CREEA - Compiling and Refining Environmental and Economic Accounts

Recommendation of terminology, classification, framework of waste accounts and MFA, and data collection guideline

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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 natural 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 natural 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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Disclaimer: When producing this inception report, we found smarter ways of organizing work that also could make it possible to produce more extensive results as foreseen in the DoW. It concerns particularly the aspiration of producing not only an update of the EXIOBASE Monetary SUT, but to expand it into a Physical and Energy SUT. We tried to express such additional ambitious cautiously in this inception report. It has to be stressed that the ambitions in the DoW, and not those in the inception report, are the required deliverables of CREEA.

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Executive Summary

In **chapter 2** the system boundaries, definitions and classifications recommended by the System of Environmental-Economic Accounts (SEEA) with regard to material flows and especially solid waste are presented. The SEEA provides an internationally agreed conceptual framework to measure the interactions between the economy and the environment and the state of the environment (United nation et al, 2003). Alignment between the SEEA and the CREEA database will increase the usability of the database, espically by national statistical institutes. Alignment can be achieved by directly implementing classifications recommended by SEEA, such as ISIC (Industries) and CPC (products). In other cases alignment with the SEEA terminology can be obtained using conversion or bridge tables.

Chapter 3 to **9** describes in detail the applied terminology and framework for MFA and waste accounts in the CREEA project. The overall framework for MFA is physical supply-use tables (PSUT) following the same product and activity classification as the monetary supply-use tables (MSUT) in the CREEA project.

Product balance is achived as: supply of products plus imported products which is equal to use of products plus capital formation plus final use plus export of products.

In order to obtain activity balances for the physical supply and use of mass flows some additional inputs and outputs to and from the economy are needed. These are inputs of natural resources and materials for treatment, and outputs of emissions, stock additions and materials for treatment. This is illustrated in **Figure 0.1** below.

PSUTs are constructed in a determined accounting period, usually one year, and for a given geographical area, typically a country.

Balanced PSUT	Activities	Stock formation	Final use	Export	Import	Total
Products	$\mathbf{V}'$				$\mathbf{N_c}$	$\mathbf{q}$
Stock additions	$\mathbf{\Delta S}$					
Materials for treatment	$\mathbf{W_V}$				$\mathbf{N_w}$	
Emissions	$\mathbf{B}$					
Total	$\mathbf{g}'$					

Products	$\mathbf{U}$	$\mathbf{s^+}$	$\mathbf{Y}$	$\mathbf{N_c}$		$\mathbf{q}$
Materials for treatment	$\mathbf{W_U}$			$\mathbf{N_w}$		
Natural resources	$\mathbf{R}$					
Total	$\mathbf{g}'$					

Figure 0.1: Format of physical supply-use tables (PSUTs).

For the applied terminology and framework, the major deviations from the recommended SEEA 2012 terminology in **chapter 2** are:

- the definition of products, which exclude secondary material in the CREEA definition;
- the definition of a term including waste; 'materials for treatment'. This term is not present in SEEA 2012. The term is further described in the following;
- inclusion of additional stock addition table ($\Delta\mathbf{S}$) in the columns of productive activities and final uses

In order to be able to model the life cycle implications of changing waste management systems using an hybrid input-output table derived from the CREEA framework, the industrial production processes that involve re-processing of waste material and secondary material into new products are disaggregated into virgin and recycling production. This also involves technical disaggregations of joint production processes, e.g. glass manufacturing which involves the use of silicate sand as well as recycled glass cullets as feedstock.

Waste accounts are created based on a calculated output of 'materials for treatment'. Therefore, materials for treatment are central. Materials for treatment are defined as output flows of a human activity that remains in the technosphere and cannot directly (i.e. without further processing or emissions) displace another principal product of an activity. After processing in a waste treatment (re-processing or recycling) activity, the recovered materials for treatment may displace other products.

The output of materials for treatment is calculated as a balancing item based on the flows shown in **Figure 0.2** below.

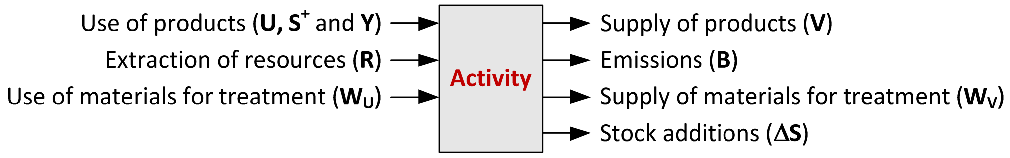

Figure 0.2: Input- and output flows for a generic activity. The output of 'materials for treatment' ($\mathbf{W_V}$) is the calculated balancing item from which waste accounts are derived.

Generally speaking, for any human activity the inputs in terms of products in **U**-table, materials for treatment in $\mathbf{W_U}$-table and natural resources in **R**-table are balanced by the outputs in terms products in **V**-table, emissions in **B**-table, materials for treatment in $\mathbf{W_V}$-table and stock additions in $\Delta\mathbf{S}$-table.

Supply of materials for treatment in a productive activity or a household can originate from three different sources: use of products (**U**, $\mathbf{S^+}$ and **Y**), extraction of natural resources (**R**) and from input of waste ($\mathbf{W_U}$). This inspires the strategy behind the CREEA approach, i.e. only a part of each type of input ends up being included in the final products. What is left out may end up in the emissions (**B**), materials for treatment ($\mathbf{W_V}$) or stock additions ($\Delta\mathbf{S}$).

When calculating the supply of materials for treatment from an activity, this is expressed in terms of the products from which it originates and also if the materials for treatment originates from resource or materials for treatment inputs. **Figure 0.3** illustrates the possible fate of each of the three types of inputs which may end up as materials for treatment plus stock additions.

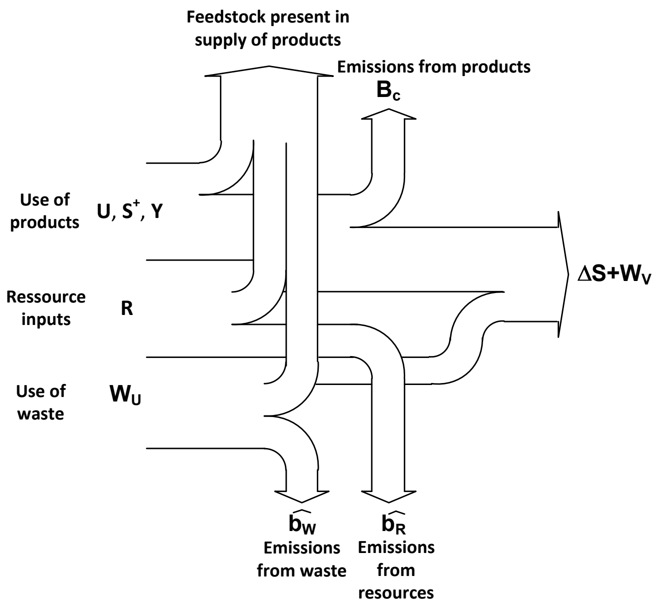

Figure 0.3: Principal fate of any input to an activity.

The default MFA account and waste account in the CREEA project will be based on information on the accounting period only, i.e. year 2007. This obviously implies some simplifying assumptions regarding mass flows from previous accounting periods (stock depreciation) and future accounting periods (stock additions). This means that the total quantity of generated materials for treatment (waste) is estimated based in the inputs of natural resources and outputs of emissions in the period. Hence, the supply of materials for treatment from degradation of stocks build up previous years is assumed to equal the formation of stocks in the accounting period.

$$\Delta \boldsymbol{S} + \mathbf{W_V} = \mathbf{W_V}$$

Better estimates can be carried out by use of time series.

The applied definitions and classifications for MFA and waste accounts in the CREEA project are presented in **chapter 7** and **8**.

1 Introduction

1.1 Introduction to CREEA

The main goal of the CREEA project 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

1.2 Scope and framework of waste accounts and MFA

Currently national waste accounts are compiled as part of the environmental accounts (Delahaye 2007, United nation et al, 2003). The waste accounts are compiled on the basis of waste registration information. As a result some waste flows in the waste accounts are not covered sufficiently: 1) some non-hazardous waste with a monetary value, and 2) illegal waste. Therefore, the current physical accounts are limited in terms of completeness, i.e. there is no direct link between the causes of waste (inputs of natural resources and transactions of physical flows) and the quantification of waste in the waste accounts. The result of this lack of integration is that the accounting system does not enable for analytic economy wide life cycle emissions calculations on the effect of different waste management interventions.

In addressing the above-mentioned limitations in current national waste accounts, the WP4 will provide recommendations regarding the following issues within the SEEA 2012:

- harmonization of terminology and classification
- methodology for linking waste and MFA accounts and for integrating the accounts into economical accounting systems (supply-use framework)
- data collection enabling; the creation of standardized waste tables, linking waste with material flow accounts, and creation of harmonized datasets ready for integration in the EXIOBASE

The accounting structure in SEEA uses the supply-use framework for economic as well as physical accounts, where physical is used for indicating the mass. The use of the supply-use framework as accounting principle is also applied in the EXIOPOL as well as the FORWAST (http://forwast.brgm.fr/) projects.

The FORWAST model measures the generation of waste residuals and waste products (this is referred to as ‘material for treatment’ in the following) as well as their passage from the economy to the environment in physical terms. This is done within the context of the other physical flows between the environment and the economy and within the economy. Inputs to the economy from the environment and other economies equal outputs from the economy to the environment and other economies plus net accumulation in the economic sphere.

A subdivision of the physical flows accounts into accounts for materials, water and energy in the SEEA2012 was agreed upon the London group. The accounts for materials can be further subdivided for instance into waste accounts and/or accounts for specific materials (e.g wood and wood products) or residuals. A new classification scheme with regard to all physical flows is still being discussed in the London group. Concerning the material flow accounts and EW-MFA several methodological and practical issues remain to be solved. Also, several of the accounting principles with regard to MFA and waste have to be further tested in the real world. It needs to be assessed how these accounts can provide policy relevant information and indicators.

2 Recommendation of terminology and classification

2.1 Introduction

The objective of this chapter is to describe the system boundaries, definitions and classifications set out in the revised System of Environmental-Economic Accounts (SEEA2012) with regard to material flows and especially solid waste[1]. Issues that concern the harmonizing between SEEA and CREEA are the main focus of this document.

The SEEA, currently under revision, will provide an internationally agreed conceptual framework to measure the interactions between the economy and the environment and the state of the environment (United nation et al, 2003). The revised SEEA-2012 will build upon its predecessors (the SEEA-2003 and the SEEA-1993) and is scheduled for completion by February 2012.

The origin of the System of Environmental-Economic Accounts (SEEA) and its revision process are described elaborately by Edens and de Haan (2010). Here, a short summary of the relevant issues is given. The SEEA-2003, issued jointly by the United Nations, the European Commission, the International Monetary Fund, the Organization of Economic Cooperation and Development, and the World Bank (UN, et al 2003), can be characterised as a book of best practices but falls short of the requirements of statistical standardization as it does not provide unique or sufficiently precise recommendations for several important issues. In 2006, the statistical community decided the time was there to elevate the SEEA into an international statistical standard. In order to manage and supervise the SEEA revision process the UN Statistical Commission created the United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA). The UNCEEA is described as fulfilling an 'umbrella function' in overseeing the work in environmental accounting carried out by, among others, the London Group. The London Group, a forum for countries to share experiences in developing environmental accounts, plays a key role in solving most of the technical issues on the research agenda. The revision issues on the research agenda were taken care of in outcome papers which detail the decisions reached. These outcome papers are input for the editor to draft SEEA2012, which in turn is distributed for global consultation. The latter results in comments and remarks that are also taken into account and may results in new revision issue.

Most relevant for this paper are the developments of chapter 3.6 on physical flow accounts for materials in volume 1 of the draft SEEA2012. This chapter deals with measuring physical flows using accounting concepts and classifications consistent with the economic accounting structure of the 2008 SNA (System of National accounts; United nations et al, 2009). One important feature of the physical flow accounts is their one-to-one relationship to the monetary accounts, especially the SNA supply-use tables. Bringing both pieces of information together, these so-called hybrid flow accounts are a

[1] A substantial part of the text used in this document is taken from the (October 2011) draft version of the SEEA2012.

powerful analytical tool for reporting on the environmental performance of consumption and production activity.

2.2 Material flow accounts in SEEA2012

The physical flow accounting framework presented in the SEEA2012 is intended to provide a set of accounting principles and boundaries within which a consistent recording of all types of physical flows relating to economic activity can be made. In material flow accounting flows can be measured in terms of mass (e.g. tonnes). In water accounts the unit of measurement is volume (e.g. cubic metres) and in energy accounts the unit of measurement is energy content (e.g. joules). The choice of unit depends on the purpose for which the tables and accounts are set up.

