Global Material Flow database

Material extraction data

Technical Report, Version 2015.1

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1. Introduction

The Global Material Flow database is set up and administrated by the Vienna University of Economics and Business (WU). It comprehensively comprises data on the extraction of a large number of different raw materials in annual time series, following the accounting standards of economy-wide material flow accounting (MFA) as developed by Eurostat and the OECD.

In the development of the database, WU collaborates with two partners:

1. The Wuppertal Institute for Climate, Environment, Energy in Wuppertal, Germany, contributes in particular factors to calculate unused domestic extraction related to material extraction.
2. The Institute for Energy and Environmental Research (IFEU) provides aggregated physical trade data for all countries worldwide.

2. General information on data coverage

The compilation of material flow data follows the nomenclature and categorisation of materials listed in the guidelines for economy-wide material flow accounting published by the Statistical Office of the European Union (EUROSTAT, 2013) and the OECD (2007).

Time coverage

The database currently comprises data for the period of 1980 to 2013.

Country coverage

The database encompasses data on 229 different countries. The following “special cases” can be identified:

- For Denmark and Greenland, Morocco and Western Sahara as well as for Serbia and Montenegro aggregated data are used.
- For Ethiopia and Eritrea, Israel and Palestine, China and Taiwan, as well as Sudan and South Sudan data are disaggregated.
- Data for former Yugoslavia and for the Soviet Union are recorded until 1991, and for the successor countries from 1992 onwards respectively.
- Data for Czechoslovakia are recorded until 1992, and for the successor countries from 1993 onwards respectively.
- Serbia and Montenegro are still recorded together due to lack of data.
- Data for Ethiopia as one country are included until 1992, then for Ethiopia and Eritrea separately.
- Zaire is listed as “DR Congo” (Democratic Republic Congo) in the database.

A list of all the countries included in the database allocated to six country groups (continents) is shown in Annex 1.

Coverage of material categories

With regard to material extraction data, the database currently comprises 311 types of materials, which can be aggregated into five material groups.

The number of material categories within each group is given in brackets.

- Fossil fuels (11)
- Metal ores (39)
- Industrial minerals (54)
- Construction minerals (14)
- Biomass (193)

A detailed list with all covered materials is attached in Annex 2.

Specification of data entries

For each country, each year and each material the database contains the:

- primary data (in the original unit as reported by the data source; e.g. tons, kilograms, cubic meters, carat, etc.),
- factors converting primary data into gross values (i.e. used extraction; e.g. gross ore)
- factors converting primary data into 1000 tons of used extraction
- factors converting primary biomass values in additional biomass quantities used as straw or feed,
- used extraction (in 1000 tonnes),
- factors to calculate unused domestic extraction by multiplying used extraction values (in tonnes per tonne),
- unused extraction (in 1000 tonnes), and
- total extraction (in 1000 tonnes), summing up used and unused extraction
- erosion factors and eroded material (in 1000 tonnes).

Furthermore, for each country data on land area, population and GDP/GDP(PPP) are compiled in separate tables within the database.

For land coverage and population, data from the FAO database are used. For population, only in some cases (e.g. Norfolk Island or Pitcairn Island) other sources (such as www.indexmundi.com) were used to fill FAOSTAT data gaps. The data on GDP in market exchange value are obtained in constant 2005 US$ from the United Nations Statistics Division (UNSD), the data on GDP in purchasing power parities are reported in constant 2011 Int$ from the World Bank. However, as data on the latter is only available from 1990 onward, the time series for 1980-1989 was interpolated by the trend of GDP in market exchange value for the respective years.

3. Used material extraction

Data on used material extraction encompasses the aggregated material categories 'Fossil Fuels', 'Metals', 'Construction Minerals', and 'Industrial Minerals', and 'Biomass'. As mentioned above, within these categories the materials are divided into various sub-categories.

In the following, we provide a detailed description of the primary data sources and the related calculation procedures applied for each of the material categories.

3.1. Fossil Fuels

Data on fossil fuel extraction are taken from the World Energy Statistics and Balances of the International Energy Agency (IEA, 2015) and complemented by data from the United Nations Energy Statistics Database (UNSD, 2015) and the International Energy Statistics of the U.S. Energy Information Administration (EIA, 2015). Most recent data were used from all three sources. The IEA dataset is the most comprehensive currently available data set reporting on fossil fuel extraction and energy use of all countries world-wide. Data can be easily compiled and retrieved with a Pivot-type tool provided by IEA.

The IEA reports all categories included in the Global Material Flow database (anthracite, coking coal, other bituminous coal, sub-bituminous coal, lignite, crude oil, natural gas, natural gas liquids, peat for energy use, oil shale and oil sands, other hydrocarbons) in primary units of 1000 metric tonnes. Only the values of natural gas have to be converted from TJ into 1000t (kt), using a conversion factor provided by IEA itself (0.018 kt/TJ).

Data from UNSD and EIA represent a relatively small share (6% and 3% respectively) which is due to the fact that high priority was given to data from IEA. The two alternative sources are only used in those cases where either there was no data available from IEA or where their coverage for a time series of a single commodity in a country accounted for at least double as many years as that of IEA. Data from UNSD includes crude oil, natural gas (incl. LNG), natural gas liquids, and peat. Data from EIA includes crude oil including lease condensate, dry natural gas, natural gas plant liquids, anthracite, bituminous coal, lignite.
In order to avoid double counting between data on coal production from IEA and EIA – due to their different classifications – such data was only included where IEA did not report any coal production for a specific country.
The EIA reports none of the retrieved commodities in metric tonnes. Therefore all that data have to be converted. The following factors are applied for conversion to 1000 tonnes.

Table 1: Factors to transform fossil fuel extraction into 1000 tonnes

Commodity	Primary source unit	Factor	Source
Coal	Short ton	0.907	EIA[1]
Crude oil	Thousand barrels per day	49.786	EIA[1]
Natural gas	Billion cubic feet	19.523	EIA[1]
Natural gas liquids	Thousand barrels per day	35.096	EIA[1]

3.2. Metal Ores

Almost all primary data for metal extraction are taken from the data base 'World Mineral Statistics' developed by the British Geological Survey (BGS, 2015), which provides comprehensive data on the extraction of metals and minerals in all countries world-wide from 1970 up to recent years. The BGS data are complemented with data from the US Geological Survey (USGS, 2015) as well as with data from the 'World Mining Data' (WMD) of the Austrian Ministry for Science, Research and Economy (Reichl et al., 2015). Additionally, we compared the different sources with regard to similarities or differences in the magnitude of the reported values.

Concerning the data on metal extraction, BGS reports the majority of the different metal types in metal content contained in the extracted ore. In these cases, to be in accordance with international MFA standards, factors are applied to calculate the corresponding extraction of gross ore (run of mine). Information on concentrations of metals in crude ores was obtained through interviews with experts from relevant agencies (e.g. USGS) and a literature survey of a large number of publications by different geological surveys, ministries, and other institutions. A list of the sources used for factors regarding each metal ore can be found in Annex 3.

The availability of the following types of factors was checked, and the respective factors were used in the following order of priorities:

National factor ➔ continental average factor ➔ world average factor

Coupled production

In the Earth crust, a large number of metal ores occur in combination with other metals – and are also extracted and refined in a coupled process. For instance, lead is usually found in ores, which include also other metals, such as zinc.

In the database, in the majority of the cases where coupled production is known this phenomenon is taken into account by calculating the amount of gross ore extracted only for the main metal in this "coupled production" and allocating the gross ore only to this metal. The other metal(s), i.e. the by-products, do not receive any gross ore.

