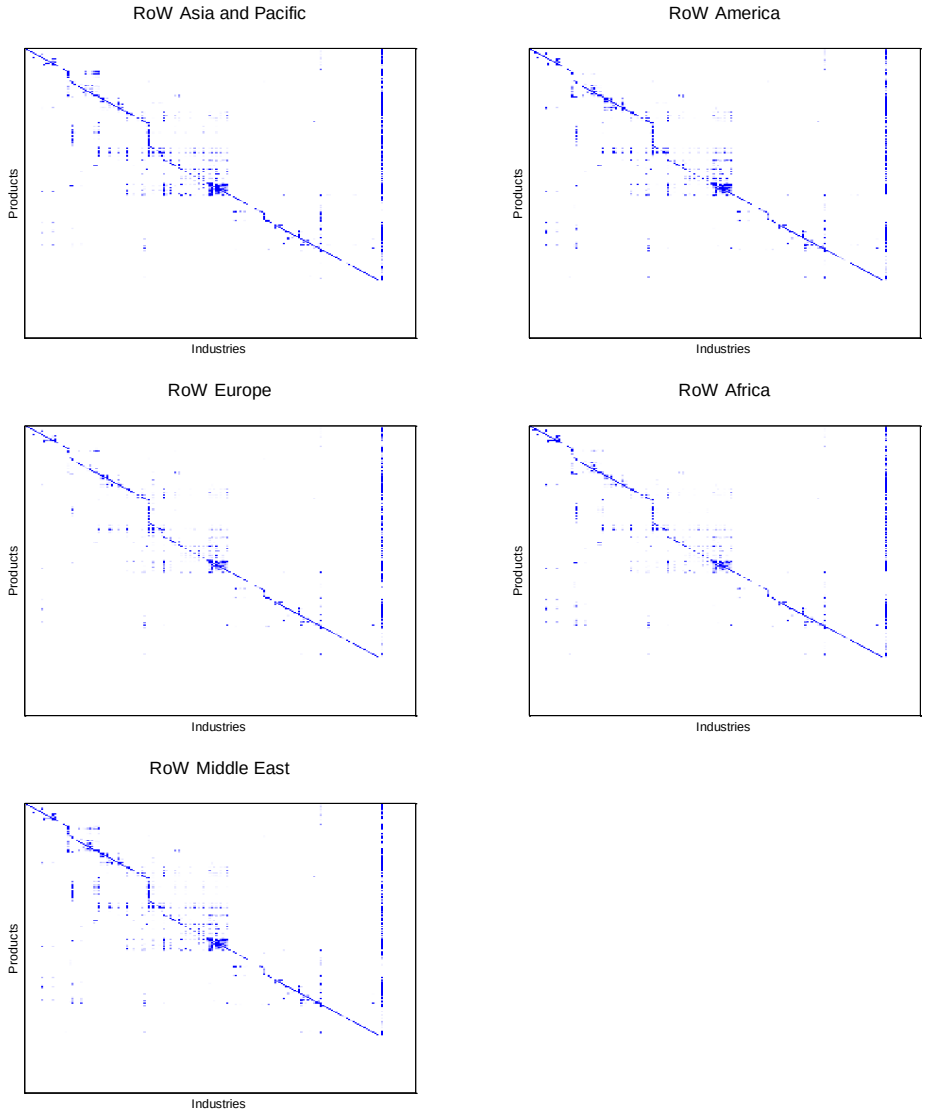

Figure 6.2: Intensity of products/industries for the 5 RoW supply tables

Use Tables

The outstanding difference between the use tables is the almost empty use of products by the mining sector for RoW Europe in the second main column (i10 to i14, cf RoW Europe with RoW Middle East).

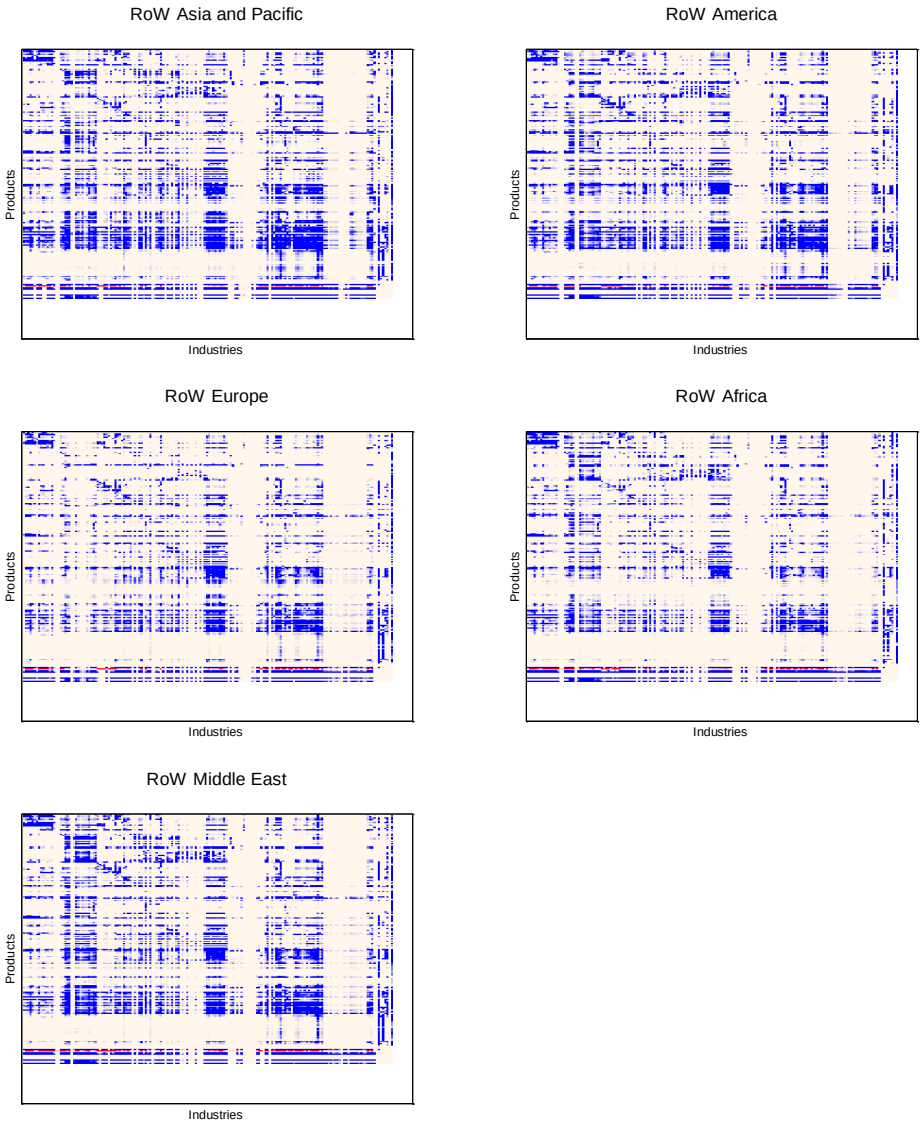

Figure 6.3: Intensity of products/industries for the 5 RoW use tables

7 Labour accounts: methodology

Socio-economic data contains information on employment for 43 countries plus five RoW regions. The indicators available are compensation of employees, total employment and hours worked, separated by gender and skill types, as given in table 7.1.

Values	Description
Compensation of employees	
V_WAGE	*Compensation of employees: Total (in millions of national currency)*
V_WLSM	Compensation of employees: Low-skilled male workers
V_WLSF	Compensation of employees: Low-skilled female workers
V_WMSM	Compensation of employees: Medium-skilled male workers
V_WMSF	Compensation of employees: Medium-skilled female workers
V_WHSM	Compensation of employees: High-skilled male workers
V_WHSF	Compensation of employees: High-skilled female workers
Employment	
E_NRTO	*Number of persons engaged (thousands)*
E_NLSM	Number of low-skilled male persons engaged (thousands)
E_NLSF	Number of low-skilled female persons engaged (thousands)
E_NMSM	Number of medium-skilled male persons engaged (thousands)
E_NMSF	Number of medium-skilled female persons engaged (thousands)
E_NHSM	Number of high-skilled male persons engaged (thousands)
E_NHSF	Number of high-skilled female persons engaged (thousands)
Hours worked	
E_HRTO	*Total hours worked by persons engaged*
E_HLSM	Total hours worked by low-skilled male persons engaged
E_HLSF	Total hours worked by low-skilled female persons engaged
E_HMSM	Total hours worked by medium-skilled male persons engaged
E_HMSF	Total hours worked by medium-skilled female persons engaged
E_HHSM	Total hours worked by high-skilled male persons engaged
E_HHSF	Total hours worked by high-skilled female persons engaged

Table 7.1. Indicators available in CREEA socio-economic database

The database was built in two stages. First, standard measures of labour inputs were collected for each country, used to quantify the dimension of labour impacts of consumption and production in the MRIO model. It consists of total compensation of employees, total employment, total employees and total hours worked by all persons engaged.

However, it is also important to include other measures of labour that will account for the heterogeneity of labour force in each country and industry. Thus, the second stage of data collection corresponded to quality inputs. It consists on information on gender and skill types for each of the first level indicators. It takes into account distinction in hours worked among genders, and wages differences between gender and skill types.

On one hand, in a static MRIO, labour quality data can show the diversity of educational attainment of labour force, women inclusion in the labour market, and payment gap between gender and skill class. On the other hand, when used in a dynamic MRIO, it can show the evolution of labour structure in the countries assessed, and how production and consumption are evolving to exclude or incorporate gaps between gender composition and wages, and thus allowing policy makers and researchers to understand the effects of international trading on socio-economic conditions globally.

In the following sections, we describe the variables used, its characteristics and sources. For detailed country-specific sources, refer to the appendix.

7.1.1 Compensation of Employees, employment and hours worked

Compensation of employees comprises wages, salaries, and employers' social contribution. For each country, this indicator was disaggregated from the National Accounts tables into 163 industries. It was used then to disaggregate employment and hours worked into the MRIO industries, as explained in the following section.

Total employment refers to total persons engaged in each industry in the MRIO. It covers both employees and self-employed persons. Definitions followed are given by the International Labour Organization (ILO). Employees are all persons with formal job attachment, even if in temporarily paid or unpaid leave; and self-employed persons include employers, own-account workers, members of producers' cooperatives, unpaid family workers at work, and persons engaged in the production of economic goods and services for own and household consumption. Number of employees and self-employed are available in the socio-economic database, but not included in the model.

Ypma and Ark (2006) identify three primary sources for labour input. Labour force surveys (LFS) provide reliable information on the composition and characteristics of labour force and account for all employed persons throughout the economy, although it has limited consistency with economic output data. Business surveys, on the other hand, provide detailed employment data often consistent with economic output measures, especially for good producing industries, but information on services sectors, smaller enterprises, and self-employment are usually not collected or underestimated. Micro databases, such as social security statistics, can provide detailed and reliable information on all legal inhabitants, although access can be restricted and very resource-intensive, especially in extensive researches.

For the purpose of this project, primary sources for labour input were national labour force surveys, gathered from the ILO LABORSTA Database (ILO 2010)[6], and a combination of labour force and industrial surveys in national accounts, gathered from the STAN Database, published by OECD Stats (OECD 2011). While labour data from ILO Database consist of 39 economic sectors, STAN's data cover up to 60 industries, providing better comparability with economic output in the 163 sectors of the MRIO. However, the latter is only available for OECD countries.

[6] ILO Department of Statistics. International Labour Office Database on Labour Statistics – LABORSTA. Available from: http://laborsta.ilo.org/. LABORSTA Database will gradually be replaced with ILOSTAT Database, available from: http://www.ilo.org/ilostat.

Albeit there is a harmonization in labour force accountings, employment can be given both in persons and in number of jobs. While the first considers that a multiple job holder counts for one, the latter counts several units per individual, and this difference can have significant effects on labour statistics. According to Lequiller (2004), multiple job holders can correspond to more than 5% of employed persons. Only five countries (Austria, Canada, Japan, United Kingdom and United States) count employment as number of jobs rather than number of persons. However, this difference was not addressed, and thus, employment results, in number of persons, can be slightly overestimated for these countries.

Hours worked, on the other hand, can be classified in four different types, which vary according to which hours are accounted for:

- *Hours actually worked* covers all types of workers, and relates to all the time that the persons spent on work activities during the reference period, whether paid or unpaid, but excluding time not worked, such as in annual, parental or sick leaves, public holidays, meal breaks, and commuter travel;
- *Hours paid for* include all hours paid for, whether worked or not. It comprises all paid leaves, and excludes hours not paid for, such as unpaid overtime;
- *Normal hours of work* covers only paid employees, and refers to hours of work established in agreements and labour regulation, and differ from hours paid for by excluding all overtime;
- *Hours usually worked* relates to average hours most commonly worked per week in paid and self-employment during a reference period, including usual paid and unpaid overtime.

The use of each category will depend on the aim of the research. For the purpose of this project, we consider *hours actually worked*, since it reflects the productivity of the industry, and are the usual output of hours worked in labour force surveys. Exceptions are Brazil and Ireland, which relate to *hours usually worked*, and Mexico, which publishes *normal hours of work*.

7.1.1.1 Disaggregation of labour inputs in the MRIO

Labour inputs were then disaggregated from broad economic sectors into industries in the MRIO according to the compensation of employees:

$NR_i = NR_g \, (wage_i/wage_g)$

Where:
NR_i = Number of persons engaged in industry *i* (in thousands)
NR_g = Number of persons engaged in broad sector *g* (in thousands)
$wage_i$ = Compensation of employees of industry *i* (in millions of national currency)
$wage_g$ = Sum of compensation of employees in all industries comprising broad sector *g*

It was considered that, inside a broad economic sector industry, average wages would be similar, as well as hours worked per person. For example, for the "*pulp, paper and paper products*" broad sector, which comprises the industries "*pulp*", "*re-processing of secondary paper into new pulp*" and "*paper*", total number of persons engaged were

divided proportionally between the industries according to their shares in total compensation of employees in the broad sector.

For estimating total hours worked in each industry, it was assumed that hours worked per person was similar among industries in the same broad economic sector. While OECD Stats offer total hours worked for each industry, ILO gives average weekly hours worked by person for each sector. For hours worked in each industry in non-OECD countries, we multiplied average weekly hours by the number of persons employed and by 52 weeks. We also considered same hours worked between employees and self-employed, as well as between skill levels. Difference in hours worked between genders was accounted for when available.

When there was no data for a specific industry, average hours worked in the entire economy was used. This can lead to errors in total hours worked, especially in the agriculture and fishing sectors, and in private households with employed people. Because these sectors usually involve greater share of self-employed workers than employees, frequently have a significant number of persons working for their own subsistence and have different dynamics than other good-producing industries, total hours worked in these sectors can be inaccurately estimated for some countries[7].

[7] Countries with no specific information on hours worked in the agricultural sector are Canada and Taiwan. Countries with no specific information on hours worked for private households with employed persons are Bulgaria, Canada, China, Japan, Malta, Romania, Russia, Taiwan, and Turkey.

7.1.2 Labour types

Labour inputs are divided for gender and skill types. We use three skill types (low-, medium-, and high-skilled), based on occupations and educational attainment levels, as related in table 7.2. For occupations, we use the definition from the *International Standard Classification of Occupations* (ILO 2012) and, for educational attainment, the *International Standard Classification of Education* (UNESCO 2012).

Skill type	Occupations [a]	Educational attainment levels [b]
Low-skilled	9 Elementary occupations	0 Less than primary education 1 Primary education 2 Lower secondary education
Medium-skilled	4 Clerical support workers 5 Services and sales workers 6 Skilled agricultural, forestry and fishery workers 7 Craft and related trades workers 8 Plant and machine operators, and assemblers	3 Upper secondary education 4 Post-secondary non-tertiary education
High-skilled	1 Managers 2 Professionals 3 Technicians and associate professionals	5 Short-cycle tertiary education 6 Bachelor's or equivalent level 7 Master's or equivalent level 8 Doctoral or equivalent level

Table 7.2. Correlation between skill types, occupations, and educational attainment levels
a) ISCO – 2008; b) ISCED - 2011

We provide industry-level information on labour types for persons engaged, hours worked, and relative share in compensation of employees, reflecting the heterogeneity of labour force and differences in remuneration by workers of different genders and skill levels.

The main source for gender and skill types information was LFS, gathered from ILO LABORSTA Database or from national statistical offices. Though number of workers by skill type is often available from these surveys, they usually do not account for hours worked or wages. Therefore, we assume no distinction in hours worked per week for different skill types.

To calculate the distribution of compensation of employees, we use relative wages inside a sector. That means that the relative difference between wages for high- and low-skilled workers would be similar inside a broad sector, even if the absolute wages are not similar. Relative wages were calculated from earning and income surveys, collected from national statistics offices, from the EU Structure of Earnings Survey for 2006 (Eurostat

2006), and, for countries with restrict access to data, relative wages were calculated from the EU KLEMS (2008) and WIOD Databases (2012).

Due to the high aggregation level for this data, labour types were calculated as shares of total inputs. We assume that the distribution of skilled workers would not differ greatly among sub-industries in an aggregated industry[8], and therefore, same distribution of gender and skill types can be applied inside a broad economic sector. Table 7.3 presents the aggregate industry sectors for which labour types shares were calculated.

Code	Industry
A & B	Agriculture, forestry, hunting and fishing
C	Mining and quarrying
D	Manufacturing
E	Electricity, gas and water supply
F	Construction
G	Wholesale and retail trade
H	Hotels and restaurants
I	Transport, storage and communication
J	Financial intermediation
K	Real estate, renting and business activities
L	Public administration and defence; compulsory social security
M	Education
N	Health and social work
O	Other community, social and personal services
P	Private households with employed persons

Table 7.3. Aggregated industries in labour types database

[8] Although there can be large differences among industries in the manufacturing sector, most of available information was highly aggregated for total manufacturing.

7.1.3 Rest of the World regions

Socio-economic data for the RoW region is also divided in five regions: RoW Asia and Pacific, RoW America, RoW Europe, RoW Africa and RoW Middle East. Total employment for each of the RoW regions was estimated by combining data from The World Bank (2011) and from the ILO (2008; 2009). Level of disaggregation for labour was in three major groups: Agriculture, forestry and fishing; Industry; and Services.