2.2.1 Physical supply and use tables

In **Table 2.1** the physical supply and use tables (PSUT) as proposed in SEEA2012 are presented. This table is based on the structure of the monetary supply and use tables used to measure economic activity as outlined by the production boundary in the 2008 SNA. In the PSUT flows to and from the environment, that do not have a monetary counterpart, can be added to the monetary supply and use table. These additions allow all physical flows: (i) from the environment, (ii) within the economy and (iii) back to the environment, to be recorded within one framework.

The rows of the **Table 2.1** distinguish natural inputs, products and residuals. Natural inputs and residuals are extensions to the monetary supply and use table in the SNA. The supply table shows the flows relating to the production and supply of natural inputs, products or residuals by different economic units or the environment. The use table shows the flows relating to the consumption and use of natural inputs, products and residuals by different economic units or the environment.

The columns of the PSUT are structured to indicate the activity underlying the flow, e.g. whether it is related to production, consumption or accumulation, and the economic units involved. The first column covers the use of natural inputs, the production and intermediate consumption of products, and the generation and receipt of residuals by all units in the economy. The second column covers the consumption of products by households and the generation of residuals from this consumption. The activity of households in extracting natural inputs from the environment for their own consumption is considered a productive activity and hence this activity should be recorded in the first column against the relevant industry class. Unlike the monetary supply and use table, no entries are made in relation to government final consumption. Government final consumption represents the purchase and consumption by governments of their own output and does not have an associated physical flow. All of the physical flows related to the intermediate consumption of governments are recorded in the first column under the relevant industry class, commonly public administration. In addition, the generation of residuals, e.g. emissions, solid waste, by governments in the production of their output is recorded in the first column. The third column, labelled accumulation, concerns changes in the stock of materials in the economy. From a supply perspective, this column records reductions in the physical stock of produced assets through, for example, demolition or scrapping. It also shows emissions from controlled landfill sites which are accumulations of residuals from previous accounting periods. Controlled and managed landfills should be considered as operating within the production boundary. From a use perspective, the accumulation column records additions to the physical stock of produced assets (gross capital formation) and the accumulation over an accounting period of materials in controlled landfill sites. Flows to emission capture and storage facilities are also recorded as use by accumulation. These accumulation flows may be classified by industry and, if so, can be combined with industry level information from the first column to provide an overall assessment of flows of residuals by industry. Retaining the distinction between residuals from current production activity (from the first column) and residuals from past production activity (from the third column) may be important for some analyses. Alternatively, the accumulation flows may be classified by product. The fourth column shows the exchanges between national economies in terms of imports and exports of products and flows of residuals. Excluded from these flows are so-called transboundary flows, for example polluted water flowing downstream into a neighbouring country or air emissions transferred into other countries' environments. Transboundary flows are considered flows within the environment and hence out of scope of the PSUT framework. The fifth column is the significant addition to the monetary supply and use table structure in the SNA. In this column flows to and from the environment are recorded. Within the PSUT the environment is a "passive" entity that does not undertake production, consumption or accumulation in the way as units inside the economy. Nonetheless, the incorporation of the environmental column allows a full accounting for flows of natural inputs and residuals that would otherwise not be possible. In order to achieve a supply-use balance, flows to and from the environment in relation to respiration of livestock and combustion processes need to be recorded.

SUPPLY						
	Production and generation of residuals		**Accumulation**	**Flows from the Rest of the World**	**Flows from the Environment**	**Total**
	Production and generation of residuals by industries (incl. household production on own account) - classified by ISIC	**Generation of residuals by households**	**Industries - classified by ISIC**			
Natural inputs					A. Flows from environment (incl. natural resource residuals)	Total Supply of Natural Inputs (TSNI)
Products	C. Domestic production (incl sale of recycled and reused products)			D. Imports of products		Total Supply of Products (TSP)
Residuals	I1. Residuals generated by industry (incl. natural resource residuals) I2. Residuals generated following treatment	J. Residuals generated by household final consumption	K1. Residuals from scrapping and demolition of produced assets K2. Emissions from controlled landfill sites	L. Residuals received from rest of the world	M. Residuals recovered from the environment	Total Supply of Residuals (TSR)
TOTAL SUPPLY						

USE							
	Intermediate consumption of products, use of natural inputs and collection of residuals		**Final consumption ***	**Accumulation**	**Flows to the Rest of the World**	**Flows to the Environment**	**Total**
	Industries - classified by ISIC		**Households**	**Industries - classified by ISIC**			
Natural inputs	B. Extraction of natural inputs						Total Use of Natural Inputs (TUNI)
	B1. Extraction used in production	B2. Natural resource residuals					
Products	E. Intermediate consumption (incl purchase of recycled and reused products)		F. Household final consumption (incl purchase of recycled and reused products)	G. Gross Capital Formation	H. Exports of products		Total Use of Products (TUP)
Residuals	N. Residuals received by waste mgt and other industries (incl residuals from scrapping and demolition of produced assets; excl accumulation in controlled landfill sites)			O. Accumulation in controlled landfill sites	P. Residuals sent to the rest of the world	Q. Residual flows direct to environment Q1. Direct from industry and households (incl. natural resource residuals & landfill emissions) Q2.Following treatment	Total Use of Residuals (TUR)
TOTAL USE							

Table 2.1: General physical supply and use table (SEEA, 2012). *No entries for government final consumption are recorded in physical terms. All government intermediate consumption, production and generation of residuals is recorded against the relevant industry in the first column of the PSUT.

Balancing supply and use

The PSUT contains a range of important accounting and balancing identities. The starting point for the balancing of the PSUT is the supply-use identity, which recognises that, within the economy, the amount of a product supplied must also used within the economy, most likely by a range of different economic units, or exported. Thus, using references to the cells in **Table 2.1**,

Total Supply of Products = Domestic production (C) + Imports (D)

is identical to

Total Use of Products = Intermediate consumption (E) + Household Final Consumption (F) + Gross capital formation (G) + Exports (H)

This supply-use identity for products also applies in the monetary supply and use table. In the PSUT the supply-use identity is extended such that the total supply of natural inputs must equal the total use of natural inputs and the total supply of residuals must equal the total use of residuals.

Total Supply of Residuals = Generated by industry (I1 & I2) + Generated by households (J) + From accumulation (K1 & K2) + From rest of the world (L) + From the environment (M)

is identical to

Total Use of Residuals = Received by industry (N) + Accumulation in controlled landfill sites (O) + To rest of the world (P) + To the environment (Q1 & Q2)

Regarding the flows of residuals a number of stages need to be recognised. In the first stage residuals are generated or come into the economy as reflected in cells (I1 and J to M). These residuals are received by other units in the economy (N & O), sent to other countries (P) or returned to the environment (Q1). The residuals received by other units (N) may be treated or processed and then either sold as recycled or reused products or returned to the environment. If sold as recycled or reused products the production is recorded in (C) and the purchase in (E) or (F). The supply of the treated residual is recorded in (I2) and the use in (Q2).

Over an accounting period, flows of materials into an economy must equal the flows of materials out of an economy plus any net additions to stock in the economy. Thus, using references to the cells in **Table 2.1**,

Materials into the economy = Natural inputs (A) + Imports (D) + Residuals from the rest of the world (L) + Residuals from the environment (M)

is equal to

Materials out of the economy = Residuals to the environment (Q) + Exports (H) + Residuals to the rest of the world (P)

plus

Net additions to stock in the economy = Gross capital formation (G) + Accumulation in controlled landfill sites (O) - Residuals from produced assets and controlled landfill sites (K)

This identity may be applied both at the level of an entire economy (as described) and also at the level of an individual industry or household. In the following chapters the system boundaries, definitions and classifications that are applied in Table 2.1 are being discussed. These issues are fundamental in constructing meaningful supply and use tables.

2.3 System boundaries

The system boundary applied in the EXIOBASE and FORWAST is to a large extent according to the EW-MFA[2] concepts (OECD, 2008; Eurostat 2011). However, the system boundary according to EW-MFA differs from the physical flow accounting as proposed in the SEEA and SNA. The main difference between system boundaries according to EW-MFA and SEEA lies in the treatment of cultivated biomass, controlled landfills and the residence principle. In this chapter recommendations are made to reconcile both approaches.

2.3.1 Cultivated biological resources

According to the SNA, cultivated biological resources[3] are within the production boundary of a country. As a result, the contribution to the growth of cultivated biological resource, e.g. natural inputs like CO_2 and water, should be recorded as flows from the environmental to the economy. This approach is referred to as the "ecosystem approach". In **Figure 2.1**, the system boundary according to the ecosystem approach is depicted by the blue circle including the green part (Schoer, 2008).

In EW-MFA, the harvest of both cultivated and non-cultivated vegetable resources are recorded as flows from the environment to the economy. This approach has been labelled the "harvest approach". It is possible to apply the harvest approach to all cultivated resources – trees, crops, livestock and fish – an approach commonly referred to as the "extended harvest approach". It is also possible to apply different approaches to different resources – the common boundary drawn, also applied in CREEA, is to treat trees and crops using the harvest approach and livestock and fish using the ecosystem approach. In **Figure 2.1** the system boundary according to the harvest approach for cultivated biomass is the blue circle excluding the green part.

[2] *"Economy-wide material flow accounts are compilations of the material inputs into national economies, the changes of material stock within the economic system and the material outputs to other economies or to the environment. EW-MFA cover all solid, gaseous, and liquid materials, except for bulk water and air; the unit of measurement is tonnes (i.e. metric tonnes) per year."*

[3] *"Cultivated biological resources cover animal and vegetable resources whose natural growth and regeneration are under the direct control, responsibility and management of institutional units."*

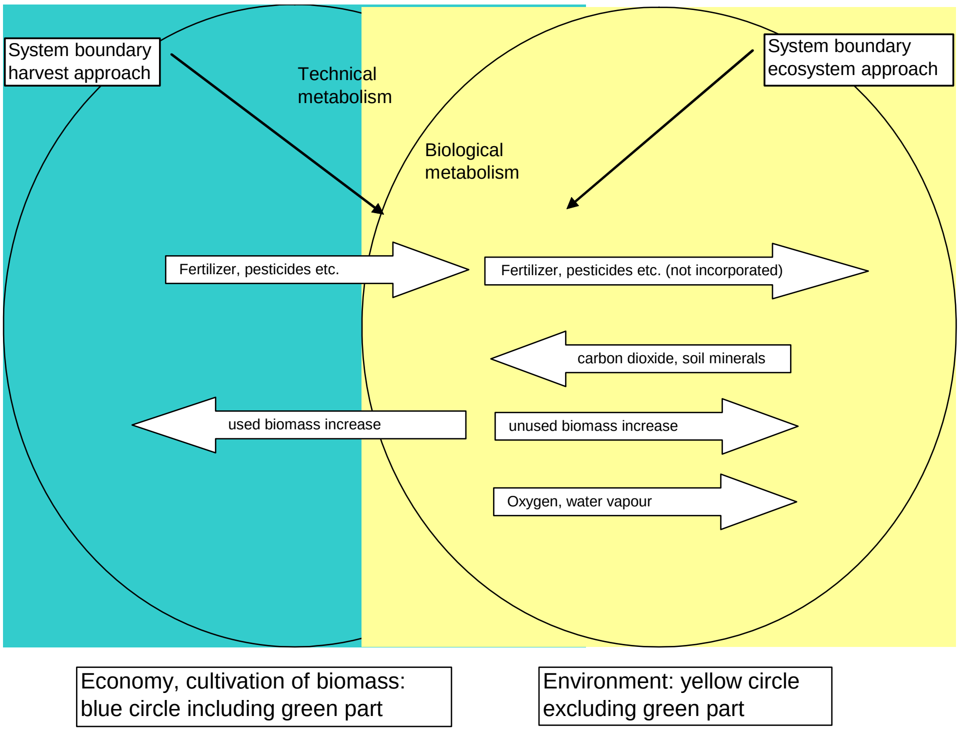

Figure 2.1: System boundaries according to "harvest" and "ecosystem" approach. (adapted from Schoer, 2008)

According to the boundaries depicted in **Figure 2.1**, a supply and use tables can be set up for both approaches (**Table 2.2**). The figures in this table are from a German input-output table of 1990 Schoer (2008) and have an illustrative character. Material flows crossing the system boundary according to the ecosystem approach are presented in the top half of the table. The bottom half of the table presents material flows crossing the system boundary according to the harvest approach. The numbers in the grey area are should not be recorded in the PSUT but are presented here in order to be able to balance supply and use.

The difference between total supply and use (excluding the grey areas) is the same for both approaches. Therefore, derived consumption indicators, like for example Domestic Material Consumption (DMC), are also the same for both approaches. However, input indicators like DMI (Domestic material consumption), are different.