However, for lead and zinc we have started to apply the approach suggested by Eurostat foreseen for cases of coupled production (EUROSTAT, 2012): Via the ore grades reported for each metal in each country the amount of gross ore is calculated. Theoretically, assuming that the two ores are always extracted together, the two values of gross ores calculated should be equal, as both metals are contained in the same "block" of ore. However, in data reality this is not the fact. Hence, as a next

[1] International Energy Statistics – Units. See http://www.eia.gov/cfapps/ipdbproject/docs/unitswithpetro.cfm

step, the metal contents of both metals are multiplied with the average annual prices of each metal. The higher of the two values identifies the main metal produced and determines which calculated gross ore value is selected. In the final step, the allocation of the selected amount of gross ore to the two metals is done following the monetary relationship of the absolute amounts of economic value.

3.3. Minerals

For the allocation of minerals to the categories Industrial Minerals and Construction Minerals we adhere to the first handbook for economy-wide material flow accounting published by the Statistical Office of the European Union (EUROSTAT, 2001). Newer conventions for MFA (EUROSTAT, 2011, 2013) suggest not splitting the two types of minerals. However, we need to apply an estimation method in order to fill data gaps in particular regarding the extraction of construction minerals (see below) and thus keep the original recommendation.

In cases where certain types of minerals (as for instance limestone, sandstone, etc.) are used for construction as well as for industrial purposes, an allocation as presented in Table 2 was developed, based on estimations on the primary purpose of use of the different materials.

Table 2: Commodity allocation Industrial Minerals versus Construction Minerals

Industrial Minerals	**Construction Minerals**
Abrasives, natural (puzzolan, pumice, volcanic cinder etc.)	Asphalt
Amber	Chert and flint
Asbestos	Common clay, clay for bricks etc.
Ball clay	Crushed stone
Barite	Igneous rock (basalt, basaltic lava, diabase, granite, porphyry, etc.)
Bentonite, sepiolite and attapulgite	Lavasand
Borate minerals	Limestone
Brine salt	Loam
Bromine	Marble, travertines etc.
Calcite	Sand and gravel
Chalk	Sandstone
Diamonds, gems	Slate including fill (incl. roof slate)
Diamonds, industrial	Turfaceous rock
Diatomite	Construction Minerals nec
Dolomite	
Evaporated salt	
Feldspar	
Fire, refactory and flint clay, Andalusite, kyanite and sillimanite (all Al-containing)	
Fluorspar	
From brine	
Fuller's earth	
Gluesand	
Graphite, natural	
Gypsum and anhydrite	
In brine, sold or used as such	
Industrial sand	
Iodine	
Iron pyrites	
Kaolin	
Magnesite	
Mica	

Nepheline syenite	
Ochre and pigment earths	
Peat for agricultural use	
Pegmatite sand	
Perlite	
Phosphate rock (natural phosphates)	
Potash	
Potter clay	
Qartz and quartzite	
Rock salt	
Salt nec	
Sea salt	
Siliceous earth	
Sillica sand (quartzsand)	
Slate clay	
Sodium carbonate, natural	
Special clay	
Strontium minerals	
Sulphur	
Sulphur as a by-product of natural gas etc.	
Sulphur from pyrites	
Talc (steatite, soapstone, pyrophyllite)	
Talcous slate	

3.3.1 Industrial Minerals

For the section of Industrial Minerals we also use primary data which is available from BGS, WMD, and USGS, and fill gaps with complementing data or estimations (see the section on metals above). In contrast to the necessary conversion of reported metal extraction, industrial minerals are mined in their processable form and as such do not have to be converted. The exceptions are diamonds and potash. Diamonds are reported in the unit "carat" in their already processed form. Therefore, mine-specific ore grades were researched for the largest mines and diamond-producing countries from company reports and scientific publications in order to estimate the mined ore. The same logic as for metals is applied, by using national averages as far as possible, otherwise regional or global averages. As all other commodities this extraction is reported in kt. In case of potash only the production of the K2O content in potash ores is reported by the primary source. Therefore estimation factors are applied to report the actually mined potash ores.

3.3.2 Construction Minerals

In general, coverage of Construction Minerals in official statistics is still unsatisfactory, even in industrialised countries, but in particular with regard to non-OECD countries, where huge data gaps can be identified (in many cases, no data on the extraction of construction minerals at all was available from published statistics).

Official data on construction minerals extraction

Official and robust data are available for European countries and the USA.

For the EU-28, for the years 2000-2013 we use aggregated data published by EUROSTAT[2]. Data on construction mineral extraction in the EU-28 before 2000 was interpolated using trends as reported

[2] See http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_mfa&lang=en

in earlier studies on material flows in the EU-15 (Weisz et al., 2007a) and for other EU member countries using trends from data generated (estimation of construction minerals extraction) with the two estimation procedures described in the following sub-chapter.

Furthermore we introduced a category of "construction minerals nec", which contains the difference between the construction minerals reported in the primary data sources and the aggregated data reported by EUROSTAT. Through this procedure, we ensured that all disaggregated information from primary sources is kept in the database, while the aggregate is equal to the official data reported by EUROSTAT.

USGS provides a solid data base for the USA, so USGS data were applied in this case and the same procedure applied for the category construction minerals nes.

Additionally, BGS reports on some of the construction minerals commodities for various countries (especially: gypsum, sand and gravel).These data are included in the database.

Estimation of construction minerals extraction

Except for countries such as the USA or the EU-27, for almost all countries world-wide, the reported data on the extraction of construction minerals are incomplete and underestimate the true levels of extraction. Therefore, we apply two different procedures for all countries except the EU-28 and the USA, to estimate the overall extraction of construction minerals per country. The first method estimates the amount of extraction of limestone, sand and gravel based on USGS data on cement production and consumption and on the production of bitumen. For all countries, for which USGS reported data on cement and bitumen (or asphalt) production, this procedure was applied. With this procedure, we cover around 50 % of all countries world-wide, including all the biggest consumers of construction minerals, such as China, India or Brazil.

Only if no data on cement and bitumen were available, a second method was applied, based on an assumption on the per capita extraction at certain levels of GDP/capita.

Procedure 1: Estimation of the extraction of limestone, sand and gravel based on physical data on cement and bitumen

Construction minerals are mainly used for two purposes: construction of buildings and construction of transport infrastructure, such as roads and runways.

<u>Construction minerals for buildings</u>

Regarding buildings, the major product applied is concrete, which generally consists of around 70% aggregates (sand and gravel), 12% cement, 18% water, and of burnt lime as binder. Thus, if the numbers for cement are known, the corresponding requirements for sand and gravel to produce concrete can be estimated, using a factor of 6.5 (Krausmann et al., 2009). However, also cement requires a construction mineral, notably limestone, for its production. For each tonne of cement, around 1.4 tonnes of limestone are required (Krausmann et al., 2009).

The calculation procedure thus starts with compiling data on cement production taken from USGS (see minerals.usgs.gov/minerals/pubs/commodity/cement). Mass data on cement production is multiplied with a factor 1.4, in order to estimate the quantities of limestone required to produce the reported amounts of cement. It is assumed that the limestone is extracted in the same country, where the cement production takes place.

In order to estimate the amount of sand and gravel required for concrete production, we first calculate the amounts of national cement consumption, by adding cement imports and subtracting cement exports from the national cement production values. Data on cement trade was taken from the UN Comtrade database (see comtrade.un.org). Thus, we calculate the Domestic Material Consumption (DMC) of cement in each country. This amount of consumed cement is then multiplied by a factor 6.5 (see above), in order to estimate the corresponding requirements for sand and gravel.

Construction minerals for transport infrastructure

Asphalt (or bitumen) is the main material used for the construction of transport infrastructure, such as roads and runways. Asphalt is the sticky, black and highly viscous liquid or semi-solid present in most crude petroleum and is used as the binder mixed with aggregate particles to create asphalt concrete. Each ton of asphalt is mixed with around 20 tonnes of sand and gravel, in order to produce asphalt (Krausmann et al., 2009).