Estimates for hours worked, labour types and average differences in wages according to skill levels were estimated using proxies, presented in table 7.4. Countries serving as proxies were chosen according to the following characteristics:

- *Hours worked*: Out of the countries in CREEA, average weekly hours worked per person were considered as the closest to those from countries in the same region, according to data available from ILO LABORSTA;
- *Gender share*: Proxies for estimating the share of women in the economy were chosen according to average share of women in non-agricultural sector. Data for countries in the CREEA region were compared to those from the RoW region available in The World Bank;
- *Skill type*: Average skill types were chosen according to the average share of education attainment (primary, secondary and tertiary education, with data from The World Bank) in the entire economy. Due to the low availability of this information, the closest distribution from the CREEA countries with the available information for the RoW region was chosen;
- *Wages for skill types*: Differences in wages from skill types were considered from those countries in CREEA in the same region and similar Gini index, based on data *from The World Bank.*

RoW region	Proxies
RoW America	Mexico, Brazil
RoW Africa	South Africa
RoW Europe	Spain, Poland
RoW Asia and Pacific	Japan, Australia
RoW Middle East	Turkey

Table 7.4. Rest of the World regions and proxies used for hours worked and labour types

8 Water Accounts

The purpose of the works on the water extensions for the EXIOBASE was to improve the water extension data in terms of data quality and, if possible, coverage. So far, modelled data has been used for estimating water use and water consumption of different sectors. In CREEA the aim was to evaluate to what extend this modelled data could be replaced by "real" gathered data.

It turned out that for a comprehensive model like the EXIOBASE with a high level of sector disaggregation the available data on water use and consumption collected e.g. by national statistical agencies (NSA) is yet not of sufficient coverage or quality – or just not existent. As a consequence, we decided to use modelled data which – in comparison to the first version of the EXIOBASE – has been improved in methodological terms (compare D3.4 for more detailed descriptions).
The extensions covering the resource water encompass the following categories:

- Agricultural water consumption (blue/green)
- Industrial water use/consumption (blue)
- Agricultural nitrogen and phosphorous emissions to water
- Thermal pollution of (heat emissions to) water from energy production

The last item - water quality data on thermal discharges – is a new quality aspect so far unaddressed by the SEEAW and also in the EXIOBASE. This data allows relating water emissions with water quality and hence environmental impacts (see D3.4).
While in some cases original data on environmental extensions within EXIOBASE are available for updated base years, various work steps were necessary to ensure the readiness of the data to be used as environmental extensions (compare D3.4):

- Collection/calculation of new data (see above)
- Reclassification to the product classifications used within EXIOBASE.
- Check for revisions for the base year, carried out by the data providers
- Disaggregation according to the sector classification used within EXIOBASE. The data disaggregations are carried out using additional physical data as well monetary data from the SUTs on sectoral activities (see chapter 12)

The above explained steps were of special relevance in the case of industrial water use/consumption, where data from the WaterGAP model were used (Flörke, Kynast et al. 2013). In contrast to the data on agricultural water appropriation, these data are not available in the full product detail but only for five manufacturing sectors, two energy producing sectors of different types of cooling systems (once-through vs. tower cooling) as well as for different types of livestock breeding. Hence, these data had to be allocated to the different product classes used in EXIOBASE. While this was a relatively straight forward task in the case of the livestock data, the data on water appropriation in the manufacturing sector had to be allocated to the more detailed EXIOBASE product classes via the data on physical production quantities of the different products. In the case of energy production the data was allocated to those energy types which use cooling water in their production systems. Next, the data was allocated to the specific EXIOBASE sectors via the monetary data from the SUTs on sectoral activities (see chapter 12). For more detail please see D3.4.

The final results are four data sets encompassing information on:

- Country
- Extension label
- Product codes
- Industry codes
- Year
- Quantity
- Unit

Table 8.1 Water extensions

Water Consumption Blue - Livestock - dairy cattle
Water Consumption Blue - Livestock - nondairy cattle
Water Consumption Blue - Livestock - pigs
Water Consumption Blue - Livestock - sheep
Water Consumption Blue - Livestock - goats
Water Consumption Blue - Livestock - buffaloes
Water Consumption Blue - Livestock - camels
Water Consumption Blue - Livestock - horses
Water Consumption Blue - Livestock - chicken
Water Consumption Blue - Livestock - turkeys
Water Consumption Blue - Livestock - ducks
Water Consumption Blue - Livestock – geese
Water Consumption Blue - Manufacturing - Products of meat cattle
Water Consumption Blue - Manufacturing - Textiles (17)
Water Consumption Blue - Manufacturing – Pulp
Water Consumption Blue - Manufacturing - Plastics, basic
Water Consumption Blue - Manufacturing - Glass and glass products
Water Consumption Blue - Manufacturing - Basic iron and steel and of ferro-alloys and first products thereof
Water Consumption Blue - Manufacturing - Rubber and plastic products (25)
Water Consumption Blue - Electricity - tower - Electricity by coal
Water Consumption Blue - Electricity - once-through - Electricity by coal
Water Consumption Blue - Domestic - domestic Water Consumption Blue
Water Withdrawal Blue - Manufacturing - Products of meat cattle
Water Withdrawal Blue - Manufacturing - Textiles (17)
Water Withdrawal Blue - Manufacturing - Pulp
Water Withdrawal Blue - Manufacturing - Plastics, basic
Water Withdrawal Blue - Manufacturing - Glass and glass products
Water Withdrawal Blue - Manufacturing - Basic iron and steel and of ferro-alloys and first products thereof
Water Withdrawal Blue - Manufacturing - Rubber and plastic products (25)
Water Withdrawal Blue - Electricity - tower - Electricity by coal
Water Withdrawal Blue - Electricity - once-through - Electricity by coal
Water Withdrawal Blue - Domestic - domestic Water Withdrawal Blue

9 Material extensions

The purpose of the works on the material extensions for the EXIOBASE was to update and improve the material extension data in terms of data quality. Data for the material extensions were retrieved from SERI's Global Material Flow database was first set up in 2006 in the course of the EU-FP5 project MOSUS (www.mosus.net). Since 2006, it has been constantly improved, extended and updated in the course of several European and national projects (SERI 2013).

The Global Material Flow Database is the first and worldwide only database which comprehensively comprises global material extraction data for all material categories in annual time series, accounted for following the standards of economy-wide material flow accounting (MFA) as provided by Eurostat and the OECD (OECD 2008, Eurostat 2012d).

The database currently comprises more than 300 different types of materials, more than 220 countries and 30 years. For the use in the EXIOBASE these data were aggregated into the 48 different classes of (groups of) materials and 9 "umbrella" classes:
The following classes are distinguished – the numbers in brackets are the specific (groups of) materials within each class:

- Primary crops (12)
- Crop residues (2)
- Fodder crops (2)
- Grazing (1)
- Wood (2)
- Animals (4)
- Metal res (9)
- Non-metallic minerals (11)
- Fossil fuels (6)

For each material (group) used and unused extraction is reported and integrated as extension.

The data in the Global Material Flow Database are mainly based on three data sources – the British Geological Survey (BGS) and the US Geological Survey (USGS) for metal and mineral data, the International Energy Agency (IEA) for the data on fossil fuels and the Food and Agriculture Organization of the United Nations (FAO) for the data on biomass extraction. All these data are transformed according to MFA standards (OECD 2008, Eurostat 2012).

However, there are cases where the coverage or quality of the reported data is not satisfying. This holds true especially for the so-called "bulk materials" where large amounts of weight are appropriated by the economic system. Hence, an important aim of the work in Task 4.2 was the improvement of data availability and data quality of material flows in key areas of importance. Three areas were selected for work on MFA in CREEA:

- Improvement of the estimation procedure for material extraction related to construction activities
- Improvement of estimation procedures for biomass uptake by animals (grazing)
- Harmonisation and improvement of extraction data of metal ores

For a more detailed description please see D4.2.
Various work steps were necessary to ensure the readiness of the data to be used as environmental extensions:

- Collection/calculation of new data (see above)
- Reclassification to the product classifications used within EXIOBASE (see above).
- Check for revisions for the base year, carried out by the data providers
- Disaggregation according to the sector classification used within EXIOBASE. The data disaggregations were carried out using monetary data from the SUTs on sectoral activities (see chapter 12).

The final result is a data set encompassing information on:

- Country
- Extension label
- Product codes
- Industry codes
- Year
- Quantity
- Unit

Table 9.1 Material extensions

Domestic Extraction Used - Primary Crops - Rice
Domestic Extraction Used - Primary Crops - Fruits
Domestic Extraction Used - Primary Crops - Fibres
Domestic Extraction Used - Primary Crops - Other crops
Domestic Extraction Used - Primary Crops - Wheat
Domestic Extraction Used - Primary Crops - Other cereals
Domestic Extraction Used - Primary Crops - Roots and tubers
Domestic Extraction Used - Primary Crops - Sugar crops
Domestic Extraction Used - Primary Crops - Pulses
Domestic Extraction Used - Primary Crops - Nuts
Domestic Extraction Used - Primary Crops - Oil crops
Domestic Extraction Used - Primary Crops - Vegetables
Domestic Extraction Used - Fodder Crops - Fodder crops
Domestic Extraction Used - Grazing - Grazing
Domestic Extraction Used - Wood - Timber
Domestic Extraction Used - Wood - Other extractions
Domestic Extraction Used - Animals - Marine fish
Domestic Extraction Used - Animals - Inland water fish
Domestic Extraction Used - Animals - Other aquatic animals
Domestic Extraction Used - Crop Residues - Straw
Domestic Extraction Used - Crop Residues - Other crop residues
Domestic Extraction Used - Metal Ores - Iron ores

Domestic Extraction Used - Non-Metallic Minerals - Gravel and sand
Domestic Extraction Used - Non-Metallic Minerals - Other construction minerals
Domestic Extraction Used - Metal Ores - Bauxite and aluminium ores
Domestic Extraction Used - Metal Ores - Copper ores
Domestic Extraction Used - Metal Ores - Lead ores
Domestic Extraction Used - Metal Ores - Nickel ores
Domestic Extraction Used - Metal Ores - Tin ores
Domestic Extraction Used - Metal Ores - Uranium and thorium ores
Domestic Extraction Used - Metal Ores - Zinc ores
Domestic Extraction Used - Metal Ores - Precious metal ores
Domestic Extraction Used - Metal Ores - Other metal ores
Domestic Extraction Used - Non-Metallic Minerals - Chemical and fertilizer minerals
Domestic Extraction Used - Non-Metallic Minerals - Clays and kaolin
Domestic Extraction Used - Non-Metallic Minerals - Limestone, gypsum, chalk, dolomite
Domestic Extraction Used - Non-Metallic Minerals - Salt
Domestic Extraction Used - Non-Metallic Minerals - Slate
Domestic Extraction Used - Non-Metallic Minerals - Other industrial minerals
Domestic Extraction Used - Non-Metallic Minerals - Building stones
Domestic Extraction Used - Fossil Fuels - Hard coal
Domestic Extraction Used - Fossil Fuels - Lignite/brown coal
Domestic Extraction Used - Fossil Fuels - Crude oil
Domestic Extraction Used - Fossil Fuels - Natural gas
Domestic Extraction Used - Fossil Fuels - Natural gas liquids
Domestic Extraction Used - Fossil Fuels - Peat for energy use
Unused Domestic Extraction - Primary Crops - Rice
Unused Domestic Extraction - Primary Crops - Fruits
Unused Domestic Extraction - Primary Crops - Fibres
Unused Domestic Extraction - Primary Crops - Other crops
Unused Domestic Extraction - Primary Crops - Wheat
Unused Domestic Extraction - Primary Crops - Other cereals
Unused Domestic Extraction - Primary Crops - Roots and tubers
Unused Domestic Extraction - Primary Crops - Sugar crops
Unused Domestic Extraction - Primary Crops - Pulses
Unused Domestic Extraction - Primary Crops - Nuts
Unused Domestic Extraction - Primary Crops - Oil crops
Unused Domestic Extraction - Primary Crops - Vegetables
Unused Domestic Extraction - Fodder Crops - Fodder crops
Unused Domestic Extraction - Wood - Timber
Unused Domestic Extraction - Animals - Marine fish
Unused Domestic Extraction - Animals - Inland water fish
Unused Domestic Extraction - Metal Ores - Iron ores
Unused Domestic Extraction - Non-Metallic Minerals - Gravel and sand
Unused Domestic Extraction - Non-Metallic Minerals - Other construction minerals
Unused Domestic Extraction - Metal Ores - Bauxite and aluminium ores
Unused Domestic Extraction - Metal Ores - Copper ores
Unused Domestic Extraction - Metal Ores - Lead ores
Unused Domestic Extraction - Metal Ores - Nickel ores

Unused Domestic Extraction - Metal Ores - Tin ores
Unused Domestic Extraction - Metal Ores - Uranium and thorium ores
Unused Domestic Extraction - Metal Ores - Zinc ores
Unused Domestic Extraction - Metal Ores - Precious metal ores
Unused Domestic Extraction - Metal Ores - Other metal ores
Unused Domestic Extraction - Non-Metallic Minerals - Chemical and fertilizer minerals
Unused Domestic Extraction - Non-Metallic Minerals - Clays and kaolin
Unused Domestic Extraction - Non-Metallic Minerals - Limestone, gypsum, chalk, dolomite
Unused Domestic Extraction - Non-Metallic Minerals - Salt
Unused Domestic Extraction - Non-Metallic Minerals - Slate
Unused Domestic Extraction - Non-Metallic Minerals - Other industrial minerals
Unused Domestic Extraction - Non-Metallic Minerals - Building stones
Unused Domestic Extraction - Fossil Fuels - Hard coal
Unused Domestic Extraction - Fossil Fuels - Lignite/brown coal
Unused Domestic Extraction - Fossil Fuels - Crude oil
Unused Domestic Extraction - Fossil Fuels - Natural gas

10 Land use

The first focus for land use is on the data for cropland which comprises according to FAO definitions arable land and permanent crops. The approach for cropland is basically to derive comprehensive detailed data on individual crop basis (FAOSTAT: primary crops), supplemented by categories not commonly reported in statistics which are fallow land, forestry plantations on arable land, land for other agricultural purposes. In addition to the FAO online data base, data and information were thus taken from a multitude of single specific sources as documented in the detailed report in the annex. This concerns the use of specific national data for Taiwan and the People's Republic of China in order to derive specific data apart from the aggregated FAO data for China. Also, Eurostat data for the aggregate categories forage plants and fallow land were taken from the agricultural data base, to fill data gaps or replace FAO data which is indicated in the basic data sets.

FAO data for primary crops inherit some specific properties which are addressed in this report, especially that they include double or multiple counts in the case of multiple cropping during one year. The data in this set were prepared in two ways. The first set leaves the FAO data as they are, i.e. including multiple area counts where they may occur. The rational for this is that resource use in terms of cropland is thus directly comparable with the total production volume (and resulting yields) and also with monetary data for the particular year. The second set attempts to derive data for single land use for one year in order to allow for balancing between the aggregate FAO data for cropland (where no multiple counts occur) and the sum of individual uses. In accordance with the approach followed in EXIOPOL, the second set was delivered as environmental extension data to CREEA.

Next to cropland, permanent meadows and pastures make up the total of utilized agricultural land. FAO reports permanent meadows and pastures as a single number. We basically used these numbers, only in some cases corrected for forage plants harvested on permanent meadows and pastures. Further, we present here a first proposal to distinguish between intensive and extensive grazing systems based on work of PBL Netherlands Environmental Assessment Agency.

Forest area is a single number in FAO statistics comprising natural forests as well as managed forests and plantations. Furthermore, only the total area is reported. Further work could attempt to distinguish between forestry land use types and apply current approaches to account for land referring to the use of forestry (wood) resources, which may either be based on the area required to produce the net annual increment (NAI) or the area used for logging. This is out of the scope of the CREEA project.

Built-up and related land includes all developed land, including transportation infrastructure and human settlements. Basis for this category's data are the 2011 Annex 1 Party GHG Inventory Submissions under the United Nations Framework Convention on Climate Change (UNFCCC). Since this data does not cover all CREEA countries and is not complete for certain countries we used additional single specific sources or international data such as from the European Corine Land Cover project. Using several sources confronted us with certain problems such as differences in definitions of built up area, in

cadastral versus satellite data or incomplete and obsolete data. In order to provide most probable data for all countries, we therefore introduced some concepts to compare data between countries and check whether a certain source seemed to be reliable, such as share of built up land compared to a countries' total area or population per one square kilometre of built up land. We also estimated areas based on simple models depending on population density or use of construction materials.

As opposed to the other environmental extensions, the land use data has been prepared specifically for WP7, and thus detailed documentation is included in an annex to this report. Besides a discussion of methods, the reader also finds a detailed discussion for the data selection for built up land in every CREEA country. For more detail please see the attached annex on land use data.

The final result is a data set encompassing information on:

- Country
- Extension label
- Industry codes
- Year
- Quantity
- Unit

Table 10.1 Land use extensions

Classification of land use extensions
Land use-Arable Land - Rice[nature]
Land use-Arable Land - Wheat[nature]
Land use-Arable Land - Other cereals[nature]
Land use-Arable Land - Roots and tubers[nature]
Land use-Arable Land - Sugar crops[nature]
Land use-Arable Land - Pulses[nature]
Land use-Arable Land - Nuts[nature]
Land use-Arable Land - Oil crops[nature]
Land use-Arable Land - Vegetables[nature]
Land use-Arable Land - Fruits[nature]
Land use-Arable Land - Fibres[nature]
Land use-Arable Land - Other crops[nature]
Land use-Arable Land - Fodder crops[nature]
Land use-Pasture - Permanent pasture[nature]
Land use-Forest - Wood land[nature]

11 Energy and Emission Accounts

One of the important inputs to the EXIOBASE system is information on the environmental pressures related to climate change and air pollution issues, i.e. energy supply/use, land use/land use change and emissions to air. The WP6 report describes the energy supply/use and air emissions data that were calculated in WP6 and will be used as input to EXIOBASE.

Energy and combustion related air emission accounts are calculated based on the IEA dataset. As a first step, the IEA database is transferred from the territory to the residence principle by applying auxiliary datasets. The most important of these transformations occur in the transport sector, where a transition is needed from the place where fuels are sold (basis for the territory principle) to where the fuels are actually used.

Meantime, emission factors for greenhouse gases and air pollutants are calculated based on the best available guidance for estimating emissions of both air pollutants and greenhouse gases at country level. These methodologies also form the basis for the UNFCCC and CLRTAP official emissions. The methods are applied for each sector and each country on global level, resulting in a global emission dataset. This dataset is compared to the official emissions to ensure the quality and verify the total emissions. Emission factors are calculated by dividing emission and fuel use.

A complicated but crucial final step concerns the transformation of energy supply/use and emission factors to the EXIOBASE industry and product classifications, i.e. translation of IEA flow and product to EXIOBASE categories. A lot of auxiliary datasets are used to perform this transformation.

For the non-combustion air emission accounts, emissions are calculated similarly to the energy accounts by using standard and accepted methodologies used by countries to make their emission inventories. Similarly, emission factors are taken from the guidance documents and applied to selected activity data for each sector. The resulting emissions are used for comparisons to official UNFCCC and CLRTAP emissions, as well as to other estimates. Finally, emission factors for each source are connected to a product in the EXIOBASE classification, to use the emission factors in the EXIOBASE system.