Ecosystem approach			
Use		**Supply**	
Products		**Products**	
A. Fertilizer, pesticides etc	11	C. Used biomass increase	195
Natural inputs		**Residuals**	
B. CO2, soil minerals etc	552	D. Unused biomass increase	160
		E. Fertilizer, pesticides etc (not incorporated)	7
		F. O2, water vapour etc.	201
Total	564	**Total**	564

Harvest approach			
Use		**Supply**	
Products		**Products**	
A. Fertilizer, pesticides etc	11	C. Used biomass increase	195
Natural inputs		**Residuals**	
C. Used biomass increase	195	A. Fertilizer, pesticides etc	11
Total	206	**Total**	206

Table 2.2: Supply and use tables according to "harvest" and "ecosystem" approach. (adapted from Schoer, 2008)

Both the ecosystem approach and the harvest approach have their advantages and disadvantages. Alignment between the harvest approach applied in EW-MFA and the ecosystem approach as recommended by SEEA2012 can be achieved by the following equation (according to **Table 2.2**):

Net use according to ecosystem approach = CO2, soil minerals etc. (B) – Unused biomass increase (D) – Fertilizer (not incorporated (E) – O2, water vapour etc. (F)

is identical to

Net use according to harvest approach = Used biomass increase (C) – Fertilizer (A)

In order to fill out **Table 2.2** several types of data are needed. The used biomass increase, as recorded in the harvest approach, equals the amount of annually harvested biomass (an exception for long standing cultivated trees is discussed later). For each type of cultivated biomass an estimate is needed of the amount of biomass that stays on the field after harvest (the so called unused biomass). On the basis of the amount of harvest biomass estimations have also to be made of the amounts of natural inputs that are taken up (e.g. CO_2) and emitted (e.g. O_2) by cultivated crops. Also, percentages of the amounts of fertilizers, farm manure and pesticides are not incorporated into cultivated plants are needed.

In cases where crop rotation cycles are greater than one year, used biomass growth does not equal annual harvest. This is especially the case for cultivated trees (for non-cultivated trees the harvest is recorded). Similar to EW-MFA, in the EIXIOPOL database the amount of harvested trees and not the used biomass increase is part of environmental-economic indicators. However, change in the stock of trees (used biomass increase) can also be an important indicator as it refers to a change of an important environmental asset. In order to be able to take this indicator into account in the CREEA database and to be more in alignment with SEEA, it is recommended to add the increase in used biomass for cultivated trees (as a memorandum item) to the CREEA database (similar as done in the Eurostat EW-MFA questionnaire).

Natural biological resources are treated differently; these enter the economy when extracted. For natural biological resources, the use of oxygen and nitrogen, etc and the uptake of soil nutrients and water are treated as flows within the environment and only the actual harvest of resources is considered to flow into the economy.

2.3.2 The residence principle

In the SNA (and, as a consequence, in the SEEA) the national economic system is defined by its residents' economic activities independent of where those activities take place geographically. For sake of consistency, the Eurostat MFA guide (Eurostat 2011) recommends to adjust import and export data, obtained from the foreign trade statistics, in order to comply with the residence principle. In practical terms this means that fuel consumed by resident units abroad (e.g. purchase of aviation fuel by domestic airlines or household that are on holiday) has to be recorded as imports in EW-MFA, while vice versa fuel provided to non-resident units domestically has to be recorded as export. The same applies to the recording of air emissions that occur during the combustion of fuel. In CREEA the issue of the residence principle is tackled in work package 6, task 6.1.

2.4 Definitions

The following recommendations are made in the draft SEEA2012 with regard to the definition of physical flows. Following the structure **Table 2.1** the following types of materials are discussed: natural inputs, products and residuals.

2.4.1 Natural inputs

Natural inputs are all physical inputs that are moved from their location in the environment as a part of economic production processes or are directly incorporated into economic production processes. The three broad classes of natural inputs are:

1. natural resource inputs
2. inputs from renewable energy sources
3. other natural inputs.

Natural resource inputs

Natural resource inputs comprise physical inputs to the economy from environmental assets defined as natural resources. Thus natural resource inputs comprise inputs from mineral and energy resources, soil resources, natural timber resources, natural fish resources, other natural biological resources and water resources. Natural resource inputs exclude the flows from cultivated biological resources. Cultivated biological resources are produced within the economy and hence are not flows from the environment.

Some natural resource inputs do not subsequently become used in production and instead immediately return to the environment. These flows are termed natural resource residuals and may be of particular interest in the assessment of sustainable resource management.

There are three types of natural resource residuals:

i. *Losses* during extraction which cover resources that the extractor would prefer to retain (for example losses of gas through flaring and venting),
ii. *Unused extraction* which covers resources in which the extractor has no ongoing interest (for example mining overburden and by-catch) and
iii. *Return flows of water*. These flows are separately identified as often they represent a very large proportion of the total amount of abstraction. For example, water abstracted for the generation of hydropower is almost completely returned to the inland water system.

Natural resource residuals are recorded four times in the supply and use table, both as natural inputs and residuals. First they are recorded in the supply table as natural inputs that flow from the environment to the economy. Subsequently they are used as residuals, and at the same time they are supplied, by industry as residuals. Finally, they are recorded as residual flows to the environment. Thus, in order to fully account for the physical flows associated with economic production, unused extraction is considered to enter the economy as natural inputs and then immediately leave the economy as residual flows. Unused extraction is not considered solid waste and, therefore, must not be recorded as such.

Inputs from renewable energy sources

Inputs from renewable energy sources are the non-fuel sources of energy provided by the environment.

Other natural inputs

These may be inputs from air or from soil used in production processes or consumption.

2.4.2 Products

According to the SNA, products are goods and services that result from a process of production. The scope of products included in physical flow accounts is generally limited to only those with positive monetary value – i.e. the existence of a product is evidenced by a transaction. However, there are some flows of materials that are used as part of own account production that are not recognized by monetary transactions in the SNA. For example flows of processed iron ore within a steel making enterprise would not be recorded as monetary transactions. According to the SEEA, for physical flow accounting these intra-enterprise flows should be recorded since a meaningful price could be imputed for these flows.

2.4.3 Residuals

Residuals are physical flows of solid, liquid and gaseous materials and energy that are discarded, discharged or emitted by businesses and households through processes of production, consumption or accumulation. Residuals may be discarded, discharged or emitted directly to the environment or be captured, collected, treated, recycled or reused by economic units. These various transformation processes may lead to the generation of new products that are of economic value to the unit undertaking the transformation even if the residual, when first discarded or emitted may have no economic value to the person or business discarding or emitting the residual.

In situations where the intent may be to discard but the generator receives money or other benefits in kind in exchange for the discarded good, this is treated as a transaction in a product and not as a residual.

Solid waste

Solid waste covers discarded materials that are no longer required by the owner or user. Solid waste includes materials that are in a solid or liquid state but excludes wastewater and small particulate matter released into the atmosphere. Solid waste can be both a residual and a product.

Solid waste includes all materials sent to or collected by waste collection or treatment schemes including landfill establishments. Solid waste also includes those same materials if they are discarded directly to the environment – whether legally or illegally. In addition, solid waste may include some discarded materials exchanged between economic units, for example scrap metal, for which the discarder receives payment. In these circumstances, the solid waste is considered a product (since the solid waste has a positive value) rather than a residual.

According to the SEEA discarded catch in fishing, felling residues from the harvesting of natural timber resources and mining overburden are not considered waste but natural resource residuals. Residuals associated with the harvesting of cultivated biological resources such as crop residues, felling residues from cultivated timber resources and manure from the farming of livestock are considered solid waste. However, the latter is only the case when the eco-system approach is adopted. According to the harvest approach adopted in EW-MFA residuals associated with the harvesting of cultivated biomass should be considered natural resource residuals and not solid waste.

It is important to distinguish between waste products and waste residuals in order set up hybrid supply and use tables in which the physical flows are matched with the monetary flows. Physical flows of waste products correspond to monetary flows in the opposite direction (physical flows from a to b correspond to monetary flows from b to a). Physical flows of waste residuals correspond to monetary flows in the same direction (both physical and monetary flows flow from a to b).

2.5 Classifications

The classifications used for the three material flows – natural inputs, products and residuals – are discussed in this chapter. In addition, the classification of industries is discussed. Compliancy with international standards such as ISIC (United Nations classification for industries) and CPC (United Nations classification for products) is a key issue.

2.5.1 Natural inputs

For natural inputs no detailed classification is available. The classes (typical components) described by SEEA are presented in **Table 2.3**. For some the classes of natural resources there are some close connections with the Central Product Classification (CPC) that are useful when making connections between the flows of natural inputs and the generation of products in the economy.

Natural resource inputs	**Extraction used in production**	Mineral and energy resources	Oil resources
			Natural gas resources
			Coal and peat resources
			Non-metallic minerals (excl. coal & peat)
			Metallic minerals
		Soil resources	
		Natural timber resources	
		Natural aquatic resources	
		Other natural biological resources (excluding timber and aquatic resources)	
		Water resources	Surface water
			Groundwater
			Soil water
	Natural resource residuals		
Inputs from renewable energy sources	Solar energy		
	Hydro energy		
	Wind energy		
	Wave and tidal energy		
	Geothermal energy		
	Other electricity and heat energy		
Other natural inputs	**Inputs from soil**	Soil nutrients	
		Soil carbon	
		Other inputs from soil	
	Inputs from air	Nitrogen	
		Oxygen	
		Carbon dioxide	
		Other inputs from air	
	Other natural inputs n.e.c.		

Table 2.3: Classes of natural inputs (draft SEEA2012)

The Natural resource inputs are the most relevant for this CREEA MFA work package. **Table 2.4** includes examples for this class.

Natural resource	Extraction used in production	Natural Resource Residual
Mineral and energy resources	Gross ore	Mining overburden
	Crude oil	Flaring, venting at well head
	Natural gas	Reinjection of natural gas
Soil resources	Excavated soil used for agricultural, construction and land reclamation purposes	Dredgings
		Unused excavated soil
Natural timber resources	Removals of timber	Felling residues
Natural fish resources	Gross catch less discarded catch	Discarded catch
Other natural biological resources	Harvest/capture	Harvest/capture residues
Water resources	Abstracted water	Mine dewatering

Table 2.4: Examples of natural resource inputs (draft SEEA2012)

2.5.2 Products

Products should be classified using the Central Product Classification (CPC). The most aggregated level of this classification is presented in **Appendix 4: CPC**. Physical flows of energy products are classified using the Standard International Energy Product Classification (SIEC) presented in the International Recommendations on Energy Statistics (ERES). Monetary flows of energy carriers will normally be classified using the CPC. Hence, in the development of accounts and indicators that combine physical and monetary data a reconciliation between these classifications will be needed. However, work undertaken to match both types of classifications (UNSD, 2011) resulted in the conclusion that full harmonization may not be realised in the current classifications.

2.5.3 Residuals

There is no single classification of all types of residuals. Especially the classifications for solid waste and natural resource residuals are of interest in workpackage 4. SEEA does include a table on the typical components for the different types of residuals (**Table 2.5**). The typical components for solid waste correspond with the classification used for the European regulation on waste statistics (EWC-Stat[4]) on an aggregated level (European communities 2002).

[4] The EWC-Stat does not include radioactive waste. In SEEA radioactive waste is included in addition to the EWC-Stat.

Group	Typical components
Solid waste (includes recovered materials) (a)	Chemical and healthcare waste, Radioactive waste, Metallic waste, Other recyclables, Discarded
Wastewater (a)	Water for treatment and disposal, Return flows, Reused water
Emissions to air	Carbon Dioxide, Methane, Dinotrogen oxide, Nitrous oxides, Hydrofluorocarbons, Perfluorocarbons,
Emissions to water	Nitrogen compounds, Phosphorous compounds, Heavy metals, Other substances and (organic)
Emissions to soil	Leaks from pipelines, chemical spills
Residuals from dissipative use of products	Unabsorbed nutrients from fertilisers, salt spread on roads.
Dissipative losses	Abrasion (tyres/brakes), Erosion/corrosion of infrastructure (roads, etc)
Residual heat	Heat released to water bodies in cooling water from electricity power plants, heat released from burning of
Natural resource residuals	Mining overburden, felling residues, discarded catch.

(a) This listing will include some flows defined as products as well as flows defined as residuals.

Table 2.5: Typical components for groups of residuals (source: SEEA concept 2011)

Solid waste

According to the SEEA, solid waste should be classified according to CPC for waste products (characterised by a positive economic value) and according to EWC-Stat classification for waste residuals. In the SEEA no bridge table is provided that links both classifications schemes. However, conciliation is needed in order to integrate waste accounts in physical supply and use tables. Integration of these accounts without a reconciled classification results in double counting. Some flows are recorded in the national accounts as well as in the waste accounts.