The main data source of bitumen production is the International Energy Agency (IEA, 2015). These are complemented with data from the United Nations Energy Statistics Database (UNSD, 2015) and the International Energy Statistics of the U.S. Energy Information Administration (EIA, 2015), applying a similar procedure as described for fossil fuel extraction above. Bitumen production as reported in 1000 tonnes is then multiplied by a factor 20, in order to estimate the corresponding requirements for sand and gravel.

Procedure 2: Construction mineral extraction in relation to per-capita income

As procedure 1 cannot be applied to all countries world-wide, a second estimation method is being used, in order to obtain a level of per capita extraction of construction minerals, which – according to interviewed experts in this field and information from other sources such as geological institutes – can be assumed as realistic in different world regions.

The following information sources are used to estimate the per capita levels of construction minerals extraction:

- In industrialised countries, numbers are estimated to range between 10- 15 tons per capita and year, for transition countries between 4 and 8 tons and for least developed countries between 1- 2 tons (personal communication with Leopold Weber, publisher of the World Mining Data; see Weber and Zsak, 2011).
- In their calculation on global resource extraction, Schandl and Eisenmenger (2006) assume an average of around 1 ton per capita in least developed countries, 2- 3 tons for developing countries and 7-8 tons for industrialised countries.

For our estimation procedure, we calculate total numbers of extraction of construction minerals according to the estimation scheme as shown in Table 3. In a second step we summed up all extraction reported in official statistics. In the database, the difference between these two numbers is listed as “construction minerals nec”. If numbers reported are higher than the numbers obtained from the estimation procedure, original numbers remained unchanged.

The basic assumption behind the estimation procedure is that extraction of construction minerals per capita is related to population and GDP. Extraction increases, when population grows and the absolute level is determined by GDP/capita levels. The scheme presented in Table 3 is oriented at the World Bank Classification of per capita income (GDP/cap in 1995 US$) and assumes a saturation effect, e.g. as countries get richer, growth in construction minerals extraction per capita slows down and comes to an end above 20.000 US$/capita. However, note that also in the highest category (10 tons per capita), numbers increase in absolute terms, if population grows. Note also that the assumed maximum value of 10 tons per capita reflects a defensive estimation according to the estimated numbers given by other information sources (see list above). As for the World Bank’s classfication GDP-data in 1995 US$ had been used but the GDP data in the new data base is reported in 2000 US$, to convert the classification into 2000 US$, the intervals were multiplied by the ratio of the GDP in the United States in 2000 US$ divided by the 1995 US$ value.

Table 3: Estimation scheme for construction minerals

<table>
<tr><th>Income/capita (constant 2000 US $)</th><th>Extraction of construction minerals in tons/year/capita</th><th>Country classification</th><th>Growth in extraction in tonnes per capita per 1100 US $</th></tr>
<tr><td>0-357</td><td>0.3</td><td rowspan="5">Low income and lower middle income</td><td>0</td></tr>
<tr><td>357-1100</td><td>1</td><td rowspan="4">1</td></tr>
<tr><td>1100-2200</td><td>2</td></tr>
<tr><td>2200-3300</td><td>3</td></tr>
<tr><td>3300-4400</td><td>4</td></tr>
<tr><td>4400-6600</td><td>5</td><td rowspan="3">Upper middle income</td><td rowspan="3">0.5</td></tr>
<tr><td>6600-8800</td><td>6</td></tr>
<tr><td>8800-11000</td><td>7</td></tr>
<tr><td>11000-16500</td><td>8</td><td rowspan="4">High income</td><td rowspan="2">0.2</td></tr>
<tr><td>16500-22000</td><td>9</td></tr>
<tr><td>22000-33000</td><td>10</td><td>0.1</td></tr>
<tr><td>More than 33000</td><td>10</td><td>0</td></tr>
</table>

While procedure 2 offers the opportunity to estimate construction mineral extraction for every country of the world, it also has its shortcomings, such as an underestimation of construction minerals extraction in countries, which build-up infrastructure, but have not yet reached high levels of per-capita income. This is in particular the case for emerging economies, such as China, for which estimation procedure 1 reveals significantly higher numbers than procedure 2. But also the inherent relationship of construction minerals extraction to the GDP of a country is a shortcoming when aiming at ecological-economic analyses.

3.4. Biomass

The category 'Biomass' has a multitude of large sub-categories: Agriculture, By-products of harvest, Grazing, Forestry, Fishing, Hunting, Other biomass. The main data source for these sub-categories was the data base of the Food and Agriculture Organisation of the United Nations (FAO, 2015a).

3.4.1. Agriculture

Data for agricultural production was retrieved from the FAO database (FAO, 2015a). In alignment to current EW_MFA guidelines (EUROSTAT, 2013) data for fodder crops were transformed to a standard of 15% water content, on the basis of moisture contents as published by Krausmann et al. (2009). Table 4 lists the relevant categories, the related database codes and the moisture contents.

Table 4: Biomass feed categories and their related moisture content

Commodity ID	Commodity Name	Moisture Content
224	Alfalfa for forage and silage	80%
225	Beets for Fodder	88%
226	Cabbage for Fodder	92%
227	Carrots for Fodder	89%
228	Clover for forage and silage	80%
229	Hay (Unspecified)	15%
230	Maize for forage and silage	80%
232	Rye grass for forage & silage	84%
233	Sorghum for forage and silage	80%
234	Swedes for Fodder	88%
235	Turnips for Fodder	88%
236	Vegetables Roots Fodder	88%
237	Forage Products	80%
238	Grasses Nes for forage; Sil	80%
239	Leguminous for Silage	80%
240	Other fodder plants	80%
241	Green Oilseeds for Silage	80%

By-products of harvest:

Based on FAO data on agricultural harvest, by-products from harvest (in particular, crop residues used as fodder and as straw), were calculated using the following approach:

It is assumed that, in addition to the agricultural harvest of biomass for direct use, a certain percentage accumulates as "fall-out". This amount can partly be used for feed purposes, partly as straw; while the rest is accounted for as “unused”. Hence, in a first step the harvested biomass is multiplied with a so-called “harvest-factor” to calculate the amount of “fall-out”. This value is then distributed into the three categories by-product feed, by-product straw and unused biomass. Finally, in alignment with the proceeding with the “normal” categories of biomass for feed purposes, the value of by-product feed is transformed into 15% moisture content (from a base value of dry matter). For each country the sum of the two by-product categories is built and accounted for in the database.

This methodology is the further development of the principles as outlined in Weisz et al. (2007b). The applied harvest, straw, feed and unused biomass factors stem from mainly two publications – Jölli and Giljum (2005) and Krausmann et al. (2009).

Grazing:

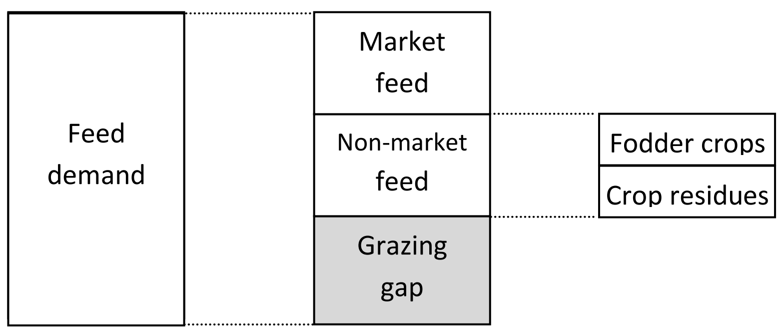
Global agricultural databases contain data on the supply of market feed and fodder crops, but do not include any information on biomass grazed by livestock or “mowed for livestock”-sustenance. Biomass uptake from grazing thus needs to be estimated. Eurostat’s MFA Guide therefore suggests two different approaches (EUROSTAT, 2013):

(A) The **“supply approach”** multiplies areas of permanent pastures with annual yield coefficients. This approach requires global data on land used for grazing and regionally specific information on grass yields.