This all in all results in a state-of-the-art dataset on energy accounts and air emission accounts to be fed into the EXIOBASE system, with several improvements implemented compared to the accounts that were created for the EXIOBASE 1.0. For more detail on the data and methods, please see the WP6 documentation.
The final result is a data set encompassing information on:

- Country
- Emission name
- Fuel carrier (Product codes)
- Industry codes
- Year
- Quantity
- Unit

Table 11.1 Air Emission extensions

Classification of air emission extensions
CO2 to air[air]
CH4 to air[air]
N2O to air[air]
SOx to air[air]
NOx to air[air]
NH3 to air[air]
CO to air[air]
Benzo(a)pyrene to air[air]
Benzo(b)fluoranthene to air[air]
Benzo(k)fluoranthene to air[air]
Indeno(1,2,3-cd)pyrene to air[air]
PAH to air[air]
PCBs to air[air]
PCDD_F to air[air]
HCB to air[air]
NMVOC to air[air]
PM10 to air[air]
PM2.5 to air[air]
TSP to air[air]
As to air[air]
Cd to air[air]
Cr to air[air]
Cu to air[air]
Hg to air[air]
Ni to air[air]
Pb to air[air]
Se to air[air]
Zn to air[air]

12 Material and water allocation

The nature of the material extraction and water extraction data is that the data is estimated on a product basis rather than an industry basis. That is, for example, the total Nickel ore extracted is known, but it is not known if there exists a specific Nickel industry, or whether the extraction of nickel ore is, say, a by-product of the iron ore industry.

The use of a Supply-Use system in the System of National Accounts (SNA), as well as the strict definition of an industry in the SNA means that the monetary Supply-Use system reflects the notion that a single industry can produce multiple products (co-production) beyond its primary product. As co-production is common in many economic sectors, it is imperative that the environmental extensions follow the same method of classification.

As such, additional information is required in order to allocate environmental extensions that refer to individual products to the industry that is producing that product. The monetary supply table (**V**) embodies such information – describing the quantity of product being produced by each industry. The subsequent allocation of extensions in a product classification to an industry classification is then straightforward using the market share matrix (percentage of each product being supplied by each industry):

$$\mathbf{T} = \mathbf{V} * \left(\widehat{\sum_{J} V_{ij}}\right)^{-1}$$

Where **T** is the transformation (in this case market share) matrix, **V** is the supply matrix of products *i* and industries *j.* Environmental extensions in product format $\mathbf{R^p}$ are then allocated to industry format $\mathbf{R^i}$ via **T**

$$\mathbf{R}^{i} = \widehat{\mathbf{R}^{p}}\mathbf{T}$$

This allocation has been performed for the material and water accounts for EXIOBASE 2.0. It is not applicable for the land use and emission accounts which were already directly collected in an industry classification.

13 Data Processing

As described, various data sets are collected, harmonized (e.g., in terms of product classification and currency), and converted into standardized Excel templates. These data include the following categories:

- intermediate use
- final use
- supply
- trade and transport margins
- international trade
- environmental and other extensions

Note that many of these data, but not all, are available in monetary as well as in physical form.

A data model was designed and implemented in the relational database management system MySQL to store all these data. On top of this DBMS, three programs were developed, using the the Java programming language. The first program does the following steps:

- creating and initializing the database
- import of the data from the Excel templates
- performing a set of checks on these data (e.g., incorrect industry codes, occurrence of double entries)
- storing of the successfully imported data in the database

The result is a filled country EE SUT database as shown in Figure 13.1.

A second Java program operates on the country EE-SUT database. In addition to enabling viewing, exporting, and consistency-checking the data, it performs the following critical steps:

- trade linking the individual country data
- creating a multi-regional SUT
- storing of this MR-SUT in the database for further use
- creating a logfile with the details of the trade-linking process

The trade-linking algorithm used has been documented by Bouwmeester (2008). It is currently done on the basis of the monetary data. Trade-linking on the basis of mixed monetary and physical SUTs is one of the options that is currently being implemented. The result of this step is a filled multi-regional SUT database as shown in Figure 1.

The stored MySQL file with the MR-SUT is the input to a third Java program. Its main tasks are:

- to convert the MR-SUT into an MR-IOT
- to calculate different properties of the MR- SUT (GDP, trade volumes etc).
- to export the IOT to files that can be processed elsewhere

The result of step 3 are several different kinds of MR-IOTs that can be read by third party tools (GAMS, Matlab) and our IO analysis tool, see Figure 13.1.

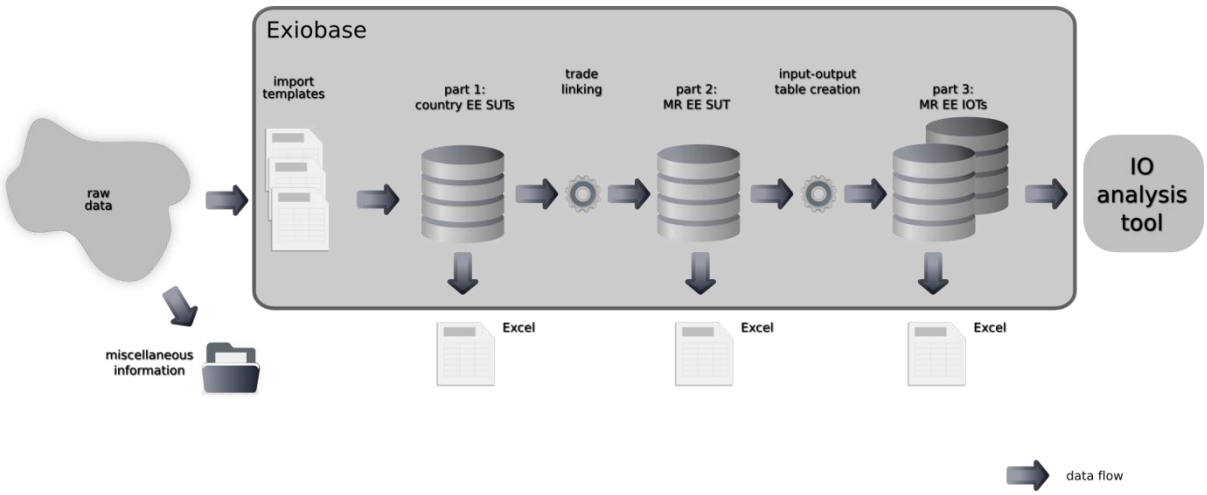

Figure 13.2 Illustration of the different components of the EXIOBASE database and the flow of data between the different components of the database. Source: Tukker et al., 2013.

For the IO-conversion, three basic types have been implemented (Eurostat, 2008):

- model B, the product-by-product IO-table based on the industry technology assumption
- model D, the industry-by-industry IO-table based on the fixed product sales structure assumption
- A PxI model, which is the only type that can be used in conjunction with a mixed unit MR-SUT but works for the monetary only MR-SUT also.

Model A (a product-by-product table based on the product technology assumption) and model C (an industry-by-industry table based on the fixed industry sales structure assumption) have not been implemented because they can yield negative results, which is often considered as unrealistic

Both model B and D can be created in transaction form or in coefficient form. The PxI model can only be provided in transaction form.

In contrast to the individual country data and the MR-SUT, the MR-IOTs are not stored as MySQL files, but directly exported in one of the two formats:

- text format, for instance to be read by Matlab or GAMS
- xml format, for easy import into CMLCA, our IO analysis tool

Like with trade-linking, the conversion of SUT into IOT is currently done on the basis of the monetary data.

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15 Appendices

15.1 APPENDIX A - Classifications

15.1.1 EXIOBASE 2.0 Product Classification

No	Name	Code1	Code2
1	Paddy rice	p01.a	C_PARI
2	Wheat	p01.b	C_WHEA
3	Cereal grains nec	p01.c	C_OCER
4	Vegetables, fruit, nuts	p01.d	C_FVEG
5	Oil seeds	p01.e	C_OILS
6	Sugar cane, sugar beet	p01.f	C_SUGB
7	Plant-based fibers	p01.g	C_FIBR
8	Crops nec	p01.h	C_OTCR
9	Cattle	p01.i	C_CATL
10	Pigs	p01.j	C_PIGS
11	Poultry	p01.k	C_PLTR
12	Meat animals nec	p01.l	C_OMEA
13	Animal products nec	p01.m	C_OANP
14	Raw milk	p01.n	C_MILK
15	Wool, silk-worm cocoons	p01.o	C_WOOL
16	Manure (conventional treatment)	p01.w.1	C_MANC
17	Manure (biogas treatment)	p01.w.2	C_MANB
18	Products of forestry, logging and related services (02)	p02	C_FORE
19	Fish and other fishing products; services incidental of fishing (05)	p05	C_FISH
20	Anthracite	p10.a	C_ANTH
21	Coking Coal	p10.b	C_COKC
22	Other Bituminous Coal	p10.c	C_OTBC
23	Sub-Bituminous Coal	p10.d	C_SUBC
24	Patent Fuel	p10.e	C_PATF
25	Lignite/Brown Coal	p10.f	C_LIBC
26	BKB/Peat Briquettes	p10.g	C_BKBP
27	Peat	p10.h	C_PEAT
28	Crude petroleum and services related to crude oil extraction, excluding surveying	p11.a	C_COIL
29	Natural gas and services related to natural gas extraction, excluding surveying	p11.b	C_GASE
30	Natural Gas Liquids	p11.b.1	C_GASL
31	Other Hydrocarbons	p11.c	C_OGPL
32	Uranium and thorium ores (12)	p12	C_ORAN
33	Iron ores	p13.1	C_IRON
34	Copper ores and concentrates	p13.20.11	C_COPO
35	Nickel ores and concentrates	p13.20.12	C_NIKO
36	Aluminium ores and concentrates	p13.20.13	C_ALUO
37	Precious metal ores and concentrates	p13.20.14	C_PREO
38	Lead, zinc and tin ores and concentrates	p13.20.15	C_LZTO
39	Other non-ferrous metal ores and concentrates	p13.20.16	C_ONFO
40	Stone	p14.1	C_STON

No	Name	Code1	Code2
41	Sand and clay	p14.2	C_SDCL
42	Chemical and fertilizer minerals, salt and other mining and quarrying products n.e.c.	p14.3	C_CHMF
43	Products of meat cattle	p15.a	C_PCAT
44	Products of meat pigs	p15.b	C_PPIG
45	Products of meat poultry	p15.c	C_PPLT
46	Meat products nec	p15.d	C_POME
47	products of Vegetable oils and fats	p15.e	C_VOIL
48	Dairy products	p15.f	C_DAIR
49	Processed rice	p15.g	C_RICE
50	Sugar	p15.h	C_SUGR
51	Food products nec	p15.i	C_OFOD
52	Beverages	p15.j	C_BEVR
53	Fish products	p15.k	C_FSHP
54	Tobacco products (16)	p16	C_TOBC
55	Textiles (17)	p17	C_TEXT
56	Wearing apparel; furs (18)	p18	C_GARM
57	Leather and leather products (19)	p19	C_LETH
58	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials (20)	p20	C_WOOD
59	Wood material for treatment, Re-processing of secondary wood material into new wood material	p20.w	C_WOOW
60	Pulp	p21.1	C_PULP
61	Secondary paper for treatment, Re-processing of secondary paper into new pulp	p21.w.1	C_PAPR
62	Paper and paper products	p21.2	C_PAPE
63	Printed matter and recorded media (22)	p22	C_MDIA
64	Coke Oven Coke	p23.1.a	C_COKE
65	Gas Coke	p23.1.b	C_GCOK
66	Coal Tar	p23.1.c	C_COTA
67	Motor Gasoline	p23.20.a	C_MGSL
68	Aviation Gasoline	p23.20.b	C_AGSL
69	Gasoline Type Jet Fuel	p23.20.c	C_GJET
70	Kerosene Type Jet Fuel	p23.20.d	C_KJET
71	Kerosene	p23.20.e	C_KERO
72	Gas/Diesel Oil	p23.20.f	C_DOIL
73	Heavy Fuel Oil	p23.20.g	C_FOIL
74	Refinery Gas	p23.20.h	C_RGAS
75	Liquefied Petroleum Gases (LPG)	p23.20.i	C_LPGA
76	Refinery Feedstocks	p23.20.j	C_REFF
77	Ethane	p23.20.k	C_ETHA
78	Naphtha	p23.20.l	C_NAPT
79	White Spirit & SBP	p23.20.m	C_WHSP
80	Lubricants	p23.20.n	C_LUBR
81	Bitumen	p23.20.o	C_BITU
82	Paraffin Waxes	p23.20.p	C_PARW
83	Petroleum Coke	p23.20.q	C_PETC
84	Non-specified Petroleum Products	p23.20.r	C_NSPP

No	Name	Code1	Code2
85	Nuclear fuel	p23.3	C_NUCF
86	Plastics, basic	p24.a	C_PLAS
87	Secondary plastic for treatment, Re-processing of secondary plastic into new plastic	p24.a.w	C_PLAW
88	N-fertiliser	p24.b	C_NFER
89	P- and other fertiliser	p24.c	C_PFER
90	Chemicals nec	p24.d	C_CHEM
91	Charcoal	p24.e	C_CHAR
92	Additives/Blending Components	p24.f	C_ADDC
93	Biogasoline	p24.g	C_BIOG
94	Biodiesels	p24.h	C_BIOD
95	Other Liquid Biofuels	p24.i	C_OBIO
96	Rubber and plastic products (25)	p25	C_RUBP
97	Glass and glass products	p26.a	C_GLAS
98	Secondary glass for treatment, Re-processing of secondary glass into new glass	p26.w.1	C_GLAW
99	Ceramic goods	p26.b	C_CRMC
100	Bricks, tiles and construction products, in baked clay	p26.c	C_BRIK
101	Cement, lime and plaster	p26.d	C_CMNT
102	Ash for treatment, Re-processing of ash into clinker	p26.d.w	C_ASHW
103	Other non-metallic mineral products	p26.e	C_ONMM
104	Basic iron and steel and of ferro-alloys and first products thereof	p27.a	C_STEL
105	Secondary steel for treatment, Re-processing of secondary steel into new steel	p27.a.w	C_STEW
106	Precious metals	p27.41	C_PREM
107	Secondary preciuos metals for treatment, Re-processing of secondary preciuos metals into new preciuos metals	p27.41.w	C_PREW
108	Aluminium and aluminium products	p27.42	C_ALUM
109	Secondary aluminium for treatment, Re-processing of secondary aluminium into new aluminium	p27.42.w	C_ALUW
110	Lead, zinc and tin and products thereof	p27.43	C_LZTP
111	Secondary lead for treatment, Re-processing of secondary lead into new lead	p27.43.w	C_LZTW
112	Copper products	p27.44	C_COPP
113	Secondary copper for treatment, Re-processing of secondary copper into new copper	p27.44.w	C_COPW
114	Other non-ferrous metal products	p27.45	C_ONFM
115	Secondary other non-ferrous metals for treatment, Re-processing of secondary other non-ferrous metals into new other non-ferrous metals	p27.45.w	C_ONFW
116	Foundry work services	p27.5	C_METC
117	Fabricated metal products, except machinery and equipment (28)	p28	C_FABM
118	Machinery and equipment n.e.c. (29)	p29	C_MACH
119	Office machinery and computers (30)	p30	C_OFMA
120	Electrical machinery and apparatus n.e.c. (31)	p31	C_ELMA
121	Radio, television and communication equipment and apparatus (32)	p32	C_RATV
122	Medical, precision and optical instruments, watches and clocks (33)	p33	C_MEIN
123	Motor vehicles, trailers and semi-trailers (34)	p34	C_MOTO
124	Other transport equipment (35)	p35	C_OTRE

No	Name	Code1	Code2
125	Furniture; other manufactured goods n.e.c. (36)	p36	C_FURN
126	*Secondary raw materials*	*p37*	*C_RYMS*
127	Bottles for treatment, Recycling of bottles by direct reuse	p37.w.1	C_BOTW
128	Electricity by coal	p40.11.a	C_POWC
129	Electricity by gas	p40.11.b	C_POWG
130	Electricity by nuclear	p40.11.c	C_POWN
131	Electricity by hydro	p40.11.d	C_POWH
132	Electricity by wind	p40.11.e	C_POWW
133	Electricity by petroleum and other oil derivatives	p40.11.f	C_POWP
134	Electricity by biomass and waste	p40.11.g	C_POWB
135	Electricity by solar photovoltaic	p40.11.h	C_POWS
136	Electricity by solar thermal	p40.11.i	C_POWE
137	Electricity by tide, wave, ocean	p40.11.j	C_POWO
138	Electricity by Geothermal	p40.11.k	C_POWM
139	Electricity nec	p40.11.l	C_POWZ
140	Transmission services of electricity	p40.12	C_POWT
141	Distribution and trade services of electricity	p40.13	C_POWD
142	Coke oven gas	p40.2.a	C_COOG
143	Blast Furnace Gas	p40.2.b	C_MBFG
144	Oxygen Steel Furnace Gas	p40.2.c	C_MOSG
145	Gas Works Gas	p40.2.d	C_MGWG
146	Biogas	p40.2.e	C_MBIO
147	Distribution services of gaseous fuels through mains	p40.2.1	C_GASD
148	Steam and hot water supply services	p40.3	C_HWAT
149	Collected and purified water, distribution services of water (41)	p41	C_WATR
150	Construction work (45)	p45	C_CONS
151	Secondary construction material for treatment, Re-processing of secondary construction material into aggregates	p45.w	C_CONW
152	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessoiries	p50.a	C_TDMO
153	Retail trade services of motor fuel	p50.b	C_TDFU
154	Wholesale trade and commission trade services, except of motor vehicles and motorcycles (51)	p51	C_TDWH
155	Retail trade services, except of motor vehicles and motorcycles; repair services of personal and household goods (52)	p52	C_TDRT
156	Hotel and restaurant services (55)	p55	C_HORE
157	Railway transportation services	p60.1	C_TRAI
158	Other land transportation services	p60.2	C_TLND
159	Transportation services via pipelines	p60.3	C_TPIP
160	Sea and coastal water transportation services	p61.1	C_TWAS
161	Inland water transportation services	p61.2	C_TWAI
162	Air transport services (62)	p62	C_TAIR
163	Supporting and auxiliary transport services; travel agency services (63)	p63	C_TAUX
164	Post and telecommunication services (64)	p64	C_PTEL
165	Financial intermediation services, except insurance and	p65	C_FINT