In this document an attempt is made to solve and clarify this problem by taking a practical approach. In Appendix 5: Correspondance between CPC and EWC-Stat aggregateda table is provided that indicates the potential overlap between product (CPC) and waste categories (EWC-Stat aggregated). The CPC classes in this table consist of two groups. The first group are all classes under CPC code 39* (waste). These classes consist of waste exclusively. The second group are classes outside code 39 that may partially include waste materials. The table is to be used as provisional and indicative rather than a final guideline.

Data on waste in the CREEA database will be provided by 2.0 LCA (Schmidt et al, 2010). The amount of waste is estimated by the amount of consumption of different products and their life span. In order to match the waste classification with the EWC classification a bridge table was generated. This table is presented in **Appendix 6: Correspondance between CREEA classification and the EWC-Stat**. However, in this table similar types of products may produce different types of waste depending on the industry (for example, wheat used by cattle breeding results in manure wastes as wheat used by food industry results in vegetable wastes). This should also be taken into account by in order to match with the EWC classification.

In the supply and use table of solid waste, recommended by SEEA, waste is classified according to EWC-Stat (**Table 2.6**). A distinction is made between waste residuals and waste products. In this table industries that are concerned with treatment of waste are disaggregated.

Physical supply table for solid waste											
		Generation of solid waste							**Rest of the world**	**Environment**	**Total supply**
(mass units - kilograms/tonnes)		Waste collection, treatment and disposal industry					industries	Households	Imports of solid waste	Recovered residuals	
		Landfill	Incineration		Recycling and reuse	Other treatment					
			Total	incineration to generate energy							
Generation of solid waste residuals											
	Chemical and healthcare waste										
	Radioactive waste										
	Metallic wastes										
	Other recyclables 1)										
	Discarded equipment										
	Animal and vegetable wastes										
	Mixed ordinary waste										
	Mineral wastes and soil										
	Combustion wastes										
	Other wastes										
Generation of solid waste products											
	Chemical and healthcare waste										
	Radioactive waste										
	Metallic wastes										
	Other recyclables 1)										
	Discarded equipment										
	Animal and vegetable wastes										
	Mixed ordinary waste										
	Mineral wastes and soil										
	Combustion wastes										
	Other wastes										
Physical use table for solid waste											
		Intermediate consumption; collection of residuals						**Final consumption**	**Rest of the world**	**Environment**	**Total use**
		Waste collection, treatment and disposal industry					industries	Households	Exports of solid waste		
		Landfill	Incineration		Recycling and reuse	Other treatment					
			Total	incineration to generate energy							
Collection and disposal of solid waste residuals											
	Chemical and healthcare waste										
	Radioactive waste										
	Metallic wastes										
	Other recyclables 1)										
	Discarded equipment										
	Animal and vegetable wastes										
	Mixed ordinary waste										
	Mineral wastes and soil										
	Combustion wastes										
	Other wastes										
Use of solid waste products											
	Chemical and healthcare waste										
	Radioactive waste										
	Metallic wastes										
	Other recyclables 1)										
	Discarded equipment										
	Animal and vegetable wastes										
	Mixed ordinary waste										
	Mineral wastes and soil										
	Combustion wastes										
	Other wastes										
1) Glass, paper, plastic, rubber and textile wastes											

Table 2.6: Supply and use of solid waste

Natural resource residuals

Natural resource residuals are discussed in the chapter on natural inputs. A classification for natural resource residuals is provided in **Table 2.4**.

2.5.4 Enterprises, establishment and industries

The following is adopted from SNA 2008 chapter 5. An enterprise is a producer of goods and services. Enterprises often engage in productive activity at more than one location. An establishment is an enterprise, or part of an enterprise, that is situated in a single location and in which only a single productive activity is carried out or in which the principal productive activity accounts for most of the value added. An industry consists of a group of establishments engaged in the same, or similar, kinds of activity. At the most detailed level of classification, an industry consists of all the establishments falling within a single class of ISIC.

Productive activities

SEEA applies the "International Standard Industrial Classification of All Economic Activities" (ISIC) classification of the UN for the division of economic activities to industries. The classification at an aggregated level is presented in **Appendix 3: ISIC Rev.4**. Enterprises can produce principle, secondary and ancillary activities (SNA2008, chapter 5, B2). The principal activity of a producer unit is the activity whose value added exceeds that of any other activity. The principal activity of an enterprise consists of the principal product and any by-products, that is, products necessarily produced together with principal products. The output of the principal activity must consist of goods or services that are capable of being delivered to other units even though they may be used for own consumption or own capital formation. A secondary activity is an activity carried out within a single producer unit in addition to the principal activity and whose output, like that of the principal activity, must be suitable for delivery outside the producer unit. An ancillary activity facilitates the efficient running of the enterprise but does not normally result in goods and services that can be marketed. Ancillary activities are the basic services that every enterprise needs to have in order to operate effectively. The sorts of services referred to include purchasing materials and equipment; hiring, training, managing and paying employees; cleaning and maintenance of buildings and other structures; repairing and servicing machinery and equipment; and providing security and surveillance. A common characteristic of ancillary activities related to their output is that they produce services, and, as exceptions, goods that do not become a physical part of the output of the principal or secondary activity, as output. For enterprises that are relatively small and have only a single location, ancillary activities are not separately identified. For larger enterprises with multiple locations, it may be useful to treat ancillary activities in the same way as a secondary or even a principal product.

Partitioning enterprises into more homogeneous units

Chapter 3.5C of the SNA discusses the partitioning enterprises into more homogeneous units. Although it is possible to classify enterprises according to their principal activities using the ISIC and to group them into "industries", some of the resulting "industries" are likely to be very heterogeneous because some enterprises may have several secondary activities that are quite different from their principal activities. In order to obtain groups of producers whose activities are more homogeneous, enterprises have to be partitioned into smaller and more homogeneous units. When an enterprise is partitioned into two or more kind-of-activity units, the resulting units must be more homogeneous with respect to output, cost structure and technology of production than the enterprise as a whole. In principle, it must be feasible to at least calculate output and intermediate consumption and thus value added and also compensation of employees, taxes on production and imports, subsidies and the operating surplus or mixed income.

There are several situations in which the organization of production is such that partitioning an enterprise into establishments is particularly difficult. This is the case for horizontally and vertically integrated enterprises. Horizontal integration occurs when an activity results in end-products with different characteristics. This could theoretically be interpreted as activities carried out simultaneously using the same factors of production. In this case, it will not be possible to separate them statistically into different processes, assign them to different units or generally provide separate data for these activities. An example would be the production of electricity through a waste incineration process. The activity of waste disposal and the activity of electricity production cannot be separated in this case. A vertically integrated enterprise is one in which different stages of production, which are usually carried out by different enterprises, are carried out in succession by different parts of the same enterprise. The output of one stage becomes an input into the next stage, only the output from the final stage being actually sold on the market.

From the above SNA recommendation we determine that the recycling within an enterprise might be regared as a vertically integrated enterprise. Take for example the manufacturers of basic metal. In ISIC 3.1 manufacture of basic metals is referred to as code 27 and includes the activities of smelting and/or refining ferrous and non-ferrous metals from ore, pig or scrap, using electrometallurgic and other process metallurgic techniques. According to the SNA guidelines above, in order for the National accounts to separate the treatment of scrap (recycling) from the use of virgin resources as different types of industries it is required that these activities take place in different enterprises and that statistical data on production and income is available. The resulting units must be more homogeneous with respect to output, cost structure and technology of production than the enterprise as a whole. These requirements are in general not met in the case of the manufacturing of basic metals. Therefore, monetary data in the National accounts on the manufacturing of basic metals includes the recycling of scrap.

From the SNA we derive that, if for analytical reasons (e.g. for estimating waste production from physcial product flows) a distinction is required between the manufacturing of metal products activity and the recycling activity, the recycling activity should be defined according to ISIC code 37 “Recycling”. Recycling is the processing of waste and scrap and other articles, whether used or not, into secondary raw material. A transformation process is required, either mechanical or chemical. It is typical that, in terms of commodities, input consists of waste and scrap, the input being sorted or unsorted but normally unfit for further direct use in an industrial process, whereas the output is made fit for direct use in an industrial manufacturing process. The resulting secondary raw material is to be considered an intermediate good, with a value, but is not a final new product. Important here is that the activity of the recycling industry is the transformation of waste into secondary raw material that can be used in the production process. It is not the activity of recycling itself: the reprocessing in a production process of waste materials. In **Figure 2.1** shows the products and industries that need to be recorded with regard to the recycling of waste. The yellow box including the small red box represents ISIC 27 (manufacturing of basic metals) and the large red box ISIC 37 (recycling). The activity of the ISIC 37 is straightforward: the transformation of waste (B) into secondary materials (C). ISIC 27 can be divided in two kind of activities: the transformation of waste (similar to the activities of ISIC 37) and the production of metal products (D). In order to separate both activities the in- and output of both activities needs to be recorded: all flows related to the arrows going in and out the yellow area as well as the arrows going in and out the small red box. Subsequently, the figures for the small red box can be added to the figures for the large red box to establish figures on the recyling industry. In order to match fysiscal and monetary data both types of data need to be recorded.

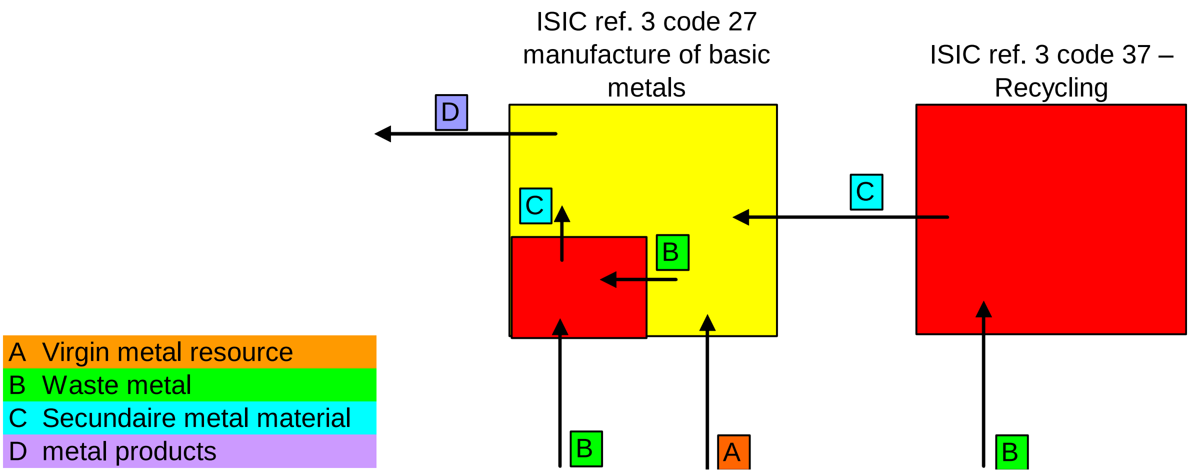

Figure 2.2: partition of "manufacturing of basic metals" into a recycling and a metal production unit.

3 The CREEA framework of MFA and waste accounts

The previous chapther describes the recommendation of terminology and classification based on SEEA 2012. **Chapter 3** to **9** describe the applied framework including terminology, classification and methodological issues.

This chapter describes the applied overall framework and calculation procedures to create MFA and waste accounts. The approach is based on the FORWAST-project (Schmidt et al. 2010) and on the recommendations from **chapter 2**. To a very large extent the applied framework is compliant with the one proposed by SEEA 2012 as of **chapter 2**. In cases where deviations have been required in order to fulfil the project objectives this is indicated; the major ones are highlighted in **chapter 3.3**. **Chapter 7** provides a comprehensive list of definitions of terms and tables in the CREEA framework. A table of correspondence between definitions in the applied framework in CREEA and the SEEA is provided in **Appendix 7: Correspondance between CREEA and SNA/SEEA definitions**.

3.1 Purpose of the CREEA framework

The purpose of the framework is to store and document MFA and waste accounts harmonized with other accounts, such as monetary supply use tables, GHG-emission accounts, forest accounts etc. An important criterion for the harmonization is to use, refine and elaborate the accounting principles as discussed in the London Group and consolidated in the future SEEA 2012. Further, it is the purpose to integrate the different accounts in order to enhance consistency between different accounts and to enable for using information in one account to establish other accounts.

The latter is especially crucial for MFA and waste accounts because these accounts in general make use of and integrate many different data sets of which some are present in other accounts. Examples where MFA makes use of data sets which are present in other accounts are forest accounts (part of resource input in MFA) and GHG-emissions accounts (part of emissions output in MFA). Also monetary supply and use tables are used to obtain information of transactions of products in the economy. Waste accounts are fully based on and integrated in other accounts. This is because waste is part of the simple equation: what goes in must come out. Most often the data quality of resource inputs, product transactions and emission outputs are better than of the data on waste quantities (if waste data are present at all). Hence, better waste data can most often be calculated by looking at what is around the waste and then establish a mass balance.