(B) In the **“demand approach“**, annual livestock data is multiplied with estimations of yearly fodder demand by different grazing animals (see EUROSTAT, 2007; for details: Krausmann et al., 2008).

We applied the demand approach, as no consistent database on land used as grazing areas is publicly available and the use of land cover data would severely distort the results. This approach requires a vast amount of data and detailed information on the livestock system and feed production. The basic logic of this approach is to calculate grazing demand as the difference between (a) feed demand and (b) the supply of market and non-market feed (with the latter including fodder crops and crop residues) in each country. The resultant amount of biomass is called the “grazing gap”, which is the amount of feed required by the livestock of a country that is not supplied from other sources (see Figure 1).

Figure 1: General concept of the grazing demand approach



For the calculation of feed demand, country-specific data on stock and production for 11 livestock species were taken from the FAO database. We then applied region-specific feed demand coefficients in kg dry matter per head and day published by Krausmann et al. (2008). For cattle and buffaloes we calculated national feed demand based on linear correlations between average daily feed intake per head and average national milk yield and carcass weight provided by Krausmann et al. (2008).

Feed supply consists of market feed and non-market feed. Market feed was taken from the FAO commodity balances that give detailed information on the supply of feed from primary crops such as soy and wheat. These values were transformed into dry matter, as FAO provides all production volumes including the moisture content at harvest.

Non-market feed is divided into fodder crops (leguminous crops, maize for silage, fodder beets, etc.) that are reported in FAO's agricultural production database, and feedstuff from crop residues (e.g. straw, leaves) that are calculated for each country based on crop residue recovery rates published in literature (collected by and listed in Krausmann et al., 2008), see above.

The grazing gap, i.e. the difference between total feed demand and supply, was assumed to equal the global volume of biomass harvested on grazing land. This number was finally converted from dry matter into fresh weight assuming 15% moisture content in accordance with the MFA guidelines (EUROSTAT, 2011).

3.4.2. Forestry

Also in the forestry section, data is taken from the FAO website and database. In the category "Industrial Roundwood" FAO reports on different roundwood products dividing them into coniferous and non-coniferous products.

FAO forestry data is reported in solid cubic metres and thus had to be transformed into tons by using density coefficients. Following the EUROSTAT publication in 2007 (Weisz et al., 2007b), the following factors were applied for all countries:

- 0.52 tons per m³ for coniferous wood, and
- 0.68 tons per m³ for non-coniferous wood.

These factors comprise the wood density coefficient (to obtain mass dry matter) as well as the water content coefficient (with a water content of 15%). In order to estimate the amount of used bark, EUROSTAT uses a correction factor of 1.1. Hence, the factors finally used are 0.572 for coniferous and 0.748 for non-coniferous wood.

In line with other MFA studies, we have to remark that wood density is varying significantly across countries and across different species. Therefore, the application of only two conversion factors for all countries represents an inaccuracy, which could be removed by calculating country- and species-specific conversion factors.

3.4.3. Fishing

Data on global fishing capture is taken from the FAO Fisheries and Aquaculture Department's website and database (FAO, 2015b). Therefore, data from the categories listed in Table 5 are combined and aggregated into "Aquatic Plants", "Marine fish catch", "Freshwater fishes", and "Other (e.g. Aquatic mammals)". Some of the data in the FAO database is not reported in tonnes but in numbers of caught animals (e.g. Whales, seals and other aquatic mammals); these values are transformed into tonnes using the following average factors: blue-wales & fin-whales at 100 tonnes, seals & walruses at 0.5 tonnes and sperm-whales and pilot-whales at 15 tonnes.

Table 5: Fishing categories available at the FAO Fisheries and Aquaculture Department's website

Aquatic plants
Crustaceans
Diadromous fishes
Freshwater fishes
Marine fishes
Miscellaneous aquatic animals
Molluscs
Miscellaneous aquatic mammals
Blue-whales, fin-whales
Sperm-whales, pilot-whales
Eared seals, hair seals, walruses

3.4.4. Hunting

No data is available for this section, neither from FAO nor from other international sources.

3.4.5. Other Biomass

The data availability for this sub-category has always been and still is quite constricted. Data is taken mainly from the FAO data bases, which provide data for example several fibre categories (e.g. flax fibres, sisal), tobacco leaves or aquatic plants. In addition, the FAO also provides time series for honey. Even though, the production of honey in hives is already taking place within the economic system (from an MFA point of view) and therefore not directly extracted from the environment, it is included in the database, as it provides a relatively robust proxy for the nectar produced by plants and collected by pollinators. Data on honey produced by wild bees is not available.

5. Data quality of sources for used extraction

As described in the previous sections, the variety of sources for the compilation of the WU MFA database is huge. Despite internal standards to compile data of largest coverage and highest quality it is a fact a statistician has to accept that these two criteria strongly vary across different data sources. In the following we present a table with an estimate of data quality of the different data sources used, as perceived during the data compilation works. Information for unused extraction is generally of low quality on the global level.

The following Table 6 provides an overview of the evaluation of the data quality in the respective material extraction categories.

Table 6: Evaluation of data quality of primary data sources for the major material groups

Data source	Quality	Comment
Fossil Fuels		
IEA	++	Most comprehensive data source; no open access
UNSD	++	Very comprehensive database
EIA	++	Very comprehensive database
Metal ores		
BGS	++	Very comprehensive database
USGS	++	Very comprehensive database
WMD	+	Comprehensive database
Industrial Minerals		
BGS	++	Very comprehensive database
USGS	++	Very comprehensive database
WMD	+	Comprehensive database
Construction Minerals		
Eurostat	+/-	Data of differing quality and low level of disaggregation
BGS	+	Good coverage but occasionally questionable values
USGS	+	Good coverage but in general underestimating mineral extraction
WMD	+/-	Low coverage of construction minerals
Estimation method 1 (based on cement/bitumen production)	+	Independent from GDP, but data not available for all countries
Estimation method 2 (based on GDP per capita)	+/-	Applicable for all countries in the world but tends to underestimate; direct relation to national GDP
Biomass – Agriculture		
FAO	++	Very high coverage
Biomass – By-products of harvest		
FAO	+/-	Method in accordance with MFA guide; however, average values for the whole world
Biomass – Grazing		
FAO	+	Grazing is calculated based on a range of regionally specific data on feed demand and feed supply. Big differences e.g. in feed demand and crop residue recovery coefficients in the literature, however, indicate high variations and related uncertainties in the calculations.
Biomass – Forestry		
FAO	+	Immense coverage; however, critique has been raised about the accuracy of FAO data on forestry
Biomass – Fishing		
FAO	++	Very high coverage

4. Unused extraction

In the MFA methodology, some material categories are defined as 'unused extraction', as they are not economically used for further processing. Unused materials include for example overburden for mining activities and unused residuals of biomass extraction (OECD, 2008).

Data on unused domestic extraction (UDE) is also included in the WU MFA database. UDE is estimated by multiplying used extraction with factors expressing amounts of unused materials per used materials (in tonne/tonne). Factors and data sources used in the database were cross-checked and harmonised with the database on factors for unused material extraction developed by the Wuppertal Institute in Germany. In order to be able to calculate unused values for all commodities in all countries, similar to the metal section for used extraction, the availability of the following types of factors was checked, and the respective factors were used in the following order of priorities:

National factor → continental average factor → world average factor

It has to be emphasised that data availability and quality for unused material extraction is still unsatisfying for many countries (in particular, non-OECD countries) and improvement of UDE estimates across all countries world-wide will require significant efforts.