No	Name	Code1	Code2
	pension funding services (65)		
166	Insurance and pension funding services, except compulsory social security services (66)	p66	C_FINS
167	Services auxiliary to financial intermediation (67)	p67	C_FAUX
168	Real estate services (70)	p70	C_REAL
169	Renting services of machinery and equipment without operator and of personal and household goods (71)	p71	C_MARE
170	Computer and related services (72)	p72	C_COMP
171	Research and development services (73)	p73	C_RESD
172	Other business services (74)	p74	C_OBUS
173	Public administration and defence services; compulsory social security services (75)	p75	C_PADF
174	Education services (80)	p80	C_EDUC
175	Health and social work services (85)	p85	C_HEAL
176	Food waste for treatment: incineration	*p90.1.a*	*C_INCF*
177	Paper waste for treatment: incineration	*p90.1.b*	*C_INCP*
178	Plastic waste for treatment: incineration	*p90.1.c*	*C_INCL*
179	Intert/metal waste for treatment: incineration	*p90.1.d*	*C_INCM*
180	Textiles waste for treatment: incineration	*p90.1.e*	*C_INCT*
181	Wood waste for treatment: incineration	*p90.1.f*	*C_INCW*
182	Oil/hazardous waste for treatment: incineration	*p90.1.g*	*C_INCO*
183	Food waste for treatment: biogasification and land application	*p90.2.a*	*C_BIOF*
184	Paper waste for treatment: biogasification and land application	*p90.2.b*	*C_BIOP*
185	Sewage sludge for treatment: biogasification and land application	*p90.2.c*	*C_BIOS*
186	Food waste for treatment: composting and land application	*p90.3.a*	*C_COMF*
187	Paper and wood waste for treatment: composting and land application	*p90.3.b*	*C_COMW*
188	Food waste for treatment: waste water treatment	*p90.4.a*	*C_WASF*
189	Other waste for treatment: waste water treatment	*p90.4.b*	*C_WASO*
190	Food waste for treatment: landfill	p90.5.a	C_LANF
191	Paper for treatment: landfill	p90.5.b	C_LANP
192	Plastic waste for treatment: landfill	p90.5.c	C_LANL
193	Inert/metal/hazardous waste for treatment: landfill	p90.5.d	C_LANI
194	Textiles waste for treatment: landfill	p90.5.e	C_LANT
195	Wood waste for treatment: landfill	p90.5.f	C_LANW
196	Membership organisation services n.e.c. (91)	p91	C_ORGA
197	Recreational, cultural and sporting services (92)	p92	C_RECR
198	Other services (93)	p93	C_OSER
199	Private households with employed persons (95)	p95	C_PRHH
200	Extra-territorial organizations and bodies	p99	C_EXTO

15.1.2 EXIOBASE 2.0 Industry Classification

No	EXIOBASE 2.0 Industry sectors	Code1	Code2
1	Cultivation of paddy rice	i01.a	A_PARI
2	Cultivation of wheat	i01.b	A_WHEA
3	Cultivation of cereal grains nec	i01.c	A_OCER
4	Cultivation of vegetables, fruit, nuts	i01.d	A_FVEG
5	Cultivation of oil seeds	i01.e	A_OILS
6	Cultivation of sugar cane, sugar beet	i01.f	A_SUGB
7	Cultivation of plant-based fibers	i01.g	A_FIBR
8	Cultivation of crops nec	i01.h	A_OTCR
9	Cattle farming	i01.i	A_CATL
10	Pigs farming	i01.j	A_PIGS
11	Poultry farming	i01.k	A_PLTR
12	Meat animals nec	i01.l	A_OMEA
13	Animal products nec	i01.m	A_OANP
14	Raw milk	i01.n	A_MILK
15	Wool, silk-worm cocoons	i01.o	A_WOOL
16	Manure treatment (conventional), storage and land application	i01.w.1	A_MANC
17	Manure treatment (biogas), storage and land application	i01.w.2	A_MANB
18	Forestry, logging and related service activities (02)	i02	A_FORE
19	Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing (05)	i05	A_FISH
20	Mining of coal and lignite; extraction of peat (10)	i10	A_COAL
21	Extraction of crude petroleum and services related to crude oil extraction, excluding surveying	i11.a	A_COIL
22	Extraction of natural gas and services related to natural gas extraction, excluding surveying	i11.b	A_GASE
23	Extraction, liquefaction, and regasification of other petroleum and gaseous materials	i11.c	A_OGPL
24	Mining of uranium and thorium ores (12)	i12	A_ORAN
25	Mining of iron ores	i13.1	A_IRON
26	Mining of copper ores and concentrates	i13.20.11	A_COPO
27	Mining of nickel ores and concentrates	i13.20.12	A_NIKO
28	Mining of aluminium ores and concentrates	i13.20.13	A_ALUO
29	Mining of precious metal ores and concentrates	i13.20.14	A_PREO
30	Mining of lead, zinc and tin ores and concentrates	i13.20.15	A_LZTO
31	Mining of other non-ferrous metal ores and concentrates	i13.20.16	A_ONFO
32	Quarrying of stone	i14.1	A_STON
33	Quarrying of sand and clay	i14.2	A_SDCL
34	Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c.	i14.3	A_CHMF
35	Processing of meat cattle	i15.a	A_PCAT
36	Processing of meat pigs	i15.b	A_PPIG
37	Processing of meat poultry	i15.c	A_PPLT
38	Production of meat products nec	i15.d	A_POME

No	EXIOBASE 2.0 Industry sectors	Code1	Code2
39	Processing vegetable oils and fats	i15.e	A_VOIL
40	Processing of dairy products	i15.f	A_DAIR
41	Processed rice	i15.g	A_RICE
42	Sugar refining	i15.h	A_SUGR
43	Processing of Food products nec	i15.i	A_OFOD
44	Manufacture of beverages	i15.j	A_BEVR
45	Manufacture of fish products	i15.k	A_FSHP
46	Manufacture of tobacco products (16)	i16	A_TOBC
47	Manufacture of textiles (17)	i17	A_TEXT
48	Manufacture of wearing apparel; dressing and dyeing of fur (18)	i18	A_GARM
49	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear (19)	i19	A_LETH
50	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (20)	i20	A_WOOD
51	Re-processing of secondary wood material into new wood material	i20.w	A_WOOW
52	Pulp	i21.1	A_PULP
53	Re-processing of secondary paper into new pulp	i21.w.1	A_PAPR
54	Paper	i21.2	A_PAPE
55	Publishing, printing and reproduction of recorded media (22)	i22	A_MDIA
56	Manufacture of coke oven products	i23.1	A_COKE
57	Petroleum Refinery	i23.2	A_REFN
58	Processing of nuclear fuel	i23.3	A_NUCF
59	Plastics, basic	i24.1	A_PLAS
60	Re-processing of secondary plastic into new plastic	i24.1.w	A_PLAW
61	N-fertiliser	i24.2	A_NFER
62	P- and other fertiliser	i24.3	A_PFER
63	Chemicals nec	i24.4	A_CHEM
64	Manufacture of rubber and plastic products (25)	i25	A_RUBP
65	Manufacture of glass and glass products	i26.a	A_GLAS
66	Re-processing of secondary glass into new glass	i26.w.1	A_GLAW
67	Manufacture of ceramic goods	i26.b	A_CRMC
68	Manufacture of bricks, tiles and construction products, in baked clay	i26.c	A_BRIK
69	Manufacture of cement, lime and plaster	i26.d	A_CMNT
70	Re-processing of ash into clinker	i26.d.w	A_ASHW
71	Manufacture of other non-metallic mineral products n.e.c.	i26.e	A_ONMM
72	Manufacture of basic iron and steel and of ferro-alloys and first products thereof	i27.a	A_STEL
73	Re-processing of secondary steel into new steel	i27.a.w	A_STEW
74	Precious metals production	i27.41	A_PREM
75	Re-processing of secondary preciuos metals into new preciuos metals	i27.41.w	A_PREW
76	Aluminium production	i27.42	A_ALUM
77	Re-processing of secondary aluminium into new aluminium	i27.42.w	A_ALUW
78	Lead, zinc and tin production	i27.43	A_LZTP

No	EXIOBASE 2.0 Industry sectors	Code1	Code2
79	Re-processing of secondary lead into new lead	i27.43.w	A_LZTW
80	Copper production	i27.44	A_COPP
81	Re-processing of secondary copper into new copper	i27.44.w	A_COPW
82	Other non-ferrous metal production	i27.45	A_ONFM
83	Re-processing of secondary other non-ferrous metals into new other non-ferrous metals	i27.45.w	A_ONFW
84	Casting of metals	i27.5	A_METC
85	Manufacture of fabricated metal products, except machinery and equipment (28)	i28	A_FABM
86	Manufacture of machinery and equipment n.e.c. (29)	i29	A_MACH
87	Manufacture of office machinery and computers (30)	i30	A_OFMA
88	Manufacture of electrical machinery and apparatus n.e.c. (31)	i31	A_ELMA
89	Manufacture of radio, television and communication equipment and apparatus (32)	i32	A_RATV
90	Manufacture of medical, precision and optical instruments, watches and clocks (33)	i33	A_MEIN
91	Manufacture of motor vehicles, trailers and semi-trailers (34)	i34	A_MOTO
92	Manufacture of other transport equipment (35)	i35	A_OTRE
93	Manufacture of furniture; manufacturing n.e.c. (36)	i36	A_FURN
94	*Recycling of waste and scrap*	*i37*	*A_RYMS*
95	Recycling of bottles by direct reuse	i37.w.1	A_BOTW
96	Production of electricity by coal	i40.11.a	A_POWC
97	Production of electricity by gas	i40.11.b	A_POWG
98	Production of electricity by nuclear	i40.11.c	A_POWN
99	Production of electricity by hydro	i40.11.d	A_POWH
100	Production of electricity by wind	i40.11.e	A_POWW
101	Production of electricity by petroleum and other oil derivatives	i40.11.f	A_POWP
102	Production of electricity by biomass and waste	i40.11.g	A_POWB
103	Production of electricity by solar photovoltaic	i40.11.h	A_POWS
104	Production of electricity by solar thermal	i40.11.i	A_POWE
105	Production of electricity by tide, wave, ocean	i40.11.j	A_POWO
106	Production of electricity by Geothermal	i40.11.k	A_POWM
107	Production of electricity nec	i40.11.l	A_POWZ
108	Transmission of electricity	i40.12	A_POWT
109	Distribution and trade of electricity	i40.13	A_POWD
110	Manufacture of gas; distribution of gaseous fuels through mains	i40.2	A_GASD
111	Steam and hot water supply	i40.3	A_HWAT
112	Collection, purification and distribution of water (41)	i41	A_WATR
113	Construction (45)	i45	A_CONS
114	Re-processing of secondary construction material into aggregates	i45.w	A_CONW
115	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessoiries	i50.a	A_TDMO
116	Retail sale of automotive fuel	i50.b	A_TDFU
117	Wholesale trade and commission trade, except of motor	i51	A_TDWH

No	EXIOBASE 2.0 Industry sectors	Code1	Code2
	vehicles and motorcycles (51)		
118	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (52)	i52	A_TDRT
119	Hotels and restaurants (55)	i55	A_HORE
120	Transport via railways	i60.1	A_TRAI
121	Other land transport	i60.2	A_TLND
122	Transport via pipelines	i60.3	A_TPIP
123	Sea and coastal water transport	i61.1	A_TWAS
124	Inland water transport	i61.2	A_TWAI
124	Air transport (62)	i62	A_TAIR
126	Supporting and auxiliary transport activities; activities of travel agencies (63)	i63	A_TAUX
127	Post and telecommunications (64)	i64	A_PTEL
128	Financial intermediation, except insurance and pension funding (65)	i65	A_FINT
129	Insurance and pension funding, except compulsory social security (66)	i66	A_FINS
130	Activities auxiliary to financial intermediation (67)	i67	A_FAUX
131	Real estate activities (70)	i70	A_REAL
132	Renting of machinery and equipment without operator and of personal and household goods (71)	i71	A_MARE
133	Computer and related activities (72)	i72	A_COMP
134	Research and development (73)	i73	A_RESD
135	Other business activities (74)	i74	A_OBUS
136	Public administration and defence; compulsory social security (75)	i75	A_PADF
137	Education (80)	i80	A_EDUC
138	Health and social work (85)	i85	A_HEAL
139	Incineration of waste: Food	*i90.1.a*	*A_INCF*
140	Incineration of waste: Paper	*i90.1.b*	*A_INCP*
141	Incineration of waste: Plastic	*i90.1.c*	*A_INCL*
142	Incineration of waste: Metals and Inert materials	*i90.1.d*	*A_INCM*
143	Incineration of waste: Textiles	*i90.1.e*	*A_INCT*
144	Incineration of waste: Wood	*i90.1.f*	*A_INCW*
145	Incineration of waste: Oil/Hazardous waste	*i90.1.g*	*A_INCO*
146	Biogasification of food waste, incl. land application	*i90.3.a*	*A_BIOF*
147	Biogasification of paper, incl. land application	*i90.3.b*	*A_BIOP*
148	Biogasification of sewage slugde, incl. land application	*i90.3.c*	*A_BIOS*
149	Composting of food waste, incl. land application	*i90.4.a*	*A_COMF*
150	Composting of paper and wood, incl. land application	*i90.4.b*	*A_COMW*
151	Waste water treatment, food	*i90.5.a*	*A_WASF*
152	Waste water treatment, other	*i90.5.b*	*A_WASO*
153	Landfill of waste: Food	i90.6.a	A_LANF
154	Landfill of waste: Paper	i90.6.b	A_LANP
155	Landfill of waste: Plastic	i90.6.c	A_LANL
156	Landfill of waste: Inert/metal/hazardous	i90.6.d	A_LANI
157	Landfill of waste: Textiles	i90.6.e	A_LANT
158	Landfill of waste: Wood	i90.6.f	A_LANW
159	Activities of membership organisation n.e.c. (91)	i91	A_ORGA

No	EXIOBASE 2.0 Industry sectors	Code1	Code2
160	Recreational, cultural and sporting activities (92)	i92	A_RECR
161	Other service activities (93)	i93	A_OSER
162	Private households with employed persons (95)	i95	A_PRHH
163	Extra-territorial organizations and bodies	i99	A_EXTO

15.1.3 CREEA country classification

Number	Country/Region	Code	EU member
1	Austria	AT	EU
2	Belgium	BE	EU
3	Bulgaria	BG	EU
4	Cyprus	CY	EU
5	Czech Republic	CZ	EU
6	Germany	DE	EU
7	Denmark	DK	EU
8	Estonia	EE	EU
9	Spain	ES	EU
10	Finland	FI	EU
11	France	FR	EU
12	Greece	GR	EU
13	Hungary	HU	EU
14	Ireland	IE	EU
15	Italy	IT	EU
16	Lithuania	LT	EU
17	Luxembourg	LU	EU
18	Latvia	LV	EU
19	Malta	MT	EU
20	Netherlands	NL	EU
21	Poland	PL	EU
22	Portugal	PT	EU
23	Romania	RO	EU
24	Sweden	SE	EU
25	Slovenia	SI	EU
26	Slovakia	SK	EU
27	United Kingdom	GB	EU
28	United States	US	nonEU
29	Japan	JP	nonEU
30	China	CN	nonEU
31	Canada	CA	nonEU
32	South Korea	KR	nonEU
33	Brazil	BR	nonEU
34	India	IN	nonEU
35	Mexico	MX	nonEU
36	Russia	RU	nonEU
37	Australia	AU	nonEU
38	Switzerland	CH	nonEU
39	Turkey	TR	nonEU
40	Taiwan	TW	nonEU
41	Norway	NO	nonEU
42	Indonesia	ID	nonEU
43	South Africa	ZA	nonEU
44	RoW Asia and Pacific	WA	nonEU
45	RoW America	WL	nonEU
46	RoW Europe	WE	nonEU
47	RoW Africa	WF	nonEU
48	RoW Middle East	WM	nonEU

15.2 APPENDIX B - Labour accounts : Country-specific sources

Code	Country	Employment	Hours of work	Labour types	Wages
AT	Austria	NA	NA	LFS	ES
AU	Australia	LFS	LFS	LFS	EU KLEMS
BE	Belgium	NA	NA	LFS	ES
BG	Bulgaria	LFS	LFS	LFS	ES
BR	Brazil	LFS	LFS	LFS	WIOD
CA	Canada	NA	NA	LFS	EU KLEMS
CH	Switzerland	NA	NA	LFS	ES
CN	China	LFS	LFS	LFS, WIOD	WIOD
CY	Cyprus	LFS	LFS	LFS	ES
CZ	Czech Republic	NA	NA	LFS	ES
DE	Germany	NA	NA	LFS	ES
DK	Denmark	NA	NA	LFS	ES
EE	Estonia	NA	NA	LFS	ES
ES	Spain	NA	NA	LFS	ES
FI	Finland	NA	NA	LFS	ES
FR	France	NA	LFS	LFS	ES
GB	United Kingdom	NA	LFS	LFS	ES
GR	Greece	NA	NA	LFS	ES
HU	Hungary	NA	NA	LFS	ES
ID	Indonesia	LFS	LFS	LFS	WIOD
IE	Ireland	NA	LFS	LFS	ES
IN	India	LFS	LFS	LFS	ES
IT	Italy	NA	NA	LFS	ES
JP	Japan	NA	LFS	LFS	EU KLEMS
KR	South Korea	NA	NA	LFS	WIOD
LT	Lithuania	LFS	LFS	LFS	ES
LU	Luxembourg	NA	LFS	…, WIOD	WIOD
LV	Latvia	LFS	LFS	LFS	ES
MT	Malta	LFS	LFS	LFS	ES
MX	Mexico	LFS	LFS	LFS	WIOD
NL	Netherlands	NA	NA	LFS	ES
NO	Norway	NA	NA	LFS	ES
PL	Poland	NA	LFS	LFS	ES
PT	Portugal	LFS	LFS	LFS	ES
RO	Romania	LFS	LFS	LFS	ES
RU	Russia	LFS	LFS	LFS	WIOD
SE	Sweden	NA	NA	LFS	ES
SI	Slovenia	NA	LFS	LFS	ES
SK	Slovakia	NA	NA	LFS	ES
TR	Turkey	LFS	LFS	LFS	ES
TW	Taiwan	LFS	LFS	…, WIOD	WIOD
US	United States	NA	NA	LFS	EU KLEMS
ZA	South Africa	LFS	LFS	LFS	ES

NA = National Accounts; LFS = Labour Force Surveys; ES = Earnings/Income Surveys; WIOD = WIOD Database; EU KLEMS = EU KLEMS Database; … = No data available, use of a proxy country for gender shares

15.3 APPENDIX C - Provision of data on land use by country and category

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This annex gives an overview of the land use data for 2000 and 2007 acquired by category for the CREEA project. Its first focus is on the data for cropland which comprises according to FAO definitions arable land and permanent crops. The approach for cropland is basically to derive comprehensive detailed data on individual crop basis (FAOSTAT: primary crops), supplemented by categories not commonly reported in statistics which are fallow land, forestry plantations on arable land, land for other agricultural purposes. In addition to the FAO online data base, data and information were thus taken from a multitude of single specific sources as documented in this report. This concerns a.o. the use of specific national data for Taiwan and the People's Republic of China in order to derive specific data apart from the aggregated FAO data for China. Also, Eurostat data for the aggregate categories forage plants and fallow land were taken from the agricultural data base, to fill data gaps or replace FAO data which is indicated in the basic data sets.