3.2 SUT framework including materials for treatment and stock changes

The supply-use framework, presented in **chapter 2.2.1**, is used for MFA and waste accounts. There are several advantages of this. The SUT framework is also used as framework of economic accounts. Using the same framework as economic accounts harmonizes with the framework of MFA and waste account, and it enables to make use of economic data, e.g. when tracking data on product transactions. Further, the SUT framework enables for establishing balances on the activity as well as the product level. Below, a brief description of the PSUT is presented. The PSUTs are described in detail in **chapter 4**.

Definitions used in the text can be seen in **Definitions used in the CREEA**.

PSUTs are constructed in a determined accounting period, usually one year, and for a given geographical area, typically a country.

Balanced PSUT	Activities	Stock formation	Final use	Export	Import	Total
Products	V'				N_c	q
Stock additions	ΔS					
Materials for treatment	W_V				N_w	
Emissions	B					
Total	g'					

Products	U	s^+	Y	N_c		q
Materials for treatment	W_U			N_w		
Natural resources	R					
Total	g'					

Figure 3.1: Format of physical supply-use tables (PSUTs).

In **Figure 3.1**, the upper part includes the flows of the supply framework and the lower part those of the use one.

The calculations of flows in the productive activities and in the accumulation and final use categories are often different. Therefore, the matrices **ΔS**, $\mathbf{W_V}$, **B** and **R** are sometimes divided into sub-sets as of **Figure 3.2**.

	Activities	Stock formation	Final use
Stock additions	ΔS_a	ΔS_f	
Materials for treatment	$W_{V,a}$	$W_{V,f}$	
Emissions	B_a	B_f	
Natural resources	R_a	R_f	
Total input/output	g_a'	g_f'	

Figure 3.2: Division of Δ**S**, $\mathbf{W_V}$, **B**, **R** and g into subsets for productive activities (subscript *a*) and for accumulation and final uses (subscript *f*).

Matrix **V'** shows the products carried out by domestic productive activities while $\mathbf{N_c}$ **and** $\mathbf{N_w}$ represents the import of products and materials for treatment respectively. Matrix Δ**S** shows additions to stocks, i.e. products which have not become materials for treatment within the accounting period. The supply of materials for treatment ($\mathbf{W_V}$) represents an output flow from a human activity that remains in the technosphere and cannot directly (i.e. without further processing or emissions) displace another principal product of an activity. Note that the calculated supply of materials for treatment from the model is Δ**S** + $\mathbf{W_V}$. Stock additions (Δ**S**) is included in this because it represents delayed supply of materials for treatment. The emissions matrix **B** represents the output of mass of emissions.

In the lower part of **Figure 3.1** are the inputs of material flows to activities. The use matrix **U** accounts for the use of intermediate products by domestic activities plus final consumption (**Y**), stock formation and change of inventories ($\mathbf{S^+}$**)** and exported products ($\mathbf{E_c}$) and materials for treatment ($\mathbf{E_w}$). Finally, the use of materials for treatment matrix ($\mathbf{W_U}$) accounts for the use of materials for treatment and the input of natural resources **R**.

The supply and use side are perfectly balanced, from both the products and activities perspectives. This means that the mass of supplied products is equal to the mass of used products and the inputs to the activities are equal to the outputs. Translated in formula the *product balance* can be traced as follows[5]:

$$\mathbf{V}' \cdot \mathbf{i} + \mathbf{N_c} \cdot \mathbf{i} = \mathbf{U} \cdot \mathbf{i} + \mathbf{S^+} \cdot \mathbf{i} + \mathbf{Y} \cdot \mathbf{i} + \mathbf{E_c} \cdot \mathbf{i} = \mathbf{q} \qquad \textbf{(1)}$$

where **i** are proper summation vectors.

The *activity balance* for productive activities can be expressed as follows:

[5] **Appendix 8**: Mathematical notation

$$\mathbf{V} \cdot \mathbf{i} + \Delta\mathbf{S}'_{\mathbf{a}} \cdot \mathbf{i} + \mathbf{W}'_{\mathbf{W,a}} \cdot \mathrm{i} + \mathbf{B}'_{\mathbf{a}} \cdot \mathbf{i} = \mathbf{U}' \cdot \mathbf{i} + \mathbf{W_U}' \cdot \mathbf{i} + \mathbf{R}'_{\mathbf{a}} \cdot \mathbf{i} = \mathbf{g_a} \quad \textbf{(2)}$$

The *activity balance* for accumulation and final uses can be expressed as follows:

$$\Delta\mathbf{S}'_{\mathbf{f}} \cdot \mathbf{i} + \mathbf{W}'_{\mathbf{W,f}} \cdot \mathrm{i} + \mathbf{B}'_{\mathbf{f}} \cdot \mathbf{i} = [\mathbf{S}^{+} \cup \mathbf{Y}]' \cdot \mathbf{i} + \mathbf{R}'_{\mathbf{f}} \cdot \mathbf{i} = \mathbf{g_f} \quad \textbf{(3)}$$

3.3 Major deviations from the recommended terminology as of SEEA2012

The major deviations from the recommended terminology in **chapter 2** are:

- the definition of products, and
- the definition of a term including waste; ‘materials for treatment’
- inclusion of additional stock addition table (Δ**S**) in the columns of productive activities and final uses

Products: The definition of products in **chapter 2.4.2** includes all transactions with a positive monetary value. This implies that some wastes and secondary material for recycling and re-processing are included as products. One of the objectives of the CREEA project is to model the life cycle environmental effects of different waste management options. Environmental optimization obviously implies to redirect waste flows from landfill and incineration to recycling. The benefit of recycling is its potential for displacing the production of virgin materials. Therefore, in order to model this, it is required to separate production systems related to virgin production and production systems related to recycling (collection, sorting, cleaning, refining) and re-processing of the secondary materials to new materials. This requirement cannot be complied with if real finished materials (e.g. basic iron) are mixed up with secondary material and wastes (old and new steel scrap) that need further processing (recycling and re-processing) before it can be comparable with the real finished product. Therefore, the term ‘products’ does not include wastes and secondary material swith a positive monetary value.

Materials for treatment: All activities are balanced so that outputs equal inputs. In this equation the most uncertain item is the one including solid waste, waste water, uncontrolled waste and secondary material for further re-processing. To be clearer about what we are talking about, this item is calculated as the input of resources and products minus the output of products and emissions.

In general, statistical information on the above mentioned flows (often referred to as waste) is associated with significant uncertainties in many countries. One of the reasons for this is that the definition of waste is not consistent and all inclusive. One example is manure from animal production. There exist no (or only very few) manure items in national waste statistics. Since the ‘waste’ item is the most uncertain, it has been decided that the group of flows that contains waste is the calculated balancing item. It has been chosen to call this balancing item ‘materials for treatment’. The reasonings behind this are:

- All these material outputs (when activities generate waste) need some kind of treatment before the material can be tuned into new products, emissions or stock addition in landfills. This treatment may be re-processing of scrap into new materials that can substitute virgin materials, it may be waste incineration,

landfill, waste water treatment, composting, or just storage of uncontrolled discharged waste in the environment involing emissions from degradation.
- It has been avoided to use the terms; waste and residuals. Waste is often associated with some specific definitions which are much narrower than the one of 'materials for treatment' used here. The term 'residuals' has another meaning, since this also includes emissions.
- The term is broardly used in LCA, e.g. the ecoinvent database v3 (Weidema et al. 2011, p 30)

In many cases, the calculated 'materials for treatment' is equivalent to what is typically associated with waste. But it also includes other flows. Below is a list of examples of flows included in the calculated balancing item 'materials for treatment':
- Waste for incineration, landfill, composting and biogasification
- Waste for recycling and re-processing
- Waste for uncontrolled disposal
- Dry matter content of waste water to treatment
- Dry matter content of animal excretion and urine

Stock addition table (ΔS): In SEEA 2012 it is recommended to keep all flows related to accumulation in separate columns different from the columns for productive activities. The stock formation table ($\mathbf{S}^+$) as of SEEA 2012 is keept in the applied framework. However, the applied framework can work with or without this table. One of the disadvantages of the recommended framework for accumulation as of SEEA 2012 in **Table 2.1** is that the supply side and the use side of the accumulation column are not balanced. Further, it seems awkward to place residuals from scrapping and demolition of produced assets in a separated column. This would imply that all emissions from assets sent to incineration and landfill would be placed in the accumulation column while the remaining emissions from incineration and landfill would be in the columns of these activities. This is inconsistent with other emissions accounts, such as Kyoto accounts and LCI databases.

The calculated balancing item which represents the so-called waste calculation in the FORWAST and the CREEA models is materials for treatment ($\mathbf{W_V}$) plus stock additions ($\Delta\mathbf{S}$). The meaning of $\Delta\mathbf{S}$ is then 'delayed waste'. The delay is determined by the life time of the product.

The part of $\Delta\mathbf{S}$ which is in the same columns as $\mathbf{S}^+$ is a balancing item ensuring that the supply side and the use side of the accumulation column are balanced.

If $\mathbf{S}^+$ is included in the framework, then idealy the sum of $\mathbf{S}^+$ is equal to the sum of $\Delta\mathbf{S}$ and all non-null values of $\Delta\mathbf{S}$ will be present in the in the same columns as $\mathbf{S}^+$ (see **Figure 3.1**). The general definition of capital formation (flows in $\mathbf{S}^+$) as well as stock additions (flows in $\Delta\mathbf{S}$) is that the life time of the products is longer than the accounting period (one year). However, this definition is seldomly strictly followed in practise for $\mathbf{S}^+$. The defined stock depreciation function (based on product life times and an assumed distribution) for $\Delta\mathbf{S}$ may also be different than the data used for splitting intermediate product flows from capital formation when creating $\mathbf{S}^+$. Therefore, the ideal equivalence indicated above will not be achieved in practise. Despite the deviations referred to above, then if $\mathbf{S}^+$ is included in the framework, the calculated balancing item 'materials for treatment' can be assumed to represent materials for treatment ($\mathbf{W_V}$) only. Summing up, if $\mathbf{S^+}$ is included, it can be assumed that $\Delta\mathbf{S} = \mathbf{0}$, and hence that the calculated $\Delta\mathbf{S} + \mathbf{W_V} = \mathbf{W_V}$.

If $\mathbf{S^+}$ is not included in the framework, then the calculated balancing item is materials for treatment ($\mathbf{W_V}$) plus stock additions ($\Delta\mathbf{S}$).

In the applied framework, all residuals supplied in waste treatment activities are recorded as being supplied in these activities, regardless if the treated material is waste or assets.

3.4 How to handle waste treatment in the supply-use framework

One of the objectives of the CREEA project is to enable for the option to model the effect of different waste treatment options, e.g. recycling, incineration and landfill. The modelling of these activities is not straightforward in the supply-use framework due to some limitations of the used system of classification and to the adopted assumption about the allocation of activities. Therefore, the issue of how to handle waste treatment is given special attention in this chapter.

3.4.1 Disaggregation in order to trace recycling activities

Usually SUTs aggregate the production from virgin materials and the production from secondary materials (see **chapter 2.5.4**). In order to model recycling separately, these industries need to be disaggregated. In the classification systems, the aggregation of production from virgin and secondary materials is a consequence of the economic criteria used to allocate an enterprise in the due activity category in the chosen system of classification. It is the principal production, identified as that one with the highest value added (Eurostat, 1996), which determines where to allocate an enterprise. In this way, since most of the times the sale of products from secondary materials is more profitable than the recycling service, the production from secondary materials will be classified together with production from virgin materials. There are also cases where virgin production and recycling take place within the same process, e.g. glass manufacturing, where it is common practise to use a mix of virgin feedstock (silicate sand) and secondary feedstock (glass cullets), and steel production in electric arc furnace, where iron ore is added to the main feedstock (scrap) to control temperature.

Technically, the distinction between virgin production and recycling is very important because the two activities perform differently, for instance the emissions caused by the production from secondary materials are significantly different from the emissions from that using virgin materials. Furthermore, the production from secondary materials implies also a service of recycling (waste treatment) that the production from virgin materials does not carry out.

Therefore, in order to highlight these relevant aspects, joint or combined virgin/recycling activities are disaggregated in the CREEA approach (the procedure for disaggregation is part of work package 7 in the CREEA project (Eurostat 1996). The reasoning behind the disaggregation is explained further in the following. It is important to notice that the following approach goes beyond the economic criteria; highest value added. Further, it should be noted that the applied approach deviates from the recommended one based on

SEEA2012, see **chapter 2.5.4** (and especially **Figure 2.2**). Below, in **Figure 3.3**, it is illustrated how the applied approach deviates from the one in **Figure 2.2**.