In the following, the main sources for unused-extraction factors ordered by material category are presented:

Fossil fuels

- Hard coal (several commodities): The main source for UDE factors for hard coal were calculations of weighted average continental UDE coefficients (based on mining data on 2003) and UDE coefficients from the UDE database of the Wuppertal Institute in Germany (Schütz, 2008). In some cases UDE factors were taken from the special issue on hard coal of the geological yearbook (Hinrichs, 1999), where the German Federal Geological Institute reports a number of country-specific factors for overburden in hard coal mining, and from the publications on total material requirement of the European Union prepared by the Wuppertal Institute in Germany (Bringezu and Schütz, 2001a, b).

- Brown coal / lignite: data on country-specific UDE factors for brown coal were taken from Bringezu and Schütz (2001b). If no country-specific data was available, the average factor of 3.2 tonnes of overburden per ton of brown coal was applied (taken from the same publication).

- Crude oil: For crude oil, only one average global factor of 0.22 tons of UDE per ton of crude oil was found in the literature (Ritthoff et al., 2002). The exception here is Germany, for which the factor 0.08, taken from a UDE factor compilation done by the Wuppertal Institute (Schütz, 2003), was used.

- Natural gas: The source for UDE factors for natural gas was Survey of Energy Resources by the World Energy Council (1992).

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

Metal ores

For UDE factors of metal ores, we used the same literature sources as described for metal ore concentrations, from which a large number of country-specific UDE factors could be extracted. If no country-specific information was available, we applied factors from neighbouring countries or continental average factors. Only if no continental information was reported, global average numbers were used.

Industrial minerals

Country-specific data on UDE factors for industrial minerals were only available for Germany extracted from several publications of the Wuppertal Institute (Bringezu and Schütz, 2001a, b; Mündl and Scharnagl, 1998).
For all other countries, global average numbers were applied based on the same publications from Bringezu and Schütz.

Construction minerals

Most important data sources for UDE factors of construction minerals were the TMR studies for the EU-15 by Bringezu and Schütz (2001a); (2001b), a material flow study on the European level by Mündl and Scharnagl (1998), and the database of the World Resource Institute (WRI, 2008).

For the commodity "Construction minerals nec" for all countries except Germany the UDE-factor of "Sand and Gravel" was used (0.01). In the case of Germany, the factor 0.14 was chosen.

Biomass

UDE factors for agriculture, forestry and fishery were derived from different sources; first, from a literature survey for the MOSUS project summarised in a separate publication (Jölli and Giljum, 2005); second, from personal communications with Helmut Schütz from the Wuppertal Institute in Germany, disposing of a database of standard agricultural tables; further a survey of the British Office of National Statistics (Gazley and Francis, 2005), Eurostat's MFA handbook (Weisz et al., 2007b) and more recent scientific literature (Krausmann et al., 2008).

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

Agriculture

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

For cereals, data for the ratio of the weight of the harvested product to the weight of total biomass extraction was taken from the Eurostat's MFA handbook (Weisz et al., 2007b), which is estimated to be 1.0 for all cereals except maize (1.4).

For all other crops, data on ratios were taken from biomass energy flow accounts by Hemstcock and Hall (1995) and Amoo-Gottfried and Hall (1999). Information on unused shares of residues was taken from Di Blasi et al. (1997) and Krausmann et al. (2008).

Forestry

In the course an earlier literature search of sources for UDE factors in forestry, three main studies calculating forestry residues, focusing on different countries and different years were identified. The first study deals with the US (McKeever and Falk, 2004), the second with China (Cuiping et al., 2004) and the third study (Koopmans and Koppejan, 1997) summarises data from several sources. While the share of woody residues is quite similar in all three publications, the results for the use of residues for other economic purposes, depending to a large extent on environmental, economic and social factors, differ considerably (between 10% and 35%).

For all countries in the WU MFA database, we calculated with an average factor of 30% woody residues in total roundwood production, of which 35% were assumed to be unused.

Fishery

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

For marine fish, an average of 19.8 tons of every 100 tons is discarded catch (and only 80.2 tons are used catch). The discarded mortality rate of marine fishes is about 98%, i.e. 98% of the fishes which are retained to the sea do not survive due to catch, handling, etc. Consequently, the average coefficient to calculate unused marine fishes from data on used catches is 0.242.

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

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

References

Amoo-Gottfried, K., Hall, D.O., 1999. A biomass energy flow chart for Sierra Leone. Biomass and Energy 16, 361-376.

BGS, 2015. World Mineral Statistics. BGS - British Geological Survey, London.

Bringezu, S., Schütz, H., 2001a. Material use indicators for the European Union, 1980-1997. Economy-wide material flow accounts and balances and derived indicators of resource use. Wuppertal Institute, Wuppertal.

Bringezu, S., Schütz, H., 2001b. Total material requirement of the European Union. Technical part. European Environmental Agency, Copenhagen.

Cuiping, L., Chuangzhi, Y.W., Haitao, H., 2004. Study on the distribution and quantity of biomass residues resource in China. Biomass and Energy 27, 111-117.

Di Blasi, C., Tanzi, V., Lanzetta, M., 1997. A study on the production of agricultural residues in Italy. Biomass and Bioenergy 12, 321-331.

EIA, 2015. International Energy Statistics. U.S. Energy Information Administration, Washington.

EUROSTAT, 2001. Economy-wide material flow accounts and derived indicators. A methodological guide. Statistical Office of the European Union, Luxembourg.

EUROSTAT, 2011. Economy-wide Material Flow Accounts (EW-MFA) - Compilation Guidelines for EUROSTAT's 2011 EW-MFA questionnaire. EUROSTAT, Luxembourg.

EUROSTAT, 2012. Economy-wide Material Flow Accounts (EW-MFA). Compilation Guide 2012. Statistical Office of the European Communities, Luxembourg.

EUROSTAT, 2013. Economy-wide Material Flow Accounts (EW-MFA). Compilation Guide 2013. Statistical Office of the European Communities, Luxembourg.

FAO, 2015a. FAOSTAT - ProdStat. FAOSTAT - ProdStat.

FAO, 2015b. Fishery Statistical Collections - Global Capture Production. Food and Agriculture Organization of the United Nations - Fisheries and Aquaculture Department.

Gazley, I., Francis, P., 2005. UK Material Flow Review. Office for National Statistics, UK.

Hemstock, S.L., Hall, D.O., 1995. Biomass energy flows in Zimbabwe. Biomass and Bioenergy 8, 151-173.

Hinrichs, W., 1999. Stoffmengenfluüsse und Energiebedarf bei der Gewinnung ausgewählter Rohstoffe. Teilstudie Steinkohle. Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover.

IEA, 2015. World energy statistics, IEA World Energy Statistics and Balances (database).

Jölli, D., Giljum, S., 2005. Unused biomass extraction in agriculture, forestry and fishery. Sustainable Europe Research Institute, Vienna.

Koopmans, A., Koppejan, J., 1997. Agricultural and Forest Residues - Generation, Utilization and Availability, Regional Consultation on Modern Application of Biomass Energy, Kuala Lumpur, Malaysia.

Krausmann, F., Fischer-Kowalski, M., Schandl, H., Eisenmenger, N., 2008. The global socio-metabolic transition: past and present metabolic profiles and their future trajectories. Journal of Industrial Ecology 12, 637-656.

Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.-H., Haberl, H., Fischer-Kowalski, M., 2009. Growth in global materials use, GDP and population during the 20th century. Ecological Economics 68, 2696-2705.

McKeever, D.B., Falk, R.H., 2004. Woody residues and solid waste wood avaible for recovery in the United States, 2002, Management of recovered wood recycling, bioenergy and other options, pp. 307-316.