FAO data for primary crops inherit some specific properties which are addressed in this report, especially that they include double or multiple counts in the case of multiple cropping during one year. The data in this set were prepared in two ways. The first set leaves the FAO data as they are, i.e. including multiple area counts where they may occur. The rational for this is that resource use in terms of cropland is thus directly comparable with the total production volume (and resulting yields) and also with monetary data for the particular year. The second set attempts to derive data for single land use for one year in order to allow for balancing between the aggregate FAO data for cropland (where no multiple counts occur) and the sum of individual uses. In accordance with the approach followed in EXIOPOL, the second set was delivered as environmental extension data to CREEA.

Next to cropland, permanent meadows and pastures make up the total of utilized agricultural land. FAO reports permanent meadows and pastures as a single number. We basically used these numbers, only in some cases corrected for forage plants harvested on permanent meadows and pastures. Further, we present here a first proposal to distinguish between intensive and extensive grazing systems based on work of PBL Netherlands Environmental Assessment Agency.

Forest area is a single number in FAO statistics comprising natural forests as well as managed forests and plantations. Furthermore, only the total area is reported. Further work could attempt to distinguish between forestry land use types and apply current approaches to account for land referring to the use of forestry (wood) resources, which may either be based on the area required to produce the net annual increment (NAI) or the area used for logging. This is out of the scope of the CREEA project.

Built-up and related land includes all developed land, including transportation infrastructure and human settlements. Basis for this category's data are the 2011 Annex 1 Party GHG Inventory Submissions under the United Nations Framework Convention on Climate Change (UNFCCC). Since this data does not cover all CREEA countries and is not

complete for certain countries we used additional single specific sources or international data such as from the European Corine Land Cover project. Using several sources confronted us with certain problems such as differences in definitions of built up area, in cadastral versus satellite data or incomplete and obsolete data. In order to provide most probable data for all countries, we therefore introduced some concepts to compare data between countries and check whether a certain source seemed to be reliable, such as share of built up land compared to a countries' total area or population per one square kilometre of built up land. We also estimated areas based on simple models depending on population density or use of construction materials. Besides a discussion of methods, the reader also finds a detailed discussion for the data selection for built up land in every CREEA country.

15.3.1 Definitions and Settings

The main and general source for data of land use in agriculture and forestry is the FAO online database. Some countries use special definitions for land use categories that will be addressed in the respective sections.

15.3.1.1 Agricultural land

The following definitions are taken from the FAO glossary:
http://faostat3.fao.org/home/index.html#METADATA_GLOSSARY

Agricultural area, this category is the sum of areas under **a) arable land** - land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included in this category. Data for "Arable land" are not meant to indicate the amount of land that is potentially cultivable; **(b) permanent crops** - land cultivated with long-term crops which do not have to be replanted for several years (such as cocoa and coffee); land under trees and shrubs producing flowers, such as roses and jasmine; and nurseries (except those for forest trees, which should be classified under "forest"); and **(c) permanent meadows and pastures** - land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land). Data are expressed in 1000 hectares.

Two data sets of FAO are used to account for land use in agriculture[9]:

- **ResourceSTAT:** The ResourceSTAT-Land-use domain includes: Country area (including area under inland water bodies), Land area (excluding area under inland water bodies), Agricultural area, Arable land and Permanent crops (also called "cropland"), Arable land, Permanent crops, Permanent meadows and pastures, Forest area, Other land and Area equipped for irrigation. Detailed information on sub-categories comprises: Temporary crops, Temporary meadows and pastures, Fallow land (temporary: less than 5 years), Permanent meadows and pastures cultivated and naturally grown, and Organic land. Data are available from 1961 to 2009 for more than 200 countries and areas. http://faostat.fao.org/site/377/default.aspx#ancor
- **ProdSTAT:** Area harvested which refers to cropland comprising arable land and permanent crops. Data refer to the area from which a crop is gathered. Area harvested,

[9] Using the FAOSTAT classic view: http://faostat.fao.org/?lang=en ; the new FAOSTAT is slightly differently organised but provides the same data.

therefore, excludes the area from which, although sown or planted, there was no harvest due to damage, failure, etc. It is usually net area for temporary crops and sometimes gross area for permanent crops. Net area differs from gross area insofar as the latter includes uncultivated patches, footpaths, ditches, headlands, shoulders, shelterbelts, etc. If the crop under consideration is harvested more than once during the year as a consequence of successive cropping (i.e. the same crop is sown or planted more than once in the same field during the year), the area is counted as many times as harvested. On the contrary, area harvested will be recorded only once in the case of successive gathering of the crop during the year from the same standing crops. With regard to mixed and associated crops, the area sown relating to each crop should be reported separately. When the mixture refers to particular crops, generally grains, it is recommended to treat the mixture as if it were a single crop; therefore, area sown is recorded only for the crop reported. http://faostat.fao.org/site/567/default.aspx#ancor

For our calculations of the aggregate of cropland we used the data of FAOSTAT for arable land and permanent crops according to the following definitions:
Arable land is defined as the "land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included in this category. Data for "Arable land" are not meant to indicate the amount of land that is potentially cultivable. Data are expressed in 1000 hectares."
Permanent crops is defined as "land cultivated with long-term crops which do not have to be replanted for several years (such as cocoa and coffee); land under trees and shrubs producing flowers, such as roses and jasmine; and nurseries (except those for forest trees, which should be classified under "forest"). Permanent meadows and pastures are excluded from land under permanent crops. Data are expressed in 1000 hectares."

Cropland comprises arable land and permanent crops land and produces primary crops as defined:
Primary crops: are those which come directly from the land and without having undergone any real processing, apart from cleaning. They maintain all the biological qualities they had when they were still on the plants. Certain primary crops can be aggregated, with their actual weight, into totals offering meaningful figures on area, yield, production and utilization; for example, cereals, roots and tubers, nuts, vegetables and fruits. Other primary crops can be aggregated only in terms of one or the other component common to all of them. For example, primary crops of the oil-bearing group can be aggregated in terms of oil or oil cake equivalent. Primary crops are divided into temporary and permanent crops. Temporary crops are those which are both sown and harvested during the same agricultural year, sometimes more than once; permanent crops are sown or planted once and not replanted after each annual harvest.

So arable land and permanent crops are thus not equal to the total agricultural area that also includes permanent meadows and pastures:
Permanent meadows and pastures is the land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land). Data are expressed in 1000 hectares.

15.3.1.2 Forestland

Forest area after FAOSTAT: Global Forest Resource Assessment 2010 (FRA 2010) is the main source of forest area data in FAOSTAT. Data were provided by countries for years 1990, 2000, 2005 and 2010. Data for intermediate years were estimated for FAO using linear interpolation and tabulation. http://faostat.fao.org/site/377/default.aspx#ancor

Forest area is the land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use. Forest is determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 metres (m) in situ. Areas under reforestation that have not yet reached but are expected to reach a canopy cover of 10 percent and a tree height of 5 m are included, as are temporarily unstocked areas, resulting from human intervention or natural causes, which are expected to regenerate. Includes: areas with bamboo and palms provided that height and canopy cover criteria are met; forest roads, firebreaks and other small open areas; forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest; windbreaks, shelterbelts and corridors of trees with an area of more than 0.5 ha and width of more than 20 m; plantations primarily used for forestry or protective purposes, such as: rubber-wood plantations and cork, oak stands. Forest area excludes tree stands in agricultural production systems, for example in fruit plantations and agro-forestry systems. The term also excludes trees in urban parks and gardens. Data are expressed in 1000 hectares.

15.3.1.3 Built-up and related land

Our objective was to establish a data set covering the built up area in 44 CREEA countries in the year 2007. In our approach to collecting data we basically used two databases (see also report on WP6, Task 2 – land use change) that provide data on an international basis:

- First, the database of the 2011 Annex 1 Party GHG Inventory Submissions under the United Nations Framework Convention on Climate Change [53], which is meant to be the basis of this work-package. It comprises in principle data on built up areas for 35 countries.
- Second, the Corine Land Cover 2006 database of the European Environment Agency [10], covering 27 European countries.

In total, 37 countries are covered by these two databases, but 7 CREEA countries aren't covered in neither of them: Brazil, India, Indonesia, Mexico, South Africa, South Korea and Taiwan.

In order to provide land use data in a balanced way as accurate as possible we tried to find at least two sources of built up areas for a country and also established methods to verify data or to estimate data for missing values.

Definitions of built up areas

a) Definition according to the *United Nations Framework Convention on Climate Change* ([23], p. 2.6):

Settlements: This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. This should be consistent with the selection of national definitions.

b) Definition according to the *European Environment Agency* ([7], p. 22):

1. Artificial surfaces
1.1. Urban fabric
1. 1. 1. Continuous urban fabric Most of the land is covered by . Buildings, roads and artificially surfaced area cover almost all the ground. Non-linear areas of vegetation and bare soil are exceptional.
1.1.2. Discontinuous urban fabric Most of the land is covered by structures. Buildings, roads and artificially surfaced areas associated with vegetated areas and bare soil, which occupy discontinuous but significant surfaces.
1.2. Industrial, commercial and transport
1.2.1. Industrial or commercial units. Artificially surfaced areas (with concrete, asphalt, tarmacadam, or stabilised, e.g. beaten earth) devoid of vegetation, occupy most of the area in question, which also contains buildings and/or vegetated areas.
1.2.2. Road and rail networks and associated land motorways, railways, including associated installations (stations, platforms, embankments). Minimum width to include: I 00 m.
1.2.3. Port areas Infrastructure of port areas, including quays, dockyards and marinas.
1.2.4. Airports. Airport installations: runways, buildings and associated land.
1.3. Mine, dump and construction sites
1.3.1. Mineral extraction sites areas with open-pit extraction of industrial minerals (sandpits, quarries) or other minerals (opencast mines). Includes flooded gravel pits, except for river-bed extraction.
1.3.2. Dump sites landfill or mine dump sites, industrial or public.
1.3.3. Construction sites spaces under construction development, soil or bedrock excavations, earthworks.
1.4. Artificial, non-agricultural vegetated areas
1.4.1. Green urban areas. Areas with vegetation within urban fabric. Includes parks and cemeteries with vegetation.
1.4.2. Sport and leisure facilities, camping grounds, sports grounds, leisure parks, golf courses, racecourses, etc. Includes formal parks not surrounded by urban zones.

Methods: General Data Restrictions, Verification and Estimation:

Satellite imaging and official cadastral data

Although a countries' built up area may be consistently defined there are often huge differences in data from different sources. We found that for European countries the built up area calculated from satellite images (Corine Land Cover) was way below official data (i.e. IPCC or official statistics). Comparing the official data submitted for 2007 to the IPCC with Corine Land Cover for 2006 we often found big differences. For example for Estonia the reported built up areas differ from each other by 324%. We have similar findings for Sweden (292%), Latvia (291%), Norway (248%), France (179%) and Germany (118-157%). Across all countries the official data exceeds the satellite data by 157% in 2007.

Why are built up areas derived from satellite data significantly lower?

We think of the resolution of satellite image as a possible solution. Corine Land Cover data used to classify land use usually are resolved on a scale of 1:25,000-1:10,000 and are analyzed with help of a 0.25 km x 0.25 km grid. We think that this might lead to an underestimation of built up areas in large-area countries, since especially in Scandinavia roads or power-lines or other small infrastructure on rural and non-settlement land is invisible to the satellites' eye.

Testing the data: Is the data complete?

Total country area
We compared the summed up area of all categories (i.e. agricultural land, forestland, built up land, inland waters, etc.) of a source with the total country area to verify whether the given areas display the whole country area. As reference we used the total country area from FAOStat [12] for the respective year and country. In some cases of 2011 Annex 1 Party GHG Inventory Submissions data for instance the total country area for Great Britain, USA and Malta diverges hugely from the official country area.

Is the size of the built up area realistic?

In order to check if the given built up area for a country is realistic we calculated the population density with help of the countries' official population:

Population density = Total population in a given year / built up area in the same year.

We compared this data to the average population density in selected cities of this country from the UN Urban Population project to get an idea if our built up area is realistic. This approach helped us also to estimate missing values.

For example, according to data from World Resources Institute [58] the population density in China is 140,000 people per sq. km or 230,000 people per sq. km in Malta according to 2011 Annex 1 Party GHG Inventory Submissions [53].

Estimation of built up areas due to urbanization rates and densities

A regular used approach to verify given built up areas or to estimate them is the comparison to urban (table 1.2) and country (table 1.1) population densities. The population density is calculated as population divided by the built up area in a given year as given above.

Table 1.1: Average densities for European countries according to satellite imaging and cadastral data

Country	Population density for Corine Land Cover data. (People per sq. km built up area)	Population density for UNFCCC data. (People per sq. km built up area)
Austria	2,031	1,652
Belgium	1,672	1,764
Bulgaria	1,369	925
Cyprus	1,344	
Czech Republic	2,055	1,537
Denmark	1,684	1,229
Estonia	1,426	463

Finland	1,094	371
France	2,184	1,301
Germany	2,739	2,250
Greece		2,113
Hungary	1,788	1,786
Ireland	2,640	3,766
Italy	3,970	3,912
Latvia	2,647	930
Lithuania	1,567	1,081
Luxembourg	1,969	1,933
Malta	5,050	228,151
Netherlands	3,218	2,690
Norway	1,853	752
Poland	3,044	1,871
Portugal	3,360	3,287
Romania	1,432	2,012
Slovakia	2,021	
Slovenia	3,602	1,853
Spain	4,328	3,966
Sweden	1,457	476
UK		
EU27		1,975

Table 1.2: Urban Densities for selected countries/regions

Region	Average Population per Square Kilometer of Urban Areas (<500k)
Western Europe (without UK)	2850
UK	4100
US	1150
Canada	1550
Australia	1450
Japan	4800
China	10550
India	15700
Russia	5250
Latin America and the Caribbean	6650
New Zealand	1950

Data is out of date: Estimating built up areas based on Corine Land Cover for 2007:

The most recent year for Corine Land Cover data is 2006. In cases where we used this data we therefore needed to estimate the value for 2007. We did this using the growth rates of built up areas between 2006 and 2007 using Annex 1 Party GHG Inventory Submissions [53]. For specific values refer to Table 1.3.

Table 1.3: Growth rates of built up areas in Europe in 2006/2007 according to Annex 1 Party GHG Inventory Submissions [53]

COUNTRY	Growth 06/07
Austria	1,61%
Belgium	0,76%
Bulgaria	0,26%
Czech Republic	0,36%
Denmark	0,74%

Estonia	0,74%
Finland	0,96%
France	1,10%
Germany	1,04%
Hungary	0,42%
Ireland	1,42%
Italy	0,75%
Latvia	0,12%
Lithuania	0,03%
Netherlands	1,87%
Norway	0%
Poland	-0,05%
Portugal	0,29%
Romania	1,10%
Slovakia	0,37%
Slovenia	1,33%
Spain	1,82%
Sweden	-0,30%
European Union (27)	0,96%

Estimating the growth of built up areas with help of material use of construction materials

We started from the hypothesis that a change in the use of construction materials leads to a change in expansion of built up areas. As we found out, the correlation between both is significant and allowed establishing a simple model to estimate the development of built up areas based on common and easy to find indicators.

The model was used for estimating the built-up area in 2007 in Mexico, South Africa and Taiwan, in every case in comparison with published data for earlier years.

Annex 1 Party GHG Inventory Submissions are used with first priority.

Data for settlements area given in the 2011 Annex 1 Party GHG Inventory Submissions under the United Nations Framework Convention on Climate Change [53] were used in first place if plausible (see blue marked numbers in table 1.4) The selection of the most reasonable data source is described in section 3.4.

For Finland, Germany, Sweden, and UK neither UNFCCC nor Corine but special national data sources were used – see 3.4 for reasoning.

Table 1.4: Characteristic data related to land use for EU countries and Norway after UNFCCC and Corine land cover

COUNTRY	Total Land Area	Population in 2007	Urbanization in 2007	Built Up Area (UNFCCC) in 2007	Share of Built Up Area	Population Density (UNFCCC)	Built Up Area (Corine) in 2000-2006 (average)	Share of Built Up Area (Corine)	Population Density (Corine)
	Area in sq. Km		Percentage of Population Residing in Urban Areas	Area in sq. Km		Population per 1 sq. km Built up Area	Area in sq. Km		Population per 1 sq. km Built up Area
Austria	82,450	8,310,000	67	5,029	6.1%	1,652	4,093	5.0%	2,031
Belgium	30,280	10,539,000	97	5,975	19.7%	1,764	6,303	20.8%	1,672
Bulgaria	108,610	7,640,000	71	8,255	7.6%	925	5,582	5.1%	1,369
Cyprus	9,240	1,063,000	70	no data			791	8.6%	1,344
Czech Republic	77,250	10,314,000	74	6,712	8.7%	1,537	5,019	6.5%	2,055
Denmark	42,430	5,469,000	86	4,449	10.5%	1,229	3,247	7.7%	1,684
Estonia	42,390	1,343,000	69	2,902	6.8%	463	942	2.2%	1,426
Finland	304,090	5,290,000	83	14,271	4.7%	371	4,834	1.6%	1,094
France	547,660	61,745,000	83	47,458	8.7%	1,301	28,272	5.2%	2,184
Germany	348,670	82,516,000	74	36,676	10.5%	2,250	30,123	8.6%	2,739
Greece	128,900	11,256,000	61	5,326	4.1%	2,113	no data		
Hungary	89,610	10,043,000	68	5,622	6.3%	1,786	5,616	6.3%	1,788
Ireland	68,890	4,291,000	61	1,140	1.7%	3,766	1,626	2.4%	2,640
Italy	294,140	59,495,000	68	15,208	5.2%	3,912	14,986	5.1%	3,970
Latvia	62,196	2,282,000	68	2,453	3.9%	930	862	1.4%	2,647
Lithuania	62,680	3,379,000	67	3,127	5.0%	1,081	2,156	3.4%	1,567
Luxembourg	2,590	476,000	85	246	9.5%	1,933	242	9.3%	1,969
Malta	320	413,000	94	2	0.6%	228,151	82	25.6%	5,050
Netherlands	33,760	16,443,000	81	6,112	18.1%	2,690	5,110	15.1%	3,218
Norway	304,280	4,722,000	78	6,282	2.1%	752	2,548	0.8%	1,853
Poland	304,250	38,190,000	61	20,410	6.7%	1,871	12,547	4.1%	3,044
Portugal	91,470	10,608,000	59	3,227	3.5%	3,287	3,157	3.5%	3,360
Romania	229,890	21,645,000	53	10,758	4.7%	2,012	15,113	6.6%	1,432
Slovakia	48,100	5,431,000	55	no data			2,687	5.6%	2,021
Slovenia	20,140	2,012,000	50	1,086	5.4%	1,853	559	2.8%	3,602
Spain	499,110	44,604,000	77	11,246	2.3%	3,966	10,305	2.1%	4,328
Sweden	410,340	9,161,000	85	19,235	4.7%	476	6,289	1.5%	1,457
UK	241,930	61,128,000	79	incomplete data			no data		
EU27	4,181,386	495,086,000		250,627	6.0%	1,975	n.a.		
Mean	160,202	17,850,286	72	9,728	6.1%	1,835	6,657	4.2%	2,681

Selected for CREEA land use data set

15.3.2 ALLOCATION TO CREEA ENVIRONMENTAL EXTENSIONS

15.3.2.1 Cropland

Land use data on the detailed level of FAO primary crops and supplementary categories are allocated to the environmental extensions categories of CREEA shown in tables A.1 and A.3 in the annex.