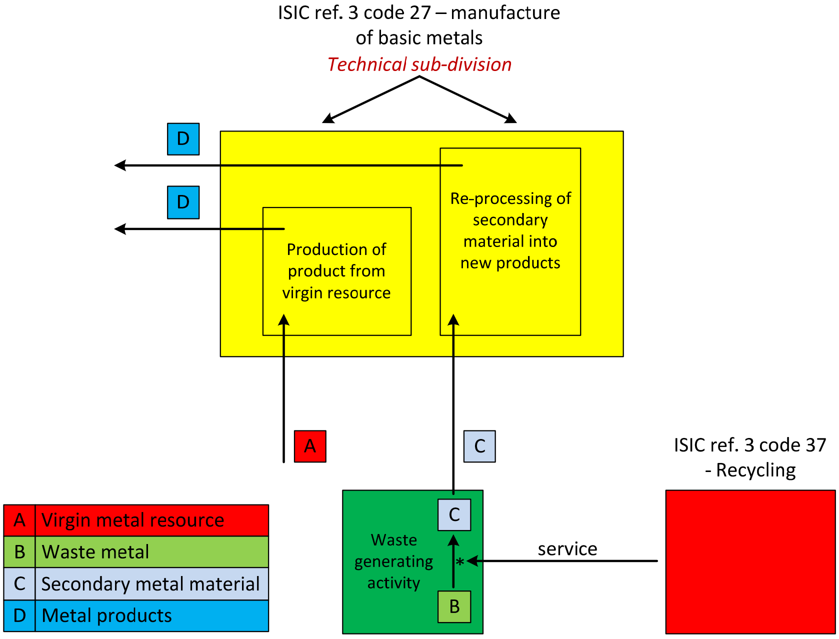

Figure 3.3: Applied approach for sub-dividing and modelling virgin production vs. production from secondary material. The figure is anologius to and should be compared with **Figure 2.2** on page 29.

In **Figure 3.3** it is illustrated that the distinction between virgin production and re-processing of secondary materials is modelled via a technical sub-division of the producting activity (in the figure this is basic metals, ISIC ref. 3 code 27). The input to the re-processing activity is secondary materials. Secondary materials are generated by the waste generating activity. In some cases the generated material is of such a quality that sorting/cleaning is required before re-processing. This is modelled via service inputs to the waste generating activity from the recycling activity (ISIC ref. 3 code 37).

In the following, the approach is further described in relation to the so-called point of substitution, i.e. where an output of a re-processing activity can substitute a principal product of one of the other activities in the SUT.

Firstly, the disaggregation is done if an activity includes stages both before and after the point of substitution, where the primary material can substitute the secondary material. Since only the part of the activity before the point of substitution will be affected, the activity is disaggregated into two activities: one before and one after the point of substitution, see **Figure 3.4**.

Secondly, the activity before the point of substitution is disaggregated into an activity producing virgin material, and a service activity having inputs of materials for treatment and providing as by-products the goods from recycled sources that can substitute virgin materials. This disaggregation will, in some cases, reflect a hypothetic situation because some material producing industries use a mix of primary raw materials and waste materials as inputs in order to produce their principal product, e.g. glass manufacture. The disaggregation is nevertheless necessary to allow correct modelling of recycling.

The two above-mentioned elements of disaggregation are illustrated in **Figure 3.4**.

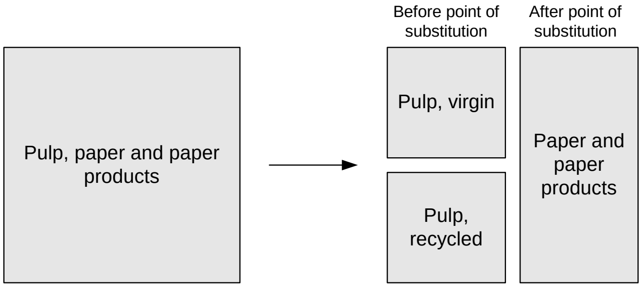

Figure 3.4: Disaggregation of activities by point of substitution and by recycled/virgin, using pulp, paper and paper products as example.

All the resulting recycling or re-processing activities have a service of recycling (waste treatment) as principal production (diagonal product in the supply table) and the product from secondary materials as by-product. In the CREEA approach, products from virgin and secondary materials are considered homogenous in the PSUT, hence they are structured in the same row.

3.4.2 Disaggregation in order to parameterize incineration and landfill of materials for treatment

The performance of the activities of incineration and landfilling rely strongly on the incoming materials for treatment. Some materials for treatment are inert, other hazardous and each one may have a different calorific value. For example the incineration of wood has completely different heat and electricity production than the incineration of glass. Similar examples are can be done for landfills.

In order to highlight these substantial differences, the CREEA approach aims to disaggregate the landfilling and incineration activity according to the input of materials for treatment.

3.5 Outputs of the PSUTs accounts

The final contribution of the construction of PSUTs in the CREEA project covers several crucial aspects. Firstly, there will be the creation of waste accounts, which are structured in a mass-balanced system of accounts. The waste accounts will be traced in a general format that is open to any types of desired aggregation and waste definition, e.g. the EWC Stat developed by Eurostat, see **Appendix 5: Correspondance between CPC and EWC-Stat aggregated**. By doing so, it is possible to create the link with official waste statistics. The waste accounts are derived from the supply of materials for treatment matrix $\mathbf{W_V}$. It is also an option to supplement the waste accounts with information of the treatment of each type of waste. This is based on the use of materials for treatment matrix $\mathbf{W_U}$.

Furthermore, fully balanced PSUTs enable to determine every indicators required by a MFA. Hence, the environmental indicators becomes an integrant part of national accounts and, in addition, are elaborated in a balanced framework that may ameliorate the robustness of the accounts.

Finally, the information structured in the PSUTs may be used together with that of MSUTs in order to create hybrid framework analytical tools, such as hybrid input-output tables (HIOTs) / IO-based databases for life cycle assessment (LCA). The HIOTs have the advantage to generate results in mass and monetary terms, enlarging the feasible spectrum of analysis and increasing the potential number of calculable indicators on several impact categories, contemporaneously in both the economic and environmental spheres.

4 Creation of Physical Supply and Use Tables (PSUTs)

PSUTs is an accounting tool where it is possible to include all the physical flows and stock formation occurring in a studied economy. The general format of the physical supply table ($\mathbf{V_P}$) is equal to the format of a monetary supply table ($\mathbf{V_M}$); the main difference lies into physical unit of measurement (mass, energy) instead of monetary units. This characteristic of PSUTs allows the inclusion of flows not accountable in monetary terms. Hence, the physical format includes more accounts. In the CREEA-project PSUTs are measured in dry weight, i.e. exclusive water.

In the following the matrices in **Figure 3.1** are described. For the sake of simplicity it is assumed that the number of product equals that of activities.

4.1 Supply (V and N) and use of products (U, Y, $\mathbf{S^+}$ and N)

4.1.1 Description

This chapter defines and explains the matrices and vectors involved in the supply and use of products as shown in **Figure 3.1.**

The matrix of Use of intermediate products (**U**) shows the consumption of products for intermediate use by domestic productive activities. The format is products by activities. In the framework to the right of the use matrix there is the matrix **Y** that includes the consumption of products by households and other final consumption categories; the format is products by households[6]. Notice that households purchase also durable goods, which have a lifetime longer than the accounting period. The Stock formation matrix ($\mathbf{S^+}$) shows the products that are accumulated at the end of the accounting period. This matrix includes the formation of fixed assets and the change in inventories. The former, for simplicity, are sometimes referred to as capital goods in the text; the format of matrix $\mathbf{S^+}$ is products by stock categories. Finally, still on the use side, there is the Export matrix (**E**) where all the products and traded to other economies are accounted; the format is products by importing countries.

Moving to the supply side, there is the matrix of Supply of products (**V'**) showing the productions carried out by the domestic activities. The format is, as for matrix **U**, products by activities. The Import matrix (**N**) indicates the imported products by exporting countries; the format is product by exporting countries.

Finally, the vector **g**, identical on both the use and supply sides, shows the total use and the total supply of products. **g** is used for balance check.

4.1.2 Creation of V and U

The CREEA approach implies a two-step procedure for creating **V** and **U**.

[6] For simplicity hereafter we refer to households to indicate all final consumption categories.

The first step PSUTs are created by distributing the total production volumes of all products (data collection) over activities using the disaggregated monetary supply and use tables, assuming fixed prices. For the disaggregation process, the monetary domestic supply of products detailed according to the CREEA classification is required. Further, in order to pursue a proper disaggregation of some specific activities, key technical coefficients in physical terms are provided. These coefficients will be used in order to disaggregate the activities respecting crucial technological constraints. The disagrgegation is carried out in work package 7 of the CREEA project (creea.eu).

Once the disaggregated MSUTs are created, the physical domestic supply, detailed in line with the CREEA classification, is distributed along the activities according to the monetary transactions, hence assuming fixed prices. By doing so, default PSUTs are constructed and a vector of prices is the conversion factor between monetary and physical levels.

4.2 Stock addition matrix ($\Delta\mathbf{S}$)

4.2.1 Description

Matrix $\Delta\mathbf{S}$ shows the gross addiitons to stocks within the accounting period. With stocks are meant those products with a lifetime longer than the accounting period, e.g fixed assets, durable products and accumulated product, including materials for treatment discharge d to landfills. The latter is referred to as stocks not in use.

$\Delta\mathbf{S}$ can be interpreted together with $\mathbf{W_V}$ (see **chapter 4.3**) as the total potential generation of materials for treatment, where $\mathbf{W_V}$ are the materials for treatment arising from the inputs of products (**U, Y** and $\mathbf{S^+}$), natural resources (**R**) and materials for treatment ($\mathbf{W_U}$) within the accounting period, and where $\Delta\mathbf{S}$ are the materials for treatment arising from the same inputs but that will be disposed of after the accounting period. The format of the $\Delta\mathbf{S}$ matrix is products by activities plus finl consumption categories.

4.2.2 Creation of ΔS

The sum of stock additions and supply of materials for treatment are calculated based on a detailed mass balance established on the information in the PSUT and some additional coefficient/transfer matrices. This mass balance approach is the core part of the method developed through the FORWAST project (Schmidt et al. 2010). The calculation of $\Delta\mathbf{S}$ + $\mathbf{W_V}$ is described in detail in **chapter 5**.

4.3 Materials for treatment supply matrix ($\mathbf{W_V}$)

4.3.1 Description

This matrix represents the generation of materials for treatment from intermediate and consumer products, natural resources and materials for treatment, where materials for treatment are meant those flows from a human activity that remains in the technosphere but cannot directly (i.e. without further processing or emissions) displace another principal product of an activity. After processing in a waste treatment (or recycling) activity, the recovered materials for treatment may displace other products, for instance the compost replacing chemical fertilisers. Notice that the matrix $\mathbf{W_V}$ includes materials for treatment traded in the economy at a positive price as well as materials for treatment for which a cost is paid in order to get rid of them.

The format of the matrix is materials for treatment (same as products) by activities plus households and stocks categories. It should be noted that the rows of the matrix also includes materials for treatment originating from inputs of natural resources and materials for treatment. These are placed on the diagonal of the $\mathbf{W_V}$ matrix.

The stock categories (columns) of the $\mathbf{W_V}$ matrix include materials for treatment produced from products previously accumulated in the economy. To the right of the $\mathbf{W_V}$ matrix the import of materials for treatment is included in the $\mathbf{N_W}$ matrix, which has format materials for treatment by exporting countries.

The format of the $\mathbf{W_V}$ can be changed in order to produce waste accounts. This may include exclusion and/or aggregation/differentiation of rows. This can be done to meet the requirements in different waste classifications and definitions, for instance materials for treatment, based on the EWC Stat waste classification.

Relating to SEEA 2012 classification of residuals (**chapter 2.5.3**) it should be mentioned that the supply of materials for treatment (which include the waste related items of SEEA residuals) include both waste products and waste residuals. Hence the total sum of all supplied materials for treatment will involve that some flows are accounted more than once. E.g. waste paper sent to re-processing plus waste outputs from the re-processing plant (the short fibers of the waste paper that will not be part of the recovered material).

4.3.2 Creation of $\mathbf{W_V}$

The sum of stock additions and supply of materials for treatment are calculated based on a detailed mass balance established based on the information in the PSUT and some additional coefficient/transfer matrices. This mass balance approach is the core part of the method developed through the FORWAST project (Schmidt et al. 2010). The calculation of $\Delta\mathbf{S} + \mathbf{W_V}$ is described in detail in **chapter 5**.

4.4 Emissions matrices/vectors ($\mathbf{B}$, $\mathbf{B_c}$, $\mathbf{b_w}$ and $\mathbf{b_R}$)

4.4.1 Description

The emissions matrices refer to the flows of materials from activities in the technosphere to the environment. Thereby the emission matrices exclude everything that is still included in the production system to be treated by human activities, i.e. materials for treatment. Two different formats of the emission table are defined:

1) Emission type by activities (matrix $\mathbf{B}$), and
2) $\mathbf{B_c}$ have format products by activities, and $\mathbf{b_w}$ and $\mathbf{b_R}$ are vector with as many components as the activities.