Mündl, A., Scharnagl, A., 1998. Modelling a socially and environmentally sustainable Europe. Final project report. Wuppertal Institute, Wuppertal.

OECD, 2007. Measuring material flows and resource productivity. The OECD guide Environment Directorate. Organisation for Economic Co-operation and Development, Paris.

OECD, 2008. Measuring Material Flows and Resource Productivity. The OECD guide Environment Directorate. Organisation for Economic Co-operation and Development, Paris.
Reichl, C., Schatz, M., Zsak, G., 2015. World Mining Data, in: Federal Ministry for Economics and Labour, A. (Ed.). Federal Ministry for Science, Research and Economy, Vienna.
Ritthoff, M., Rohn, H., Liedtke, C., 2002. Calculating MIPS - Resource productivity of products and services., in: Institut, W. (Ed.), Wuppertal Spezial. Wuppertal Institut, Wuppertal.
Schandl, H., Eisenmenger, N., 2006. Regional Patterns in Global Resource Extraction. Journal of Industrial Ecology 10, 133-147.
Schütz, H., 2003. Calculations of weighted average continental UDE coefficient (based on mining data on 2003) and UDE coefficients in Excel UDE database. Wuppertal Institute, Wuppertal.
Schütz, H., 2008. Calculations of weighted average continental UDE coefficient (based on mining data on 2003) and UDE coefficients in Excel UDE database. Wuppertal Institute, Wuppertal.
UNSD, 2015. Energy Statistics Database. United Nations Statistics Division.
USGS, 2015. International Minerals Statistics and Information. US Geological Survey, Washington D.C.
Weisz, H., Haas, W., Eisenmenger, N., Krausmann, F., Schaffartzik, A., 2007a. Economy-wide Material Flow Accounts Resource Productivity. EU-15. 1990-2004 EUROSTAT, Luxembourg.
Weisz, H., Krausmann, F., Eisenmenger, N., Schütz, H., Haas, W., Schaffartzik, A., 2007b. Economy-wide Material Flow Accounting. "A compilation guide". European Comission, Eurostat, Luxembourg.
World Energy Council, 1992. Survey of Energy Resources. World Energy Council, London.
WRI, 2008. World Resources Insitute Data Base, New York.

Annex 1: Countries included in the database

Africa
Algeria
Angola
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Cape Verde
Central African Republic
Chad
Comoros
Cote d'Ivoire
Djibouti
DR Congo
Egypt
Equatorial Guinea
Eritrea
Ethiopia
Gabon
Gambia
Ghana
Guinea
Guinea-Bissau
Kenya
Lesotho
Liberia
Libya
Madagascar
Malawi
Mali
Mauritania
Mauritius
Mayotte
Morocco
Mozambique
Namibia
Niger
Nigeria
Reunion
Rep Congo
Rwanda

Europe
Albania
Austria
Belarus
Belgium
Bosnia and Herzegovina
Bulgaria
Croatia
Cyprus
Czech Republic
Czechoslovakia
Denmark
Estonia
Falkland Islands (Malvinas)
Faroe Islands
Finland
France
Germany
Gibraltar
Greece
Hungary
Iceland
Ireland
Italy
Latvia
Liechtenstein
Lithuania
Luxembourg
Macedonia
Malta
Moldova
Montenegro
Netherlands
Norway
Poland
Portugal
Romania
Saint Helena
San Marino
Serbia (and Montenegro)
Slovakia
Slovenia

Sao Tome and Principe
Senegal
Seychelles
Sierra Leone
Somalia
South Africa
South Sudan
Sudan
Swaziland
Tanzania
Togo
Tunisia
Uganda
Zambia
Zimbabwe

Asia

Afghanistan
Armenia
Azerbaijan
Bahrain
Bangladesh
Bhutan
British Indian Ocean Territory
Brunei Darussalam
Cambodia
China
Fiji Islands
Georgia
India
Indonesia
Iran
Iraq
Israel
Japan
Jordan
Kazakhstan
Kiribati
Kuwait
Kyrgyzstan
Laos
Lebanon
Malaysia
Maldives
Mongolia
Myanmar
Nepal
Spain
Sweden
Switzerland
Ukraine
United Kingdom
Yugoslavia SFR

Latin America & Caribbean

Anguilla
Antigua and Barbuda
Argentina
Aruba
Bahamas
Barbados
Belize
Bermuda
Bolivia
Brazil
Cayman Islands
Chile
Colombia
Costa Rica
Cuba
Dominica
Dominican Republic
Ecuador
El Salvador
French Guiana
Grenada
Guadeloupe
Guatemala
Guyana
Haiti
Honduras
Jamaica
Martinique
Mexico
Montserrat
Netherlands Antilles
Nicaragua
Panama
Paraguay
Peru
Puerto Rico
Saint Kitts and Nevis
Saint Lucia
Saint Vincent/Grenadines

North Korea
Oman
Pakistan
Palestine
Philippines
Qatar
Russian Federation
Saudi Arabia
Singapore
South Korea
Sri Lanka
Syria
Taiwan
Tajikistan
Thailand
Timor-Leste
Turkey
Turkmenistan
United Arab Emirates
USSR
Uzbekistan
Viet Nam
Yemen

North America

British Virgin Islands
Canada
Guam
Saint Pierre and Miquelon
United States of America
US Virgin Islands
Suriname
Trinidad and Tobago
Turks and Caicos Islands
Uruguay
Venezuela

Oceania

American Samoa
Australia
Christmas Island
Cocos (Keeling) Islands
Cook Islands
French Polynesia
Marshall Islands
Micronesia
Nauru
New Caledonia
New Zealand
Niue
Norfolk Island
Northern Mariana Islands
Palau
Papua New Guinea
Pitcairn Islands
Samoa
Solomon Islands
Tokelau
Tonga
Tuvalu
Vanuatu
Wallis and Futuna Islands

Annex 2: Material categories included in the database

Commodity Group	Main data source	Commodity Name	ID	Commodity Sub-group
Biomass	**Food and Agriculture Organization of the United Nations (FAO)**	Almonds	200	Biomass Food
		Anise, Badian, Fennel	206	
		Apples	168	
		Apricots	169	
		Aquatic plants	222	
		Arecanuts	302	
		Artichokes	147	
		Asparagus	148	
		Avocados	170	
		Bambara beans	274	
		Bananas	294	
		Barley	110	
		Beans, dry	275	
		Beans, green	276	
		Berries nec (including Cranberries)	195	
		Blueberries	172	
		Brazil nuts, with shell	303	
		Broad beans, horse beans, dry	277	
		Buckwheat	111	
		Cabbages	150	
		Canary Seed	112	
		Carobs	173	
		Carrots	151	
		Cashew nuts, with shell	304	
		Cashewapple	295	
		Cassava	270	
		Cassava leaves	335	
		Castor oil seed	283	
		Cauliflower	152	
		Cereals nec (including Pop Corn, Fonio and Quinoa)	122	
		Cherries	174	
		Chestnuts	201	
		Chick peas	278	
		Chicory Roots	207	
		Chillies and peppers, dry	325	
		Chillies and peppers, green	153	
		Cinnamon (canella)	309	
		Citrus Fruit nec	196	
		Cloves	310	