For People's Republic of China and Taiwan we used national data sources as indicated below and allocated to the CREEA categories as indicated.

In addition to FAO primary crops the following aggregate land use categories were introduced in order to derive a comprehensive land use account for cropland:
- Fallow Land: no allocation to CREEA categories, however, an additional category was made up to present the data
- Forestry plantation: allocation to CREEA category "other crops"
- Other agricultural purposes: allocation to CREEA category "other crops"

The validity of this approach was tested on the basis of national data sets such as from Germany and Australia.

15.3.2.2 Permanent meadows and pastures

is allocated to a single category "L_2 Pasture - Permanent pasture".

15.3.2.3 Forest land

is allocated to a single category "L_3 Forest - Wood land"

15.3.2.4 Built-up and related land

is allocated to an extra category named "L_4 Settlements".

15.3.3 Land use data for countries

15.3.3.1 Cropland

Original data used to compile the land use account for cropland and existing limitations are shown in table 3.1. Unless otherwise stated in the table, FAO data sets as described above (see section 1) were used to compile the area for primary crops and fallow land as well as the aggregate area for arable land and permanent crops (FAO (2011a), FAO (2011b)). For all 27 EU countries agricultural statistics of Eurostat were used to derive data for fallow land and forage crops (Eurostat (2011a), Eurostat (2011b)).

The data set compiled from the original data was further refined by allocating surplus cropland area (due to multiple cropping) respectively missing cropland area (not represented by sum of primary crops) to the categories of primary crops in relation to their individual shares of the sum of reported primary crops area. This reflects the approach chosen in the EXIOPOL project. The resulting data set was provided as environmental extension data set to CREEA.

Table 3.1: Sources used to compile cropland area by country and current limitations (refers to original, not modified data).

Country / Region	Sources (additional to FAO and Eurostat)	Comments
Australia	Detailed data by region were available from the Australian Bureau of Statistics: ABS (2008) & ABS (2009)	Data were synchronised with FAO aggregate categories for arable land, permanent crops, permanent meadows and pastures. This way, data for other agricultural purpose not indicated by FAO were obtained. Data of ABS were available only from 2007 onwards, no data for 2000 were found. Data for 2000 are balanced, for 2007 primary crops land is by 11% higher than total FAO cropland.
Austria	FAO and Eurostat only	Sufficiently balanced
Belgium	FAO and Eurostat only	Sufficiently balanced
Brazil	Edward (2004) for fallow land; Instituto Brasileiro de Geografia e Estatística, IBGE (2007), for alignment with FAO data and forest plantations.	*Fallow land*: Placeholder only, taken from Edward 2004 (original source): cultivated land makes up ca. 47 million ha, Pastures ca 220 Mha, Cleared fallow land ca 20 Mha. Thus fallow land would make up around 30% of reported FAO cropland. *Forestry plantation*: value is for 2006. *Forage plants*: no data found *Other agricultural purpose*: - *General*: multiple cropping area is likely, primary crops total area exceeds FAO cropland total by 15% in 2000 and by 27% in 2007.
Bulgaria	FAO and Eurostat only	Sufficiently balanced
Canada	FAO only	*Fallow land*: estimates for 2000 and 2007-2009 based on extrapolation of ResourceSTAT data for 2001-2006. *Forestry plantation*: Data relating to "Permanent Crops" is largely the area on farms that is covered by "Forest and Woodland": whereas, the area used to cultivate fruit and fibre crops, which is less than one percent of the land in crops is included in the "Arable Land" category (FAOSTAT). We therefore took the area for permanent crops for the category forestry plantations. *Forage plants*: Land use for forage crops not reported by FAO was estimated from the difference of the aggregate arable land and permanent crops minus the sum of all individual land use categories as described.
China (People's Republic of)	National Bureau of Statistics of China (2008) – and current online data	FAO data need correction for separation into P.R. China and Taiwan; therefore, data for P.R. China could only be derived for the crop classifications reported by Statistics P.R. China.
China (Republic of) – Taiwan	Council of Agriculture, Executive Yuan R.O.C (2008a), Council of Agriculture, Executive Yuan R.O.C (2008b); Worldstat info for area of permanent meadows and pastures: http://en.worldstat.info/Asia/Taiwan/Land	Taiwan data are by crop classification as reported by Statistics Taiwan. Data for permanent pastures are only for 2007. Data for forest land are only for 2007.
Cyprus	FAO and Eurostat only	primary crops plus fallow land and forage crops make up 107% of cropland in 2007 (2000 is well balanced)
Czech Republic	FAO and Eurostat only	primary crops plus fallow land and forage crops make up 87% of cropland in 2007 (2000 is well balanced)
Denmark	FAO and Eurostat only	Primary crops aggregate (plus fallow land) is

		by about 10% more than cropland total. So, it contains most probably harvested pasture land (another indication is that FAO data for forage crops area are significantly higher than respective ESTAT data) which was therefore subtracted from permanent meadows and pastures.
Estonia	FAO and Eurostat only	Slight overshoot of primary crops and fallow land in 2007 (105%). For the same reason as stated for Denmark, the area of permanent meadows and pastures was adjusted.
Finland	FAO and Eurostat only	Sufficiently balanced
France	FAO and Eurostat only	Sufficiently balanced
Germany	Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz – BMELV (2011)	Primary crops aggregate (plus fallow land) was by about 150% more than cropland total. It actually comprised all pasture land. Even more, it exceeded total agricultural area. Therefore, a correction factor had to be introduced for forage crops. In the delivery data set the area of permanent meadows and pastures was taken from the FAO land resources data base and subtracted from the fodder crops area identified under individual primary crops.
Greece	FAO and Eurostat only	Sufficiently balanced
Hungary	FAO and Eurostat only	Sufficiently balanced
India	Indian Council of Agricultural Research, ICAR (2010), for forage crops	multiple cropping area is likely
Indonesia	FAO only	*Fallow land*: estimate for 2007 based on extrapolation of ResourceSTAT data for 2001-2005. Date for 2000 = 2001. *Forage plants*: no data found *General:* multiple cropping area is likely
Ireland	FAO and Eurostat only	Sufficiently balanced
Italy	FAO and Eurostat only	Sufficiently balanced
Japan	Yamada (2009)	*Fallow land*: estimated by difference to all other crop categories. *General:* Starting in 2001, data relating to "Permanent meadows and pastures" are classified under the category "Temporary meadows" and therefore included under the category "Arable land".
Latvia	FAO and Eurostat only	Sufficiently balanced
Lithuania	FAO and Eurostat only	Sufficiently balanced for 2007; 10% of cropland not allocated in 2000
Luxembourg	FAO and Eurostat only	Sufficiently balanced
Malta	FAO and Eurostat only	Primary crops make up around 160% of cropland – is there a mistake in FAO data for arable land and permanent crops? Another independent source (http://www.ourmalta.info/01_infos/landwirtschaft.html) confirms this data which means that ca. 31% of the land area of Malta is for agricultural use. Same confirmed by worldstat.info which further states that there is no pasture area in Malta. Yet another independent source (http://malta-informationen.de/malta-wirtschaft/) speaks of four fifth of the islands area being used for dryland-, irrigation- and arable land cultivation. Multiple cropping is probably very unlikely? The issue needs further clarification. For the time

		being, the missing part of cropland is allocated to "other crops".
Mexico	FAO only	Primary crops including fallow land make up only ca. 90% of cropland
Netherlands	FAO and Eurostat only	Sufficiently balanced
Norway	FAO and Eurostat only	Sufficiently balanced
Poland	FAO and Eurostat only	Sufficiently balanced
Portugal	FAO and Eurostat only	Primary crops make up around 110% of cropland
South Korea	FAO only	*General:* multiple cropping area is likely
Romania	FAO and Eurostat only	Sufficiently balanced
Russia	For fallow land: Pravda Article from 4.5.2008: "Russia may prevent global food crisis"	*Fallow land*: see source besides – "Consequently, in the last 15 years, some 40m hectares of rich farmland have lain fallow." With this crude estimate Russian cropland is sufficiently balanced
Slovakia	FAO and Eurostat only	Sharp drop in cropland use from 2000 to 2001 most probably causes rather low coverage by primary crops of 90%. 2007 is sufficiently balanced.
Slovenia	FAO and Eurostat only	Sufficiently balanced
South Africa	Department of Agriculture, Forestry and Fisheries of the Republic South Africa (2011)	No data for fallow land Only 53% (2000) resp. 41% (2007) of cropland balanced by primary crops – even the official agricultural statistics of South Africa do not provide any better data – they do confirm the aggregate FAO data; probably agricultural experts in SA would need be contacted to solve the problem
Spain	FAO and Eurostat only	Sufficiently balanced
Sweden	FAO and Eurostat only	Sufficiently balanced
Switzerland	FAO and Eurostat only	Sufficiently balanced
Turkey	FAO country profile Turkey: FAO (2011d)	Sufficiently balanced
United Kingdom	FAO and Eurostat only	Sufficiently balanced
USA	United States Department of Agriculture - USDA (2007) for fallow land: idle land. USDA (2011) online database for (forage) crops	*Fallow (idle) land:* FAO data coincide for 2002 with USDA data. *General*: in 2000 only 85% of cropland is covered by primary crops plus fallow land (93% in 2007)
RoW Europe	No additional	Europe without European CREEA countries; cropland is sufficiently balanced
RoW Africa	No additional	Africa without South Africa; cropland is by about 85% balanced for all Africa;
RoW Americas	No additional	Central America plus Caribbean plus South America minus Brazil and Mexico;
RoW Asia & Pacific	No additional	Asia minus Cyprus, Japan, China P.R., South Korea, India, Turkey, Taiwan, Indonesia and Middle East; Oceania minus Australia;
RoW Middle East	No additional	Western Asia minus Cyprus and Turkey;

Note: sufficiently balanced means deviations of ±6% are considered still acceptable.

15.3.3.2 Permanent meadows and pastures

Data are taken from FAO ResourceSTAT as the "category permanent meadows and pastures". These deliver data for all countries except Taiwan. Data for Taiwan are taken from worldstat.info (see above). Next, Taiwan data are subtracted from data for China as reported by FAO to obtain data for P.R. China.

Besides data for the total area of permanent meadows and pastures, the shares of intensive respectively extensive grazing systems were estimated based on data obtained from the IMAGE model[10]. Table 3.2 shows the applied shares for intensive grazing land.

Table 3.2: Shares of intensive grazing systems of total area of permanent meadows and pastures.

grazing systems - share of intensive systems	2007	region if not country
Australia	0,17	Oceania
Austria	1,00	OECD Europe
Belgium	1,00	OECD Europe
Brazil	0,41	
Bulgaria	1,00	OECD Europe
Canada	0,77	
China	0,33	
Cyprus	1,00	OECD Europe
Czech Republic	1,00	OECD Europe
Denmark	1,00	OECD Europe
Estonia	1,00	OECD Europe
Finland	1,00	OECD Europe
France	1,00	OECD Europe
Germany	1,00	OECD Europe
Greece	1,00	OECD Europe
Hungary	1,00	OECD Europe
India	0,33	
Indonesia	0,76	
Ireland	1,00	OECD Europe
Italy	1,00	OECD Europe
Japan	1,00	
Latvia	1,00	OECD Europe
Lithuania	1,00	OECD Europe
Luxembourg	1,00	OECD Europe
Malta	1,00	OECD Europe
Mexico	0,33	
Netherlands	1,00	OECD Europe
Norway	1,00	OECD Europe
Poland	1,00	OECD Europe
Portugal	1,00	OECD Europe
Republic of Korea	0,43	
Romania	1,00	OECD Europe
Russian Federation	1,00	
Slovakia	1,00	OECD Europe
Slovenia	1,00	OECD Europe
South Africa	0,09	Southern Africa
Spain	1,00	OECD Europe
Sweden	1,00	OECD Europe
Switzerland	1,00	OECD Europe
Taiwan	1,00	assumed
Turkey	0,63	
United Kingdom	1,00	OECD Europe
United States of America	0,76	

[10] By email communication with Stehfest, E., PBL/NL, on 30 August 2010 with reference to Klein Goldewijk et al. (2007). Based on grassland productivity modelled by the IMAGE crop model, the authors classified grasslands into intensive and extensive pastures. Data for total grassland are in line with FAOSTAT data for permanent pastures and meadows. Reference to the productivity level definition of extensive and intensive grassland is in Bouwman et al. (2006).

Rest of World		
World + (Total)	0,38	

Thus, three data sets per country could be obtained:
- permanent meadows and pastures – total
- permanent meadows and pastures – intensive grazing
- permanent meadows and pastures – extensive grazing

Table 3.3 shows the results for 2007.

Table 3.3: Areas of permanent meadows and pastures – total, intensive, extensive by country in 2007 – 1000 ha

	2007	**2007 - intensive**	**2007 - extensive**
Australia	380.919	64.107	316.812
Austria	1.790	1.790	0
Belgium	507	507	0
Brazil	196.000	79.992	116.008
Bulgaria	1.835	1.835	0
Canada	15.450	11.949	3.501
China	399.992	132.052	267.940
Cyprus	2	2	0
Czech Republic	978	978	0
Denmark	350	350	0
Estonia	307	307	0
Finland	34	34	0
France	9.899	9.899	0
Germany	4.875	4.875	0
Greece	1.445	1.445	0
Hungary	1.017	1.017	0
India	10.425	3.448	6.977
Indonesia	11.000	8.354	2.646
Ireland	3.213	3.213	0
Italy	4.460	4.460	0
Japan	0	0	0
Latvia	641	641	0
Lithuania	830	830	0
Luxembourg	68	68	0
Malta	0	0	0
Mexico	75.188	24.636	50.552
Netherlands	821	821	0
Norway	175	175	0
Poland	3.271	3.271	0
Portugal	1.781	1.781	0
Republic of Korea	58	25	33
Romania	4.533	4.533	0
Russian Federation	92.095	92.095	0
Slovakia	528	528	0
Slovenia	297	297	0
South Africa	83.928	7.969	75.959
Spain	10.608	10.608	0
Sweden	489	489	0
Switzerland	1.093	1.093	0
Taiwan	9	9	0
Turkey	14.617	9.155	5.462
United Kingdom	11.516	11.516	0
United States of America	238.000	181.792	56.208

Rest of World	1.787.220	593.343	1.193.877

15.3.3.3 Forest land

In a first step, data for the total forest area are acquired.

Data for the total forest area are taken from FAO ResourceSTAT by the category "forest area". These deliver data for all countries except Taiwan. Data for Taiwan are taken from the same source as given in table 3.1. Next, Taiwan data are subtracted from data for China as reported by FAO to obtain data for P.R. China.

Table 3.4 shows the results for 2007.

Table 3.4: Forest area by country in 2007 – 1000 ha

countries	country codes	2007
Australia	10	152.072
Austria	11	3.872
Belgium	255	675
Brazil	21	526.105
Bulgaria	27	3.761
Canada	33	310.134
P.R. China	351	196.469
Cyprus	50	173
Czech Republic	167	2.651
Denmark	54	538
Estonia	63	2.238
Finland	67	22.157
France	68	15.810
Germany	79	11.076
Greece	84	3.812
Hungary	97	2.001
India	100	67.999
Indonesia	101	96.487
Ireland	104	713
Italy	106	8.915
Japan	110	24.953
Latvia	119	3.320
Lithuania	126	2.137
Luxembourg	256	87
Malta	134	0
Mexico	138	65.268
Netherlands	150	365
Norway	162	9.836
Poland	173	9.255
Portugal	174	3.445
Republic of Korea	117	6.242
Romania	183	6.464
Russian Federation	185	808.910
Slovakia	199	1.932
Slovenia	198	1.247
South Africa	202	9.241
Spain	203	17.645
Sweden	210	28.203
Switzerland	211	1.226

Taiwan		2.102
Turkey	223	10.978
United Kingdom	229	2.859
United States of America	231	302.874
Rest of World		1.303.557

15.3.3.4 Built-up and related land

Table 3.5 shows the selected data for built-up area in CREEA countries in 2007, the selections are described in the following.

Table 3.5: Built up area in 2007 for CREEA countries in square kilometres

Country ID	Built Up Area in sq. Km	Country ID	Built Up Area in sq. Km
Australia	36,081	Malta	82
Austria	5,029	Mexico	12,750
Belgium	5,975	Netherlands	6,112
Brazil	38,000	Norway	6,282
Bulgaria	8,255	Poland	20,410
Canada	22,712	Portugal	3,227
China	296,000	Romania	10,758
Cyprus	799	Russia	61,022
Czech Republic	5,019	Slovakia	2,687
Denmark	4,449	Slovenia	1,086
Estonia	2,902	South Africa	18,705
Finland	10,000	South Korea	6,854
France	47,459	Spain	11,246
Germany	46,789	Sweden	13,054
Greece	5,326	Switzerland	3,124
Hungary	5,622	Taiwan	2,017
India	120,000	Turkey	12,652
Indonesia	25,617	United Kingdom	14,194
Ireland	1,649	United States	450,100
Italy	15,208	World	2,603,519
Japan	36,770		
Latvia	2,453		
Lithuania	3,127		
Luxembourg	246		

Built up area data by country

AUSTRALIA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	15984

We suggest a built up area of 36081 sq. km for 2007.