The purpose of the first format of the emissions table is to account for emissions by emissions type, e.g. CO_2, NO_x, SO_2 etc. This is most often used when the accounts are used for environmental analysis, either Leontief model applications (e.g. IO LCA) or national accounting (e.g. Kyoto emissions inventories). The list of emissions taken into account is showed in **chapter 8.4**.

The purpose of the second format of the emissions table is to account for the total mass of emissions. This is used when MFA accounts are established where the origin of the emissions outputs are traced to the inputs. The $\mathbf{B_C}$ matrix shows the emissions that originate from the inputs of products. For instance if a power plant (activity) has 1 tonne emissions in the row representing the product coal, then it means, that 1 tonne of emissions from power plants originates from the inputs of coal. The $\mathbf{b_W}$ vector shows the emissions that originates from the inputs of materials for treatment. This is only relevant for waste treatment activities. For instance if a waste incineration plant (activity) has 1 tonne emissions in the row representing materials for treatment of the product paper, then it means, that 1 tonne of emissions from the waste incineration plant originates from the inputs of paper waste. The $\mathbf{b_R}$ vector represents the emissions originating from the inputs of natural resources. The most common element in this matrix will be related to respiratory and combustion water when oxygen from the atmosphere forms water with hydrogen from respiration/combustion. But it also includes e.g. the carbon from flaring in oil and gas extraction, dust from mining, and respiratory methane (part of carbon and hydrogen originating from cattle grassing which is defined as resource extraction).

4.4.2 Creation of the emissions tables

The emissions tables will be created by mean of emission factors. Emission factors may be defined relative to a certain input (product, material for treatment or resource) or to the output of products (supply) of an activity. The latter is often referred to as process emissions. An example where the latter is relevant is N_2O emissions from fertiliser production.

In some cases emission factors may also be defined mutually with activity-specific flow balances, e.g. animal metabolism balance of feed input (several feed products + grass resources) equals product output (meat + milk), respiratory water, CO_2 and CH_4, and excretion and urine.

When emission data are stored as emission factors it is always possible to create the desired emission matrix by combining with information in the resource, use and supply table.

4.5 Materials for treatment use matrix ($\mathbf{W_U}$)

4.5.1 Description

The matrix $\mathbf{W_U}$ represents the use of materials for treatment produced in the accounting period (see **chapter 4.3**) and concerns particularly waste treatment activities.

If non-waste treatment activities are utilising materials for treatment, e.g. if a cement industry uses waste as fuel, then this is included as a by-product of waste treatment service by the cement industry. In this case, the cement industry will supply a by-product ‘incineration of waste’ or ‘landfill of waste’

The format of the $\mathbf{W_U}$ matrix is homogenous materials for treatment (see **chapter 5.4.3**) by activities and diverges from $\mathbf{W_V}$ matrix format (see **chapter 4.3**). The columns specify where the materials for treatment are used, and the rows specify the type of the material for treatment. Since materials for treatment can go across the borders of a specified economy hence also the trade of materials for treatment is included.

4.5.2 Creation of W_U

Several entries in the $\mathbf{W_U}$ matrix are related to the supply of by-products of waste treatment/recycling activities. E.g. usually 0.9 kg pulp (by-product) will be produced per 1 kg recycled paper waste in the recycling of waste paper activity. Hence, when the by-products are known (supply table) and the proportions between input of materials for treatment and by-products are known, the associated elements in the $\mathbf{W_U}$ table can be derived.

The rows of the $\mathbf{W_U}$ matrix are balanced with the rows in $\mathbf{W_V}$**.** Hence, all materials for treatment which are not fixed based on by-products in the supply table are distributed on the remaining waste treatment activities.

4.6 Natural resources matrix (**R**)

4.6.1 Description

This account refers to the flows from biosphere entering the productive system. In this way matrix **R** takes into account what the domestic human activities require to the environment to carry out their output and to satisfy their needs. The format of matrix **R** is natural resources by activities plus households. The list of natural resources taken into account is showed in **chapter 8.3**.

The **R** matrix is accounted as dry matter. Inputs of oxygen to combustion processes are included.

A complicating issue for combustion processes is to determine the proportion of nitrogen in NO_x emissions that originates from atmospheric nitrogen (this is a resource input) and how much that originates from the combusted product's content of nitrogen. For simplifying reasons, it is decided to assume that all nitrogen originates from the atmosphere. In cases where this causes mass balance problems, the assumption can be adjusted for the specific activity.

4.6.2 Creation of R

The natural resources matrix (**R)** is constructed in conjunction with the columns of the supply table which concern resource extracting activities. Hence, it is ensured that the proportion between the supplied products and the extracted natural resources reflects what is lost of the extracted natural resources as emissions and materials for treatment within the resource extracting activity.

4.7 Time perspectives and simplifying assumptions

The MFA account (PSUT) can be established based on information for the accounting period only, or it can include other accounting periods as well, i.e. time series of MFA accounts are integrated.

4.7.1 MFA accounts based on data for accounting period only

The default MFA account and waste account in the CREEA project will be based on information on the accounting period only, i.e. year 2007. This obviously implies some simplifying assumptions regarding mass flows from previous accounting periods (stock depreciation) and future accounting periods (stock additions). This means that the total quantity of generated materials for treatment (waste) is estimated based in the inputs of natural resources and outputs of emissions in the period. Hence, the supply of materials for treatment from degradation of stocks build up previous years is assumed to equal the formation of stocks in the accounting period.

$$\Delta S + \mathbf{W_V} = \mathbf{W_V} \qquad \textbf{(4)}$$

The assumption introduced in **(4)** implies that a steady state economy is presumed, i.e. no net stock accumulation or depreciation.

It should be noticed that the supply of materials for treatment from landfill sites, then the sum of $\Delta\mathbf{S}$ and $\mathbf{W_V}$ in **(4)** is assumed to be $\Delta\mathbf{S}$ because this is addition to stocks not in use.

A related issue is present for emissions from landfill sites, where some of the emissions arise from waste disposed in earlier years. Again a steady state situation is assumed where the current emissions (including emissions from waste from previous years) represent future emissions frm the addition to stocks not in use.

4.7.2 MFA accounts based on time series

In order to obtain a better estimate of the actual generation of materials for treatment, time series combined with product life times ($\mathbf{L_S}$) are needed. The calculation of accumulated supply of materials for treatment in 2007 is illustrated in **Figure 4.1**.

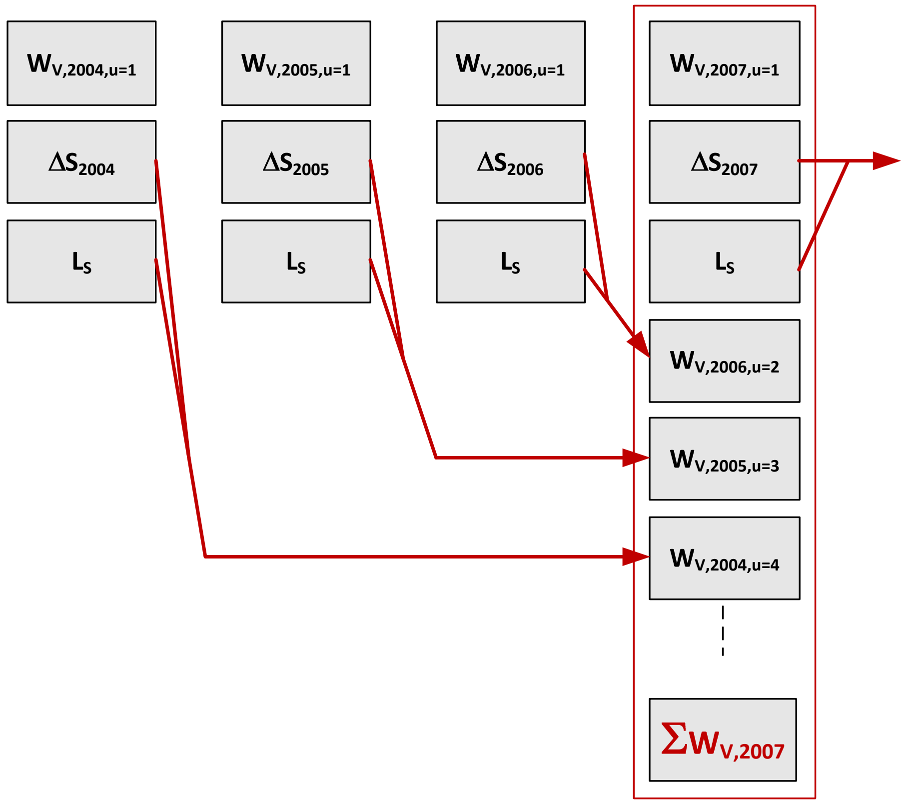

Figure 4.1: Materials for treatment calculation based on time series of PSUTs. The subscript of years indicated the year of the origin of the flow, and the subscript *u* indicates the age of stocks. The $\mathbf{L_S}$ matrix represents the stock depreciation matrix which contains information of product life times.

It should be noticed that when time series for landfill sites and emissions from stocks not in use are taken into account, then the 'materials for treatment degradation matrix' ($\mathbf{L_w}$) is used in a similar way as $\mathbf{L_S}$ in **Figure 4.1**.

5 Approach for calculating the supply of materials for treatment

In this chapter, the approach used in the CREEA project in order to calculate the materials for treatment flows to determine the waste accounts and to integrate waste flows in the MFA accounts is described. It is noteworthy that we refer to materials for treatment rather than waste. The purpose of this is to operate with the broadest possible definition of waste in the model to enable the application of any waste definition when extracting data for the waste accounts (model outputs).

A material for treatment is defined as a flow from a human activity that remains in the technosphere but cannot directly (i.e. without further processing or emissions) displace another principal product (product on diagonal in the supply table) of an activity. By using this definition, the materials for treatment are open to any further aggregation and classification, for instance waste and by-products, as consequence on prices and costs information coming from the monetary level.

The CREEA approach is based on a coherent mass balance for every activity. **Figure 5.1** shows the mass balance for a general activity, which summarizes what is accounted in the PSUTs.

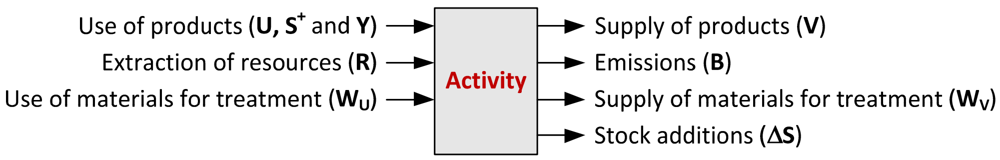

Figure 5.1: Input- and output flows for a generic activity. Inputs and outputs are always balanced. The matrices referred to in the figure contain the input and output flows.

Generally speaking, for any human activity the inputs in terms of products in **U**-table, materials for treatment in $\mathbf{W_U}$-table and natural resources in **R**-table are balanced by the outputs in terms products in **V**-table, emissions in **B**-table, materials for treatment in $\mathbf{W_V}$-table and stock additions in $\Delta\mathbf{S}$-table.

Supply of materials for treatment in a productive activity or a household can originate from three different sources: use of products (**U**, $\mathbf{S^+}$ and **Y**), extraction of natural resources (**R**) and from input of waste ($\mathbf{W_U}$). This inspires the strategy behind the CREEA approach, i.e. only a part of each type of input ends up being included in the final products. What is left out may end up in the emissions (**B**), materials for treatment ($\mathbf{W_V}$) or stock additions ($\Delta\mathbf{S}$).

When calculating the supply of materials for treatment from an activity, this is expressed in terms of the products from which it originates and also if the materials for treatment originates from resource or materials for treatment inputs. The following three sections concern the supply of materials for treatment originating from natural resources, products and materials for treatment respectively. **Figure 5.2** illustrates the possible fate of each of the three types of inputs which may end up as materials for treatment plus stock additions. The proportions of the inputs that end up in the supply of products are specified in transfer coefficients ($\mathbf{D_0}$, $\mathbf{f_0}$, and $\mathbf{e_0}$ in **Figure 5.2**).