		Cocoa Beans	217	
		Coconuts	285	
		Coffee, Green	208	
		Cottonseed	334	
		Cow peas, dry	279	
		Cranberries	296	
		Cucumbers and Gherkins	154	
		Currants	175	
		Dates	176	
		Eggplants	155	
		Figs	177	
		Fonio	268	
		Fruit Fresh Nes	297	
		Fruit, tropical fresh nes	298	
		Garlic	156	
		Ginger	311	
		Gooseberries	178	
		Grapefruit and Pomelos	179	
		Grapes	180	
		Groundnuts in Shell	133	
		Hazelnuts (Filberts)	202	
		Hempseed	134	
		Honey	220	
		Hops	209	
		Jojoba Seeds	318	
		Kapokseed in Shell	287	
		Karite Nuts (Sheanuts)	288	
		Kiwi Fruit	181	
		Kolanuts	305	
		Leeks and other Alliac. Veg.	158	
		Leguminous vegetables, nes	312	
		Lemons and Limes	182	
		Lentils	129	
		Lettuce	159	
		Linseed	135	
		Lupins	130	
		Maize (grain maize)	113	
		Maize, green	313	
		Mangoes, mangosteens, guavas	299	
		Mate	218	
		Melonseed	136	
		Millet	114	
		Mixed Grain	115	
		Mushrooms	161	
		Mustard Seed	137	

		Nutmeg, mace and cardamoms	314	
		Nuts, nes	306	
		Oats	116	
		Oil Palm Fruit	183	
		Oilseeds nec (including Castor Beans, Kapokseed in Shell, Karite Nuts /Sheanuts/,Tung Nuts, Coconuts)	146	
		Okra	289	
		Olives	138	
		Onions (inc. shallots), green	290	
		Onions, dry	291	
		Oranges	184	
		Other melons (inc.cantaloupes)	292	
		Papayas	300	
		Peaches and Nectarines	185	
		Pears	186	
		Peas, dry	280	
		Peas, Green	163	
		Pepper (Piper spp.)	320	
		Peppermint	210	
		Persimmons	187	
		Pigeon peas	281	
		Pineapples	188	
		Pistachios	203	
		Plantains	301	
		Plums	189	
		Pome fruit, nes	321	
		Poppy Seed	139	
		Potatoes	123	
		Pulses nec	132	
		Pumpkins, Squash, Gourds	164	
		Pyrethrum, Dried Flowers	212	
		Quinces	190	
		Quinoa	269	
		Rapeseed (rape and turnip rape)	140	
		Raspberries	191	
		Rice, Paddy	117	
		Roots and Tubers, nes	271	
		Rye	118	
		Safflower Seed	141	
		Sesame Seed	143	
		Sorghum	119	
		Sour Cherries	192	
		Soybeans	144	
		Spices nec (including	216	

		Cinnamon,Ginger,Nutmeg,Mace,Cardamons, Pepper,Vanilla,Cloves)		
		Spinach	165	
		Stone Fruit nec,	199	
		Strawberries	193	
		String beans	282	
		Sugar Beets	213	
		Sugar Cane	214	
		Sugar Crops nes	219	
		Sunflower Seed	145	
		Sweet Potatoes	124	
		Tallowtree Seeds	322	
		Tang. Mand Clement. Satsma	194	
		Taro (cocoyam)	272	
		Tea	215	
		Tea nes	336	
		Tomatoes	166	
		Triticale	120	
		Tung Nuts	307	
		Vanilla	315	
		Vegetables Fresh nec (including Okra)	167	
		Vetches	131	
		Walnuts	204	
		Watermelons	293	
		Wheat (and spelt)	121	
		Yams	125	
		Yautia (cocoyam)	273	
		Alfalfa for Forage and Silage	224	Biomass Feed
		Beets for Fodder	225	
		Cabbage for Fodder	226	
		Carrots for Fodder	227	
		Clover for Forage and Silage	228	
		Forage Products nec	237	
		Grasses nec for Forage and Silage	238	
		Green Oilseeds for Fodder	241	
		Leguminous nec for forage and Silage	239	
		Maize for Forage and Silage (green maize)	230	
		Rye Grass, Forage and Silage	232	
		Sorghum for Forage and Silage	233	
		Swedes for Fodder	234	
		Turnips for Fodder	235	
		Vegetables and Roots, Fodder	236	
		Inland waters fish catch	251	Biomass Animals
		Marine fish catch	250	
		Other (e.g. Aquatic mammals)	252	

		Coniferous wood - Industrial roundwood	247	Biomass Forestry
		Coniferous wood - Wood fuel	332	
		Non-coniferous wood - Industrial roundwood	248	
		Non-coniferous wood - Wood fuel	333	
		Abaca (Manila Hemp)	257	Other Biomass
		Agave Fibres nes	258	
		Beeswax	331	
		Coir	259	
		Cotton Lint	254	
		Fibre Crops nes	260	
		Flax Fibre and Tow	255	
		Hemp Fibre and Tow	256	
		Jute and Jute-like Fibres	264	
		Kapok Fibre	263	
		Natural Gums	266	
		Natural Rubber	267	
		Other Bastfibres	308	
		Ramie	261	
		Sisal	262	
		Tobacco Leaves	265	
	Estimate based on data from Food and Agriculture Organization of the United Nations (FAO)	Crop Residues Feed	324	Biomass Feed
		Grazing	243	Biomass Feed
		Crop Residues Straw	323	Other Biomass
Fossil fuels	**International Energy Agency (IEA)**	Anthracite	327	Coal
		Coking Coal	328	
		Lignite	326	
		Other bituminous coal	329	
		Sub-bituminous coal	330	
		Natural gas	4	Gas
		Natural gas liquids	5	
		Crude oil	3	Oil
		Other hydrocarbons	350	
		Oil shale and oil sands	349	Other fossil fuels
		Peat for energy use	6	
	United Nations Energy Statistics Database	Natural gas	4	Gas
		Natural gas liquids	5	
		Crude oil	3	Oil
		Peat for energy use	6	Other fossil fuels

	International Energy Statistics of the U.S. Energy Information Administration	Anthracite	327	Coal
		Lignite	326	
		Other bituminous coal	329	
		Natural gas	4	Gas
		Natural gas liquids	5	
Ind. & Const. Minerals	**British Geological Survey (BGS)**	Crushed stone	68	Construction minerals
		Sand and gravel	108	
		Asbestos	94	Industrial Minerals
		Barite	72	
		Bentonite, sepiolite and attapulgite	50	
		Borate minerals	73	
		Brine salt	344	
		Bromine	337	
		Diatomite	76	
		Evaporated salt	345	
		Feldspar	77	
		Fire, refactory and flint clay, Andalusite, kyanite and sillimanite (all Al-containing)	51	
		Fluorspar	78	
		Fuller's earth	52	
		Graphite, natural	79	
		Gypsum and anhydrite	96	
		Iodine	339	
		Kaolin	53	
		Magnesite	81	
		Mica	82	
		Nepheline syenite	341	
		Perlite	97	
		Phosphate rock (natural phosphates)	85	
		Potash	86	
		Rock salt	347	
		Salt nec	348	
		Sea salt	346	
		Sodium carbonate, natural	343	
		Strontium minerals	88	
		Sulphur	89	
		Sulphur as a by-product of natural gas etc.	91	
		Sulphur from pyrites	90	
		Talc (steatite, soapstone, pyrophyllite)	92	
		Vermiculite	316	
		Wollastonite	317	

	US Geological Survey (USGS)	Asphalt	104	Construction minerals
		Common clay, clay for bricks etc.	105	
		Crushed stone	68	
		Igneous rock (basalt, basaltic lava, diabase, granite, porphyry, etc.)	64	
		Limestone	65	
		Marble, travertines etc.	100	
		Sand and gravel	108	
		Sandstone	66	
		Slate including fill (incl. roof slate)	67	
		Abrasives, natural (puzzolan, pumice, volcanic cinder etc.)	70	Industrial Minerals
		Ball clay	49	
		Bentonite, sepiolite and attapulgite	50	
		Bromine	337	
		Calcite	60	
		Chalk	61	
		Diamonds, gems	74	
		Diamonds, industrial	75	
		Diatomite	76	
		Dolomite	63	
		Feldspar	77	
		Fire, refactory and flint clay, Andalusite, kyanite and sillimanite (all Al-containing)	51	
		Gypsum and anhydrite	96	
		Iron ore for pigments	80	
		Kaolin	53	
		Peat for agricultural use	69	
		Perlite	97	
		Phosphate rock (natural phosphates)	85	
		Potter clay	54	
		Qartz and quartzite	87	
		Salt nec	348	
		Sillica sand (quartzsand)	58	
		Sodium carbonate, natural	343	
		Special clay	55	
		Sulphur	89	
		Sulphur as a by-product of natural gas etc.	91	
		Vermiculite	316	
	World Mining Data (WMD)	Barite	72	Industrial Minerals
		Diamonds, gems	74	
		Diamonds, industrial	75	
		Diatomite	76	
		Feldspar	77	
		Fluorspar	78	