The area of Australian settlements is being defined as:
"Settlements include areas of residential and industrial infrastructure, including cities and towns, and transport networks," The National Inventory Report of Australia, Volume 2, p. 12 [53].
This definition does not totally match with the official definition which also contains areas of mining and waste. According to the Australian Collaborative Land Use and Management Program [47], these areas comprise for 20097 sq. km. Since these areas are so huge compared to the officially given build up area, we added them to the built up area given in the 2011 Annex 1 Party GHG Inventory Submissions [53] (15984+20097).

AUSTRIA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	5029
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	4092.55

We suggest an area of 5029 sq. km for 2007, being defined as:

"Settlements: trade, industry and mining, traffic areas, landfills, touristic areas, houses and parking places, garden and parks," The National Inventory Report of Austria, p. 420 [53].

BELGIUM:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	5975
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	6303.47

We suggest an area of 5975 sq. km for 2007, being defined as following:

„Settlements include all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. Some specific issues regarding the application of the definition have been raised during the Belgian LULUCF study, regarding the photo-interpretation as presented in NIR chapter 10.2.2.1. For example, points of sampling points located on the side of a road are classified as settlements if the management of this land is linked to the road management" National Inventory Report of Belgium [53].

BRAZIL:

We suggest an built area of 38,000 sq. km. for 2007.

We estimated the area using data on urbanization in Brazil with urban areas as a proxy for built up areas.
Brazil is a highly urbanized country. The rate of urbanization was 0,842 in 2007 [55], while the average population density of urban areas was about 5500 people per sq. km in 2005-2010 [4]. We assumed that the rural population density was half the urban density. We therefore estimated the rural and urban population density to be 5000 people per sq. km.
Given a population of 190 million people in total, the built up area therefore would be

190,000,000 people / 5,000 (people/sq. km.) = 38,000 sq. km.

BULGARIA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	8255.1
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	5582.19

We suggest a built up area of 8255.1 sq. km for 2007 being catogorized as:

"Settlements: This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories," The National Inventory Report auf Bulgaria, p. 342 [53].

CANADA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	22712.4
Statistics Canada. Total surface area of settlements by settlement class, 2001 and 2006. [32]	2006	19019.3

We suggest a built up area of 22712.4 sq. km for 2007 being categorized as:

"Settlements include all built-up land: urban, rural residential, land devoted to industrial and recreational use; roads, rights-of-way and other transportation infrastructure; and resource exploration, extraction and distribution (mining, oil and gas)," National Inventory Report of Canada, p. 169 [53]

The population density for large urban areas in Canada is about 1550 people per sq. km of built up area [39]. We think of the total density to be below this value, assuming that rural area in Canada having a lower density than urban. We therefore suggest 22703.5 sq. km as the built up area of Canada leading to a density of 1470.

CHINA:

Source	Survey Date	Area in sq. km
Ministry of Land and Resources of the People's Republic of China. Communiqué on Land and Resources of China 2006. [32]	2006	287497
J. Y. Liu, D. F. Zhuang, D. Luo and X. Xiao. Land-cover classification of China: integrated analysis of AVHRR imagery and geophysical data. [22]	2000	36915

We suggest an area of 296,000 sq. km for 2007.

Coverage: Both sources exclude Hong Kong and Macao. We do not know whether Taiwan or Kashmir is included.

We found two very different information of which we excluded the value given in Liu et al. [22] due its small size: A built up area of 36,915 sq. km would result in a population density of about 35,000 people per sq. km of built up area, a value not even reached in Asia's most populous cities.

We therefore choose the data from Ministry of Land and Resources of the People's Republic of China [32] and estimated the build-up area for 2007: 296,000 sq. km using the growth rate of the previous year as a proxy. (Cp. [32])

Based on this, the population density for China is about 4700 people per sq. km of built up area. Although Chinese cities have densities around 10000 people per sq. km the overall density seems to be plausible since the rate of urbanization is very low in China (about 35%) [24]. The resulting share of built up areas is therefore 3% which is a plausible value.

CYPRUS:

Source	Survey Date	Area in sq. km
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	791.03

We suggest an area for 2007 of 798.6 sq. km.

The only reliable source for Cyprus we found is Corine Land Cover for 2006. We estimated the built up area for 2007 based on the average growth rate of built up areas for the European Union, which was 0.96% in 2006.

CZECH REPUBLIC:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	6712.40
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	5018.99

We suggest an area for 2007 of 5018.99 sq. km.

The reason for using the EEA CLC data is that using the UNFCCC data would result in a significant overshoot of the total land use balance. As Czech Republic has probably no multiple cropping, and remaining areas according to EEA CLC are less than 1% of the total area, this assumption seems justified, leading to roughly balanced land use data.

DENMARK:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	4449.2
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	3247.25

We suggest a built up area of 4449.2 sq. km in 2007, being defined as

"[…] all areas with infrastructures, roads, graveyards, sport facilities etc," The National Inventory Report of Denmark, p. 459 [53].

ESTONIA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	2902
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	941.73

We suggest a built up area of 2902 sq. km in 2007, being defined as

"The built-up areas, with roads, streets and squares, traffic and power lines, urban parks, industrial and manufacturing land, sports facilities, airports, legal waste down points, construction site and a couple of buildings with up to 0.3 ha of garden yard, open cast areas (except peat extraction area)," The National Inventory Report of Estonia, p. 256 [53].

FINLAND:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	14270.5
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	4834.22
Ministry of the Environment of Finland. [25 A]	2011	Less then 10000

We suggest a built up area of about 10000 sq. km for 2007.

We decided to use the built up area given by the Ministry of Environment of Finland. (No detailed classification given there).

We think that the area given in [53] is too high compared to other countries also taking into account a much lower population density for Finland: Finland (14000 sq. km / 5.3 mio. inhab.) compared to Italy (15000 sq. km / 59 mio. inhab.) or Spain (12000 sq. km / 44 mio inhab.)

For completeness' sake: The definition of Finish built up areas according to [53]:

"Settlements. The combined area of NFI built-up land, traffic lines and power lines. Also parks, yards, farm roads and barns are included. Only the areas of settlements remaining settlements and lands converted to settlements are reported. Settlements are considered as managed land," The National Inventory Report of Finland, p. 259 [53].

FRANCE:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	47458.5
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	28271.61

We suggest a built up area of 47458.5 sq. km being defined as:

"Les zones urbanisees correspondent aux terres artificialisees (habitations, parcs urbains, routes, pelouses, etc.)," The National Inventory Report of France, p. 762 [53]

GERMANY:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	36676
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	30123.04
Federal Statistics Office of Germany. Siedlungs- und Verkehrsfläche nach Art der tatsächlichen Nutzung. [18]	2007	46789

We suggest a built up area of 46789 sq. km for Germany in 2007, compromising all built up area [53].

For Germany we have three sources covering nearly the same point in time and are defined similarly but differ largely in the given built up area.
We decide to take the value given by the German Federal Statistics office, because we think that it is more accurate than Corine Land Cover.
We also did not take [53] into account since the composition of the given area also includes fallow land and glades, which are not part of built up area.

GREECE:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	5326.10
European Environment Agency. Land accounts for Europe 1990—2000. [4]	2000	2700.84

We suggest an build up area of 5326.1 sq. km for 2007:

"Settlements include all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other land-use categories. Parties have to estimate and report carbon stock changes in living biomass in Land converted to Settlements," The National Inventory Report of Greece, p. 259 [53].

HUNGARY:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	5621.8

European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	5615.65

We suggest an area of 5621.8 sq. km [53]

In the case of Hungary both sources are identical: " [The settlement] category matches with the 'Artificial surfaces' category of the CORINE land-cover database, which comprises the urban areas, industrial, commercial and transport units; mine, dump and construction sites and artificial non agricultural vegetated areas", National Inventory Report of Hungary, p. 142. [53]

INDIA:

Source	Survey Date	Area in sq. km
Ministry of Agriculture, Government of India. Land Use Statistics at a Glance. [30]	2007	260,170*

We suggest an area of 120,000 sq. Km for 2007.

Coverage: Official Indian Data covers only 3,056,850 sq. km of the total official area of 3,287,260 sq. km, first and foremost due to the fact that parts of Kashmir are claimed by China and Pakistan. Therefore Kashmir is only covered by 15% [30].

*The Indian Ministry of Agriculture does not provide detailed data for built up areas, but for "area under non-agricultural uses": This includes all land occupied by buildings, roads and railways or under water, e.g. rivers and canals, and other land put to uses other than agriculture. It excludes fallow land, wasteland and barren and uncultivable land.
The area reported for 2007 is 260,170 sq. km [30]

We estimated India's built up area based on population density. The population of India was 1.2 billion in 2007. **Given an estimated population density of 7000-10000 people per sq. km built up area the built up area for India should be somewhere between 120000 sq. km and 170000 sq. km** Such a high value seems to be legit since Indian urban areas belong to the densest. According to Angel et al. [39] Indian cities had a population density of 15700 people per sq.km in the mid 2000's. The resulting share of built up area is 3.6% and 5.2% then.

Based on the thoughts above an area around 120,000 sq. km seems to be realistic.

INDONESIA:

Source	Survey Date	Area in sq. km
Penman, A., and Nurwadjedi. The National Land Cover Database in Indonesia. [37]	2005	25163.65

Suggested Area for 2007: 25617 sq. km.

As shown in Poniman and Nurwadjedi, p. 22, the built up area increased in Indonesia between 2003 and 2005 by astonishing 35%. We estimated the growth rate in 2005-2007 to be 1.8% based on the use of construction materials. The area therefore is according to our estimation 25617 sq. km.

IRELAND:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	1139.5
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	1625.65

We suggest a built up area of 1649 sq. km. (1625.65 sq. km*1.0142 (cp. Table 3.3)) for 2007.

In the case of Ireland we suggest the data from Corine Land Cover [10], since the inventory submission [53] seems to be incomplete:
"The area of settlements in 1990 is that given by CORINE 1990. Land converted to settlements is the area taken up by new road building, available from the National Roads Authority, and the area covered by new residential, commercial and industrial construction based on CSO annual statistics, which are extracted from floor area records for permitted development. An incomplete time series of housing types (for the years 1995-2000) was used to estimate the residential building footprint from floor area. It was assumed that approximately 50 percent of the planning permits granted for construction were for green-field sites previously not part of the urban fabric," The National Report of Ireland, p. 128 [53].

ITALY:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	15208.3
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	14985.58

We suggest an area of 15208.3 sq. km for 2007, being defined as:
"All artificial surfaces, transportation infrastructures (urban and rural), power lines and human settlements of any size, comprising also parks, have been included in this category," National Inventory Report of Italy, p. 216. [53]

JAPAN:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	36770

We suggest an area of 36770 sq. km for 2007, being categorized as:

"Settlements are all developed land, including transportation infrastructure and human habitats, and preclude lands that have been placed in other land-use categories. In Settlements, trees existing in urban green areas such as urban parks and special greenery conservation zones absorb carbon." The National Inventory Report of Japan, p. 7-41, [53].

LATVIA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	2453.1
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	862.24

We suggest a built up area of 2453.1 sq. Km for 2007:

"Settlements include: forest road, fire break, road, railways, quarries, cities, industrial networks, forest compartment break, mineralized band, ditch, seed orchard, resting places, other special purposes land," The National Inventory Report of Latvia, pp. 237-238 [53].

LITHUANIA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	3127
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	2156.48

We suggest a built up area of 3127 sq. Km for 2007:

„Area of settlements is defined in the Land Fund of the Republic of Lithuania (urban territory and roads)," The National Inventory Report of Lithuania, p.136 [53].

LUXEMBOURG:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	246.2
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	241.71

We suggest a built up area of 246.2 sq. km for 2007 being categorized as:

„The settlement area in correspondence to the LULUCF category comprises the following subcategories: building land: sealed, partly sealed and unsealed area; parks and gardens, road, railway, track and excavation area, other, not further differentiated settlement area," The National Inventory Report of Luxembourg, p. 346 [53].

MALTA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	1.8
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	81.78

We suggest a built up area of 82 sq. km for 2007.

With a built up area of 1.8 sq. km value for Malta in the United Nations Framework Convention on Climate Change [53] is definitely too low and therefore useless for our report.
But also our second source, Corine Land Cover [7] seems to have a similar bias when we take a look at the total country area, which is 15% lower (278 sq. km) than our reference value from Faostat (320 sq. km) [15].
Since we have no clue how these values are calculated, we propose two solutions:

1. We assume the official area of 320 sq. km including the main island and the other islands[11] to be correct. And we also assume that the deviation of 15% from the area given by Corine Land Cover is equally distributed over all different types of land use categories.
The most probable value for Malta's built up area therefore is 81.78 sq. km * 1.15 = 94.14 sq. km.

2. We assume that the error does not affect built up areas and the value of 81.78 sq. Km is our chosen value.

In our opinion the second option is more reliable. Based on this we estimated the area in 2007 to be 82 sq. km assuming a slight growth between 2006 and 2007. This means that about one quarter of Malta is built-up land, the highest share of all CREEA countries (next is Belgium at 20%, Netherlands at 18%, Germany at 13.5%).

MEXICO:

Source	Survey Date	Area in sq. km
Francisco Javier Jimenez Nava. [21]	2005	12497.63

We suggest an area of 12750 sq. km for 2007.

Taking 12497.63 sq. km for 2005 as a starting point we estimated the built up area in 2007 using growth rate of construction material as a proxy for the growth of built up area as shown above. The growth rates of the use of construction material were 6.2% in 2005 and 4.1% in 2006. This implies a growth of 2% in built up area over this span. The total built up area therefore is 12750 sq. km.

Based on this the population density is 8600 people per sq. km and the share of built up area is 0.6%.

NETHERLANDS:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1	2007	6111.5

[11] (comprising Manoel Island, ca 246 km^2), Gozo (malt. Għawdex, ca 67 km^2) and Comino (Kemmuna, ca 3 km^2) as well as the uninhabited islands Cominotto (Kemmunett), Filfla (Filfola), St. Paul's Islands and Fungus Rock.

Party GHG Inventory Submissions. [53]		
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	5109.95

We suggest a built up area of 6111.5 sq. km in 2007. It is defined according to Good Practice Guidance for Land Use, Land-Use Change and Forestry p. 2.6, [23]: (Cp. p. 122 of the Dutch National Inventory Report [53].)

NORWAY:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	6281.7
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	2548.43
Statistics Norway. [42], [43]	2007	2294.08*

*urban areas only.

We suggest a built up area 6281.7 sq. km in 2007 based on the definition of The National Inventory Report of Norway, p. 253 [53].

POLAND:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	20410
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	12547.49

We suggest a built up area of 20410 sq. km in 2007.

This category includes all developed lands, including transportation infrastructure and human settlements refers to:
residential areas include land not used for agricultural and forest production, put under dwelling buildings, devices functionally related to dwelling buildings (yards, drives, passages, playgrounds adjacent to houses), as well as gardens adjacent to houses.
industrial areas include land put under buildings and devices serving the purpose of industrial production,
other built-up areas include land put under buildings and devices related to administration, not listed under residential and industrial areas.
undeveloped urbanised areas include land that is not built over, allocated in spatial management plans to building development and excluded from agricultural and forest production
recreational and resting areas comprise the following types of land not put under buildings:
areas of recreational centres, children playgrounds, beaches, arranged parks, squares, lawns (outside street lanes);
areas of historical significance: ruins of castles, strongholds, etc.
sport grounds: stadiums, football fields, ski-jumping take-offs, toboggan-run, sports rifle-ranges, public baths etc.
area for entertainment purposes: amusement, grounds, funfairs etc.,
zoological and botanical gardens;
areas of non-arranged greenery, not listed under woodlands or land planted with trees or shrubbery
transport areas including land put under:
roads: national roads; voivodship roads; poviat roads; communal roads; roads within housing estates; access roads to agricultural land and woodlands and to facilities of public utility; stopping and manoeuvring yards next to railway stations, bus stations and airports, maritime and river ports and other ports, as well as universal accesses to unloading platforms and storage yards.
railway grounds,
other transport grounds

Source: National Inventory Report of Poland, p. 171 [53].

PORTUGAL:

Source	Survey Date	Area in sq. km

United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	3227.3
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	3157.05

We suggest 3227.3 sq. km [53] for 2007 being defined as:
"Settlements: includes artificial areas such has urban fabric, industrial, commerce and transport units, mines, dump and construction sites and artificial non-agricultural vegetated areas," National Inventory Report of Portugal, p. 7-7 [53]

ROMANIA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	10758.3
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	15113.04

We suggest an built up area of 10758.3 sq. km for 2007. It is categorized as:
"This category includes all lands, regardless of the category of use, located in urban and rural area, inside a certain boundary according legal provisions. It also includes, special purpose land category used for roads, railways, air and water transport, those representing works of hydraulic engineering, heating systems, electricity and gas transport, mining and oil fields, those needed for the national defense; natural reserves and monuments as well as those for archaeological sites and historical ensembles and others alike," The National Inventory Report of Romania, p. 284 [53].

RUSSIA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	61021.6
E.V. Milanova and M.M. Sennikova [28]	2006	136785.92

For Russia we suggest an area of 61021.6 sq. km [53]:

We stick to the official UNFCCC data.

Note: The National Inventory Report is only available in Russian. Therefore no definition is given here.

SLOVAKIA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	No data
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	2687.18

We suggest a built up area of 2687.2 sq. km.

SLOVENIA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	1085.7
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	558.54

We suggest a built up area of 1085.7 sq. km for 2007 being defined as:

"Built-up areas and related surfaces," The National Report of Slovenia, p. 187 [53].

SOUTH AFRICA:

Source	Survey Date	Area in sq. km

United Nations Environmental Program - GRID Arendal. About South Africa. [42]	1999	17067.26

Suggested Built up Area in 2007: At least 18705 sq. km.

We estimated the area based on the use of construction minerals between 1999 and 2007.
As we found in Sec. 1.3 for data from the European Union that the change in use of construction minerals seems to be strongest indicator for a change in growth of built up area.
The growth in use of construction minerals was 83.78% between 1999 and 2007 according to SERI [46].
According to our model the resulting growth of built up areas over this span is 9.6%:

This implies a population density of 2700 people per sq. km and a share of built up area of 1.5%.

SOUTH KOREA:

Source	Survey Date	Area in sq. km
Korea National Statistics Office. Korea Statistical Yearbook 2007. [20]	2007	6854.1

We suggest an area of 6854.1 sq. km. for 2007.

The Korea Statistical Yearbook 2007 is our only source for built up area for Korea in 2007 and provides no detailed definition on built up areas.
The area of 6854.61 leads to a population density of 7100 people per sq. km. of built up area and a share of 7%.
Having a high level of urbanization, this value seems to be accurate since, in comparison, the density of Korean cities was about 10500 in the mid 2000's.

SPAIN:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	11246.3
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	10305.35

We suggest an area of 11246.3 sq. km being defined as:

„Asentamientos o artificial (SL), que comprende toda la tierra desarrollada, con inclusión de la infraestructura de transporte y los asentamientos humanos de todo tamaño, a menos que estén incluidos en otras categorías. - *Settlements or artificial land (SL), which includes all developed land, including transport infrastructure and human settlements of all sizes, unless they are included in other categories,*" National Inventory Report of Spain, p. 7-3 [53]

SWEDEN:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	19235.1
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	6289.29
Statistics Sweden [45]	2005	13053.56

We suggest a built up area of 13053.56 sq. km for 2007.
"Settlements are defined as infrastructure components such as roads and railways, power lines within forests, municipality areas, gardens and gravel pits," The National Inventory Report of Sweden, p. 267 [53].

SWITZERLAND:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	3123.7

Federal Statistics Office of Switzerland. Arealstatistik 2004/9. [14]	2008	2761.67

We suggest an area of 3123.7 sq. km for 2007.

TAIWAN:

Source	Survey Date	Area in sq. km
Forestry Bureau, Council of Agriculture Executive Yuan. [16]	2005	1980

We suggest an area of 2017sq. Km in 2007 being defined as "Constructional Field", i.e. buildings, roads, mines and graves [16].

We estimated the growth of the built up area between 2005 and 2007 with help of use of constructional minerals.
The use of construction minerals decreased by 4.7% in 2005-2007 in Taiwan [46].
Based on our model derived in sec. 1.3, we have an estimated growth rate of 1.86% of built up areas over this time frame leading to a built up area of 2017 sq. km and a population density of 11733 people per sq. km.

TURKEY:

Source	Survey Date	Area in sq. km
European Environment Agency. Corine Land Cover 2006. Land Accounts. [10]	2006	12531.33

We suggest a built up area of 12652 sq. km in 2007.

We have only one value for the built up area for Turkey which is from Corine Land Cover: It is 12531.33 sq. km which leads to a high population density of 5963 people per sq. km.

As an estimator for the built up area in 2007 we used the average growth of built up areas in the European Union, which was 0.96% in 2006.
12531sq. km * 1.0096 = 12652 sq. km.

UNITED KINGDOM:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	Data are not complete, no data for "settlements remaining settlements"
Communities and Local Government. Generalised Land Use Database. [6] Alan Cooper, T. M., and Rogers, D. Northern Ireland Countryside Survey 2007. [1] The Scottish Government. Land Cover and Land Use Statistics. [48] Own Estimations	2005-07	14193.84

We suggest a built up area of 14194 sq. km in 2007.

UNITED STATES OF AMERICA:

Source	Survey Date	Area in sq. km
United Nations Framework Convention on Climate Change. 2011 Annex 1 Party GHG Inventory Submissions. [53]	2007	119533.20
U.S. Department of Agriculture. Summary MISC: 2007 National Resources Inventory. [57]	2007	450100

For the United States of America **we suggest a built up area of 450100 sq. km. in 2007.**

For the United States we have two reports on built up area in 2007, which are defined similarly, but differ hugely:

"Settlements: A land-use category representing developed areas consisting of units of 0.25 acres (0.1 ha) or more that includes residential, industrial, commercial, and institutional land; construction sites; public administrative sites; railroad yards; cemeteries; airports; golf courses; sanitary landfills; sewage treatment plants; water control structures and spillways; parks within urban and built-up areas; and highways, railroads, and other transportation facilities. Also included are tracts of less than 10 acres (4.05 ha) that may meet the definitions for Forest Land, Cropland, Grassland, or Other Land but are completely surrounded by urban or built-up land, and so are included in the settlement category. Rural transportation corridors located within other land uses (e.g., Forest Land, Cropland) are also included in Settlements," National Inventory Report of the United States of America, p. 7-8 [53].
Area in total: 119533.20 sq. km.
Developed Land: The NRI category of developed land differs from that used by some other data collection entities. For the NRI, the intent is to identify which lands have been permanently removed from the rural land base, while other studies are interested in human populations (e.g., Census of Population) and housing units (e.g., American Housing Survey). The NRI developed land category includes (a) large tracts of urban and built-up land; (b) small tracts of built-up land of less than 10 acres; and (c) land outside of these built- up areas that is in a rural transportation corridor (roads, railroads, and associated rights-of-way)." [57]

Area in total: 450100 sq. km.

Validating by population density:

According to Demographia [4] the urban areas of the United States are sparsely populated. The average population per square kilometer of U.S. urban areas with a population greater than 500000 people was 1150 in 2006.
We therefore think that the total population density has to be below that value assuming that U.S. rural areas have a lower density than urban areas.
Population density of the United States given a built up area of: 119533.20 sq. km: 2600 people per sq. km.
Share of built up area of the United States' total area: 1.2%
Population density of the United States given a built up area of: 450100 sq. km: 690 people per sq. km.
Share of built up area of the United States' total area: 4.7%.

World

The global land area of the continents is 14.9 billion ha (Bha). Depending on the definition and method of measurement, around the year 2005, built-up area covered by settlements and infrastructure takes up a relatively small amount of land - 1 to 3% of the total[12].

We took the average number of 2% of the total global land area (without water) to estimate the area of worldwide built-up land, resulting in 2,603,519 sq. km.

EU27 as data consistency check

Data compiled as described above were summed up for the EU27 territory. A comparison with data from the UNFCCC inventory report for the EU by EEA showed a difference of only 1.01%.

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Table A.1: CREEA land use classification and proposed additional categories

Land use occupation, 1 item [hectares/yr] (extensions); derived from FAOSTAT		
		IndustryTypeCode
L_0	Land use	
N.B. the following FAOSTAT categories allow for allocating land use to agricultural sectors		
L_1.1.	Land use-Arable Land - Rice	i01.a
L_1.2.	Land use-Arable Land - Wheat	i01.b
L_1.3.	Land use-Arable Land - Other cereals	i01.c
L_1.4.	Land use-Arable Land - Roots and tubers	i01.h
L_1.5.	Land use-Arable Land - Sugar crops	i01.f
L_1.6.	Land use-Arable Land - Pulses	i01.d
L_1.7.	Land use-Arable Land - Nuts	i01.d
L_1.8.	Land use-Arable Land - Oil crops	i01.e
L_1.9.	Land use-Arable Land - Vegetables	i01.d
L_1.10.	Land use-Arable Land - Fruits	i01.d
L_1.11.	Land use-Arable Land - Fibres	i01.g
L_1.12.	Land use-Arable Land - Other crops	i01.h
L_1.13.	Land use-Arable Land - Fodder crops	i01.h
L_2	Land use-Pasture - Permanent pasture	i01.h

L_3	Land use-Forest - Wood land	i02

additional categories by HSC/WI:

L_1.14	Cropland - Fallow land	n.a.
L_4	Settlements	n.a.

Note: The term "arable land" is used here synonymous with "cropland" which comprises in a strict sense arable land plus permanent crops (see also section 1.1).
The category "fallow land" has been introduced in order to be able to check for comprehensiveness of the countries' agricultural land use accounts.
The area for settlements was introduced as another type of land use by human activities, and to check for plausibility of the entire anthropogenic land use by countries. Settlements area can currently not be allocated to industries, this was also not the purpose in CREEA.

Table A.3: CREEA land use classification and corresponding classifications by FAO and Eurostat.

Land use occupation, 1 item [hectares/yr] (extensions); derived from FAOSTAT

L_0 Land use *N.B. the following FAOSTAT categories allow for allocating land use to agricultural sectors*		**FAOSTAT CLASSIFICATION**		**ESS HS+**	
		Product	**Code**	**Product**	**Code**
L_1.1.	Arable Land - Rice	Rice, paddy	27	Rice, paddy	1006.10_a
L_1.2.	Arable Land - Wheat	Wheat	15	Wheat	1001_a
L_1.3.	Arable Land - Other cereals				
		Barley	44	Barley	1003.00_a
		Buckwheat	89	Buckwheat	1008.90aa
		Canary seed	101	Canary seed	1008.90ab
		Cereals, nes	108	Cereals, nes	1008.90_b
		Fonio	94	Fonio	1008.90ad
		Maize	56	Maize	1005_a
		Millet	79	Millet	1008.20_a
		Mixed grain	103	Mixed grain	1008.90af
		Oats	75	Oats	1004.00a
		Popcorn	68	Popcorn	1904_c
		Quinoa	92	Quinoa	1008.90ac
		Rye	71	Rye	1002.00_a
		Sorghum	83	Sorghum	1007.00_a
		Triticale	97	Triticale	1008.90ae
L_1.4.	Arable Land - Roots and tubers				
		Cassava	125	Cassava	0714.10_a
		Potatoes	116	Potatoes	0701_a
		Roots and Tubers, nes	149	Roots and Tubers, nes	0714.90_bc
		Sweet potatoes	122	Sweet potatoes	0714.20_a
		Taro (cocoyam)	136	Taro (cocoyam)	0714.90_bb
		Yams	137	Yams	0714.90_a
		Yautia (cocoyam)	135	Yautia (cocoyam)	0714.90_ba
L_1.5.	Arable Land - Sugar crops				
		Sugar Cane	156	Sugar cane	1212.99aa
		Sugar Beet	157	Sugar beet	1212.91_a
		Sugar crops, nes	161	Sugar crops, nes	1212.99ab

L_1.6.	Arable Land - Pulses				
		Bambara beans	203	Bambara beans	0713.90ad
		Beans, dry	176	Beans, dry	0713.3_a
		Broad beans, horse beans, dry	181	Broad beans, horse beans, dry	0713.50
		Chick peas	191	Chick peas	0713.20
		Cow peas, dry	195	Cow peas, dry	0713.3_b
		Lentils	201	Lentils	0713.40
		Lupins	210	Lupins	0713.90ab
		Peas, dry	187	Peas, dry	0713.10
		Pigeon peas	197	Pigeon peas	0713.90aa
		Pulses, nes	211	Pulses, nes	0713.90ae
		Vetches	205	Vetches	0713.90ac
L_1.7.	Arable Land - Nuts				
		Almonds, with shell	221	Almonds, with shell	0802.11_a
		Arecanuts	226		
		Brazil nuts, with shell	216	Brazil nuts, with shell	0801.21
		Cashew nuts, with shell	217	Cashew nuts, with shell	0801.31_a
		Chestnuts	220	Chestnuts	0802.40
		Hazelnuts, with shell	225	Hazelnuts, with shell	0802.21_a
		Nuts, nes	234	Nuts, nes	0802.90ac
		Pistachios	223	Pistachios	0802.50_a
		Walnuts, with shell	222	Walnuts, with shell	0802.31_a
L_1.8.	Arable Land - Oil crops				
		Castor oil seed	265	Castor oil seed	1207.30_a
		Coconuts	249	Coconuts	0801.19_a
		Groundnuts, with shell	242	Groundnuts, with shell	1202.10_a
		Hempseed	336	Hempseed	1207.9ag
		Jojoba Seeds	277	Jojoba Seeds	1207.9aj
		Kapok Fruit	310	Kapok Fruit	1402_a
		Karite Nuts (Sheanuts)	263	Karite Nuts (Sheanuts)	1207.9ah
		Linseed	333	Linseed	1204.00_a
		Melonseed	299	Melonseed	1207.9ab
		Mustard seed	292	Mustard seed	1207.50
		Oil palm fruit	254	Oil palm fruit	1207.10ab

		Oilseeds, Nes	339	Oilseeds, Nes	1207.9ak
		Olives	260	Olives	0709.90aa
		Poppy seed	296	Poppy seed	1207.9aa
		Rapeseed	270	Rapeseed	1205
		Safflower seed	280	Safflower seed	1207.60
		Seed cotton	328	Seed cotton	1207.20_b
		Sesame seed	289	Sesame seed	1207.40_a
		Soybeans	236	Soybeans	1201.00_a
		Sunflower seed	267	Sunflower seed	1206.00_a
		Tallowtree Seeds	305	Tallowtree Seeds	1207.9ad
		Tung Nuts	275	Tung Nuts	1207.9ai
L_1.9.	Arable Land - Vegetables				
		Artichokes	366	Artichokes	0709.10
		Asparagus	367	Asparagus	0709.20
		Beans, green	414	Beans, green	0708.20_a
		Cabbages and other brassicas	358	Cabbages and other brassicas	0704.90_a
		Carrots and turnips	426	Carrots and turnips	0706.10
		Cassava leaves	378	Cassava leaves	0709.90cc
		Cauliflowers and broccoli	393	Cauliflowers and broccoli	0704.10
		Chillies and peppers, green	401	Chillies and peppers, green	0709.60
		Cucumbers and gherkins	397	Cucumbers and gherkins	0707.00
		Eggplants (aubergines)	399	Eggplants (aubergines)	0709.30
		Garlic	406	Garlic	0703.20
		Leeks, other alliaceous veg	407	Leeks, other alliaceous veg	0703.90
		Leguminous vegetables, nes	420	Leguminous vegetables, nes	0708.90_a
		Lettuce and chicory	372	Lettuce and chicory	705
		Maize, green	446	Maize, green	0709.90ca
		Mushrooms and truffles	449	Mushrooms and truffles	0709.5_a
		Okra	430	Okra	0709.90cb
		Onions (inc. shallots), green	402	Onions (inc. shallots), green	0703.10_a
		Onions, dry	403	Onions, dry	0703.10_b
		Other melons (inc.cantaloupes)	568	Other melons (inc.cantaloupes)	0807.19
		Peas, green	417	Peas, green	0708.10
		Pumpkins, squash and gourds	394	Pumpkins, squash and gourds	0709.90_b

		Spinach	373	Spinach	0709.70
		String beans	423	String beans	0708.20_b
		Tomatoes	388	Tomatoes	0702.00_a
		Vegetables fresh nes	463	Vegetables fresh nes	0706.10_a
		Watermelons	567	Watermelons	0807.11
L_1.10.	Arable Land - Fruits				
		Apples	515	Apples	0808.10_a
		Apricots	526	Apricots	0809.10_a
		Avocados	572	Avocados	0804.40
		Bananas	486	Bananas	0803.00aa
		Berries Nes	558	Berries Nes	0810.40_b
		Blueberries	552	Blueberries	0810.40_c
		Carobs	461	Carobs	1212.10
		Cashewapple	591	Cashewapple	0810.90ad
		Cherries	531	Cherries	0809.20_a
		Citrus fruit, nes	512	Citrus fruit, nes	0805.90_a
		Cranberries	554	Cranberries	0810.40_d
		Currants	550	Currants	0810.30_a
		Dates	577	Dates	0804.10
		Figs	569	Figs	0804.20_a
		Fruit Fresh Nes	619	Fruit Fresh Nes	0810.90_d
		Fruit, tropical fresh nes	603	Fruit, tropical fresh nes	0804.50_b
		Gooseberries	549	Gooseberries	0810.30_b
		Grapefruit (inc. pomelos)	507	Grapefruit (inc. pomelos)	0805.40_a
		Grapes	560	Grapes	0806.10_a
		Kiwi fruit	592	Kiwi fruit	0810.50
		Lemons and limes	497	Lemons and limes	0805.50_a
		Mangoes, mangosteens, guavas	571	Mangoes, mangosteens, guavas	0804.50_a
		Oranges	490	Oranges	0805.10_a
		Papayas	600	Papayas	0807.20
		Peaches and nectarines	534	Peaches and nectarines	0809.30
		Pears	521	Pears	0808.20_a
		Persimmons	587	Persimmons	0810.90aa
		Pineapples	574	Pineapples	0804.30_a

		Plantains	489	Plantains	0803.00_b
		Plums and sloes	536	Plums and sloes	0809.40_a
		Pome fruit, nes	542	Pome fruit, nes	0810.90ab
		Quinces	523	Quinces	0808.20_b
		Raspberries	547	Raspberries	0810.20_a
		Sour cherries	530	Sour cherries	0809.20_b
		Stone fruit, nes	541	Stone fruit, nes	0810.90ac
		Strawberries	544	Strawberries	0810.10
		Tangerines, mandarins, clem.	495	Tangerines, mandarins, clem.	0805.20_a
L_1.11.	Arable Land - Fibres				
		Agave Fibres Nes	800	Agave Fibres Nes	5304_c
		Fibre Crops Nes	821	Fibre Crops Nes	5305.90_c
		Flax fibre and tow	773	Flax fibre and tow	5301.2
		Hemp Tow Waste	777	Hemp Tow Waste	5302
		Jute	780	Jute	5303aa
		Kapok Fruit	310	Kapok Fruit	1402_a
		Manila Fibre (Abaca)	809	Manila Fibre (Abaca)	5305.2_a
		Other Bastfibres	782	Other Bastfibres	5303ab
		Ramie	788	Ramie	5305.90_b
		Seed cotton	328	Seed cotton	1207.20_b
		Sisal	789	Sisal	5304_b
L_1.12.	Arable Land - Other crops				
		Anise, badian, fennel, corian.	711	Anise, badian, fennel, corian.	909
		Chicory roots	459	Chicory roots	0709.90cd
		Chillies and peppers, dry	689	Chillies and peppers, dry	0904.20
		Cinnamon	693		
		Cloves	698	Cloves	0907.00
		Cocoa beans	661	Cocoa beans	1801.00_a
		Coffee, green	656	Coffee, green	0901.1_a
		Coir	813		
		Ginger	720	Ginger	0910.10
		Hops	677	Hops	1210.10
		Kolanuts	224	Kolanuts	0802.90aa
		Mate	671	Maté	0903.00

		Natural rubber	836	Natural rubber	4001.10_a
		Nutmeg, mace and cardamoms	702	Nutmeg, mace and cardamoms	908
		Pepper (Piper spp.)	687	Pepper (Piper spp.)	0904.11
		Peppermint	748	Peppermint	0709.90_d
		Pyrethrum,Dried	754	Pyrethrum,Dried	1211.90
		Spices, nes	723	Spices, nes	0910.9aa
		Tea	667	Tea	902
		Tobacco, unmanufactured	826	Tobacco, unmanufactured	2401_a
		Vanilla	692	Vanilla	0905.00
L_1.13.	Arable Land - Fodder crops				
		Alfalfa for forage and silage	641		
		Beets for Fodder	647		
		Cabbage for Fodder	644		
		Carrots for fodder	648		
		Clover for forage and silage	640		
		Forage Products	651		
		Grasses Nes for forage;Sil	639		
		Green Oilseeds for Silage	642		
		Leguminous for Silage	643		
		Maize for forage and silage	636		
		Pumpkins for Fodder	645		
		Rye grass for forage & silage	638		
		Sorghum for forage and silage	637		
		Swedes for fodder	649		
		Turnips for Fodder	646		
		Vegetables Roots Fodder	655		
L_2	Pasture - Permanent pasture	Permanent meadows and pastures	6655		
L_3	Forest - Wood land	Forest area	6661		