		Salt nec	348	
		Sulphur	89	
		Talc (steatite, soapstone, pyrophyllite)	92	
	Estimate based on data from USGS, BGS, Eurostat, IEA, UNSD, EIA, UN Comtrade	Construction Minerals nec	109	Construction minerals
Ores	**British Geological Survey (BGS)**	Antimony	8	Ores
		Arsenic	9	
		Bauxite (Aluminium)	10	
		Beryllium	11	
		Bismuth	12	
		Cadmium	13	
		Chromium	15	
		Cobalt	16	
		Copper	17	
		Gallium	18	
		Germanium	19	
		Gold	20	
		Indium and Thallium	21	
		Iron ores	7	
		Lead	22	
		Lithium	23	
		Magnesium	24	
		Manganese	25	
		Mercury	26	
		Molybdenum	27	
		Nickel	28	
		Niobium + Tantalum	29	
		Platinum-group (PGM)	30	
		Rare Earths Metals	31	
		Rhenium	342	
		Selenium	32	
		Silver	34	
		Tellurium	36	
		Tin	37	
		Titanium (incl/ Ilmenite and Rutile)	38	
		Tungsten	39	
		Uranium	40	
		Vanadium	41	
		Zinc	42	
		Zirconium and Hafnium	43	

	US Geological Survey (USGS)	Arsenic	9	Ores
		Gold	20	
		Indium and Thallium	21	
		Iron ores	7	
		Lead	22	
		Monazite (Thorium)	340	
		Nickel	28	
		Silver	34	
		Titanium (incl/ Ilmenite and Rutile)	38	
		Uranium	40	
		Vanadium	41	
		Zinc	42	
	World Mining Data (WMD)	Bauxite (Aluminium)	10	Ores
		Cadmium	13	
		Germanium	19	
		Gold	20	
		Iron ores	7	
		Rare Earths Metals	31	

Annex 3: List of sources - Estimation factors of metal ores

Metal	Institution/Author	Publications
Antimony	**US Geological Survey**	USGS – Country Reports
		Personal Communication
	Wagner, H., Weber, L.	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
Bauxite	**Federal Institute for Geosciences and Natural Resources, Germany**	Geological yearbook, SH 2, Aluminium
		Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
		Studies on supply and demand of mineral raw materials
	US Geological Survey	USGS – Country Reports
Beryllium	**Federal Institute for Geosciences and Natural Resources, Germany**	Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
	Wagner, H., Weber, L.	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished manuscript.
Chromium	**Federal Institute for Geosciences and Natural Resources, Germany**	Geological yearbook, Chromium
		Studies on supply and demand of mineral raw materials
Cobalt	**US Geological Survey**	Personal Communication
	Wagner, H., Weber, L.	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
Copper	**Bureau of Mines**	The availability of primary copper in market economy countries. United States Department of the Interior. IC 9310.
	Federal Institute for Geosciences and Natural Resources, Germany	Geological yearbooks
		Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
		Studies on supply and demand of mineral raw materials XI
	Mudd, G.	The sustainability of mining in Australia: key production trends and their environmental implications. Melbourne, Department of Civil Engineering, Monash University and Mineral Policy Institute.
	US Geological Survey	USGS – Country Reports

		Personal Communication
	Wuppertal Institute	Database of Wuppertal Institute (WI)
Gold	**Federal Institute for Geosciences and Natural Resources, Germany**	Geological yearbooks
		Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
	Mudd, G.	The sustainability of mining in Australia: key production trends and their environmental implications. Melbourne, Department of Civil Engineering, Monash University and Mineral Policy Institute.
	US Geological Survey	USGS – Country Reports
	Wagner, H., Weber, L.	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
	Wuppertal Institute	Database of Wuppertal Institute (WI)
Iron ores	**Federal Institute for Geosciences and Natural Resources, Germany**	Geological yearbook
		Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
	US Geological Survey	Iron ore statistical compendium
		USGS – Country Reports
		Personal Communication
Lead	**Federal Institute for Geosciences and Natural Resources, Germany**	Geological yearbook
		Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
	Mudd, G.	The sustainability of mining in Australia: key production trends and their environmental implications. Melbourne, Department of Civil Engineering, Monash University and Mineral Policy Institute.
	US Geological Survey	USGS – Country Reports
	Wuppertal Institute	Database of Wuppertal Institute (WI)
Lithium	**Federal Institute for Geosciences and Natural Resources, Germany**	Studies on supply and demand of mineral raw materials XXI
	US Geological Survey	USGS – Country Reports
	Wagner, H., Weber, L.	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
Manganese	**Federal Institute for Geosciences and Natural Resources, Germany**	Geological yearbook
		Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)

	US Geological Survey	USGS – Country Reports
		Minerals Yearbook, Manganese
		Manganese ore statistical compendium
Mercury	**Federal Institute for Geosciences and Natural Resources, Germany**	Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
	US Geological Survey	USGS – Country Reports
		Personal Communication
	Wagner, H., Weber, L.	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
Nickel	**Federal Institute for Geosciences and Natural Resources, Germany**	Geological yearbook
		Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
	US Geological Survey	USGS – Country Reports
		Personal Communication
	Wagner, H., Weber, L.	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
Platinum group (PGM)	**US Geological Survey**	USGS – Country Reports
		Personal Communication
	Wagner, H., Weber, L.	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
Rare Earths Metals	**Schütz, H.**	Technical Details of NMFA (Inputside) for Germany (Imports to Germany). Wuppertal Institute, Wuppertal.
Silver	**Federal Institute for Geosciences and Natural Resources, Germany**	Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
		Studies on supply and demand of mineral raw materials XI
	US Geological Survey	USGS – Country Reports
	Wagner, H., Weber, L.	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
Tin	**Bureau of Mines**	Tin availability – market economy countries. United States Department of the Interior. IC 9086.
	Wagner, H., Weber, L.	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
Titanium	**Wagner, H., Weber, L.**	Gesichtspunkte für die bergtechnische und

(including Ilmenite and Rutile)		bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
Tungsten	**Federal Institute for Geosciences and Natural Resources, Germany**	Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
	Schütz, H.	Technical Details of NMFA (Inputside) for Germany (Imports to Germany). Wuppertal Institute, Wuppertal.
	US Geological Survey	Personal Communication
Uranium	**Federal Institute for Geosciences and Natural Resources, Germany**	Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
	US Geological Survey	USGS – Country Reports
Vanadium	**Wagner, H., Weber, L.**	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
Zinc	**Federal Institute for Geosciences and Natural Resources, Germany**	Rohstoffwirtschaftliche Länderstudien (Raw material country studies – in German)
	Mudd, G.	The sustainability of mining in Australia: key production trends and their environmental implications. Melbourne, Department of Civil Engineering, Monash University and Mineral Policy Institute.
	US Geological Survey	USGS – Country Reports
	Wagner, H., Weber, L.	Gesichtspunkte für die bergtechnische und bergwirtschaftliche Beurteilung von Vorkommen mineralischer Rohstoffe. Unpublished German manuscript.
	Wuppertal Institute	Database of Wuppertal Institute (WI)