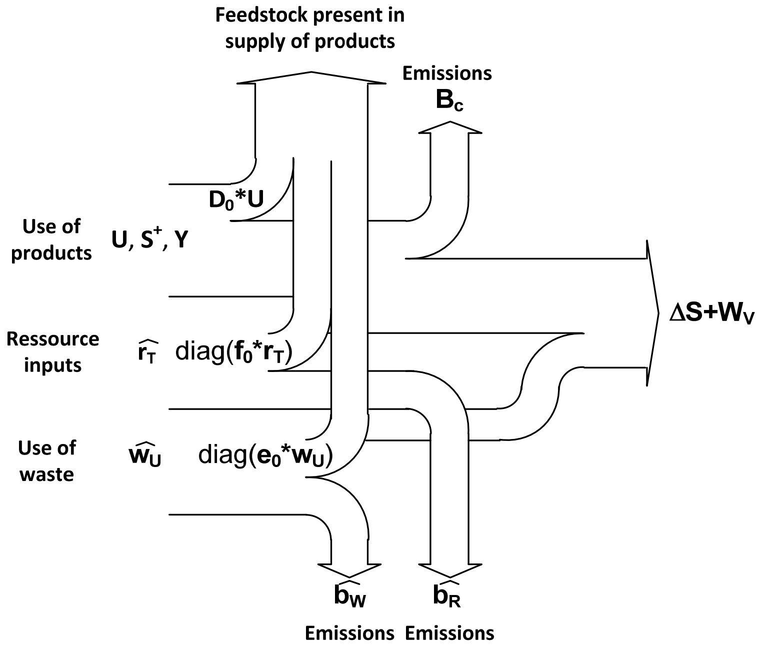

Figure 5.2: Principal fate of any input to an activity. Based on physical supply-use tables inclusive emissions and natural resources as well as some transfer-coefficients, the stock additions plus materials for treatment can be calculated.

5.1 Materials for treatment from input of natural resources

The resource matrix, presented in **chapter 4.6**, shows the mass of natural resources entering into human activities. The natural resources may entirely, partially or not at all end up as part of the supply of products. The part of resource not becoming part of the supply of products will be an output of the activity in the form of emissions and/or materials for treatment.

A transfer coefficient vector $\mathbf{f_0}$ is defined to specify the proportion of the total mass of resource input to an activity that is present in the supply of products of the same activity. $\mathbf{f_0}$ is a vector with as many components as the activities. All the values of $\mathbf{f_0}$ fall in the interval [0;1]. A value equal to 0 can indicates:

1) that no of the extracted natural resources are present in the product output
2) that no natural resources are extracted in the given activity

Values of $\mathbf{f_0}$ in the interval]0;1] indicate the feedstock efficiency.

The total mass of natural resources row vector ($\mathbf{r_T}$) has format one by activities, and it is derived by:

$$\mathbf{r_T} = \mathbf{R}' \cdot \mathbf{i} \quad \textbf{(5)}$$

The supply of products originating from inputs of natural resources ($\mathbf{v_R}$) can be expressed as **(6)**. The vector $\mathbf{v_R}$ has format one by activities.

$$\mathbf{v_R} = \widehat{\mathbf{r}}_\mathbf{T} \cdot \mathbf{f}_0 \quad \textbf{(6)}$$

The vector of emissions originating from inputs of natural resources is denoted $\mathbf{b_R}$, and it has format one by activities. In the following, notice that $\mathbf{b_R}$ is subdivided accordingly to **Figure 3.2** using subscript a for productive activities and subscript f for accumulation and final uses.

The supply vector of materials for treatment plus stock additions ($\mathbf{w_{V,R}}+\Delta\mathbf{s_R}$) originating from the input of natural resources to productive activities can be calculated as shown in **(7)**.

$$\mathbf{w_{V,a,R}} + \Delta\mathbf{s_{a,R}} = \widehat{\mathbf{r_{T,a}}} \cdot (\mathbf{i} - \mathbf{f_0}) - \mathbf{b_{a,R}} \tag{7}$$

Correspondingly, the supply of materials for treatment plus stock additions for the household and stock categories (indicated with f) are calculated as in **(8)**, where the only difference from **(7)** is that no of the inputs ends up as supply of products:

$$\mathbf{w_{V,f,R}} + \Delta\mathbf{s_{f,R}} = \mathbf{r_{f,T}} - \mathbf{b_{f,R}} \tag{8}$$

In order to operate with only one matrix with supply of materials for treatment information, it has been decided that the vector in **(7)** is diagonalised and merged into the $\mathbf{W_V}+\Delta\mathbf{S}$ square matrix. This implies that materials for treatment originating from resource inputs are present on the diagonal in the $\mathbf{W_V}$ table.

5.2 Materials for treatment from input of materials for treatment

The 'use of materials for treatment' matrix ($\mathbf{W_U}$), presented in **chapter 4.5**, shows the mass of materials for treatment entering into waste treatment activities. The materials for treatment may entirely, partially or not at all end up as part of the supply of products. The part of materials for treatment not becoming part of the supply of products will be an output of the activity in the form of emissions, materials for treatment and/or stock additions. The latter is the case for landfills where inputs of material accumulate in the activity.

A transfer coefficient vector $\mathbf{e_0}$ is defined to specify the proportion of the total mass of materials for treatment input to an activity that is present in the supply of products of the same activity. $\mathbf{e_0}$ is >0 for activities which transform waste/secondary material into new products, i.e. recycling activities. $\mathbf{e_0}$ has format one by activities. All the values of $\mathbf{e_0}$ fall in the interval [0;1]. A value equal to 0 can indicates:

1) that no of the inputs of materials for treatment are present in the product output
2) that there are no inputs of materials for treatment in the given activity

The total mass of materials for treatment row vector ($\mathbf{w_{U,T}}$) has format one by activities, and it is derived by:

$$\mathbf{w_{U,T}} = \mathbf{W_U}' \cdot \mathbf{i} \tag{9}$$

The supply of products originating from inputs of materials for treatment (**$\mathbf{v_W}$**) can be expressed as **(10)**. The vector **$\mathbf{v_W}$** has format one by activities.

$$\mathbf{w_w} = \widehat{\mathbf{w}}_{\mathbf{U,T}} \cdot \mathbf{e_0} \tag{10}$$

The vector of emissions originating from inputs of materials for treatment is denoted **$\mathbf{b_W}$**, and it has as many components as the productive activities.

The supply of materials for treatment plus stock additions (**$\mathbf{w_{V,W}}$+Δ$\mathbf{s_W}$**) originating from the input of materials for treatment can be calculated as shown in **(11)** for productive activities. The format of **$\mathbf{w_{V,W}}$+Δ$\mathbf{s_W}$** is one by activities.

$$\mathbf{w_{V,W}} + \Delta\mathbf{s_W} = \widehat{\mathbf{w}}_{\mathbf{U,T}} \cdot (\mathbf{i} - \mathbf{e_0}) - \mathbf{b_W} \tag{11}$$

In order to operate with only one matrix with supply of materials for treatment information, it has been decided that the vector in **(11)** is diagonalised and merged into the **$\mathbf{W_V}$+Δ$\mathbf{S}$** square matrix. This implies that materials for treatment originating from inputs of materials for treatment are present on the diagonal in the **$\mathbf{W_V}$** table. Notice that there is not any overlapping problem down the diagonal of **$\mathbf{W_V}$** between natural resources and materials for treatment (see **chapter 5.1**) since in general activities using natural resources in the supplied products do not use materials for treatment and vice versa.

5.3 Materials for treatment from input of products

The matrices **U, Y** and **$\mathbf{S^+}$,** described in **chapter 4.1**, show the total mass of products entering human activities. Also for these products an analogous approach to the previous chapter on natural resources can be applied.

A transfer coefficient matrix **$\mathbf{D_0}$** is defined to specify the proportion of inputs of products to an activity that is present in the supply of products of the same activity. The format of **$\mathbf{D_0}$** is products by productive activities. All the values of **$\mathbf{D_0}$** fall in the interval [0;1]. A value equal to 0 can indicate that:

1) the input of the given product is not present in the product supply of the activity
2) the input of the given product does not have a physical mass

Values of **$\mathbf{D_0}$** in the interval]0;1] indicate the feedstock efficiency of each input. The transfer coefficient matrix **$\mathbf{D_0}$** is created as a combination of manual specified and calculated coefficients. This ensured consistency between inputs (natural resources, products, materials for treatment), outputs of products, and the transfer coefficients. This is further described in equations **(15)** and **(16)**.

The total supply of products originating from inputs of products (**$\mathbf{V_C}$'**) can be expressed as:

$$\mathbf{V}_\mathrm{C} \cdot \mathbf{i} = (\mathbf{D_0} * \mathbf{U})' \cdot \mathbf{i} \tag{12}$$

The matrix of emissions originating from inputs of products is denoted **$\mathbf{B_C}$**, and it has format products by activities.

The supply of materials for treatment plus stock additions (**$W_{V,C}$**+Δ**S_C**) originating from the input of products can be calculated as shown in **(13)** for productive activities. The format of **$W_{V,C}$**+Δ**S_C** is products by activities.

$$\mathbf{W_{V,a,C}} + \Delta\mathbf{S_{a,C}} = \mathbf{U} - \mathbf{D_0} * \mathbf{U} - \mathbf{B_{a,C}} \tag{13}$$

Correspondingly, the supply of materials for treatment plus stock additions for the household and stock categories are calculated as **(14)**, where the only difference from **(13)** is that no of the inputs ends up as supply of products:

$$\mathbf{W_{V,f,C}} + \Delta\mathbf{S_{f,C}} = (\mathbf{Y} \cup \mathbf{S^+}) - \mathbf{B_{f,C}} \tag{14}$$

The transfer coefficient matrix **D_0** is based on specified information and calculated mass balances. This enables to specify the coefficients for which good information is available, while the remaining coefficients are calculated to ensure consistency between inputs (natural resources, products, materials for treatment), outputs of products, and the transfer coefficients. For this purpose a feedstock specification matrix **D_1** is defined for data inputs regarding product feedstocks. This matrix has same format as the **D_0** matrix. In **D_1** feedstocks can be specified if the value of a cell is within the interval]0;1]. If the value 1 is entered, the feedstock will be calculated based on mass balance, and if a value]0;1[is entered, then this specific feedstock efficiency is carried on to the corresponding cell in **D_0**. This is specified in **(15)**.

$$\mathbf{D_0}_{i,j} = \begin{cases} \mathbf{D_1}_{i,j} = 0 \rightarrow \ \mathbf{D_0}_{i,j} = 0 \\ \mathbf{D_1}_{i,j} =]0{,}1[\ \rightarrow \ \mathbf{D_0}_{i,j} = \mathbf{D}_{i,j} \\ \mathbf{D_1}_{i,j} = 1 \rightarrow \ \mathbf{D_0}_{i,j} = \hat{\mathbf{d}}_j \ [\text{see (16)}] \end{cases} \tag{15}$$

The last term in **(15)** is calculated as:

$$\hat{\mathbf{d}} = \ \mathbf{mdiag}\left[\mathbf{V}\cdot\mathbf{i} - \widehat{\mathbf{r_{T,a}}}\cdot\mathbf{f_0} - (\mathbf{W_U}'\cdot\mathbf{i})\cdot\mathbf{e_0} - \left(\mathbf{D_{1ij<1}} * \mathbf{U}\right)'\cdot\mathbf{i}\right] \cdot \ \mathbf{mdiag}\left[\left(\mathbf{D_{1ij=1}} * \mathbf{U}\right)'\cdot\mathbf{i}\right] \tag{16}$$

Also in the case, if the vector in the denominator has some null components, by default the value 0 is assigned to all values in that column of the **D_0** matrix.

Equation (16) says that components of **D_0** for **D_{1ij}=1** are the ratio between the total mass of the supplied products less the natural resources, materials for treatment and products already transferred, and the total mass of products still to be transferred.

5.4 Description of the framework for special activities and final use categories

5.4.1 Households

Households purchase durable and non-durable products and do not supply any kind of products. Usually households produce services, e.g, cleaning, maintenance, transportation, preparation of meals, etc. (UN et al, 2009).

Therefore the inputs to the households are transformed into emissions and materials for treatment, for what concerns the non-durable products, and in stock addition for the durable-goods. As a consequence, all the resource-, materials for treatment- and product transfer coefficients related to households are null. Also see equations **(8)** and **(14)**.

5.4.2 Stock formation

This chapter concerns the formation of fixed assets, i.e. machinery, constriction works, etc., and the change in inventories, i.e. the products accumulated at the end of the accounting periods.

By definition the fixed asset contribute to the formation of stock while the change in inventories can generate both materials for treatment and stocks, depending on the nature of the accumulated products.

In general the fixed assets generate materials for treatment when they are dismissed entirely or partially while the intermediate and non-durable products included in the formation of new inventories, create materials for treatment in a subsequent accounting periods when products are purchased. These aspects become of fundamental relevant when the analysis of waste scenarios requires the time dynamic as was pursued in the FORWAST project (Schmidt et al. 2010).

The stock formation is not a productive activity in the sense that the incoming products are delivered in the same shape, without any processing, only a degradation may take place. Hence the incoming flows are included in the supply side straightforward in the stock change accounts, of course excluding the degraded part that generates materials for treatment and emissions. As a consequence, the product transfer coefficients related to stock formation are null.

One of the advantages of the introduction of transfer coefficient matrices, as seen in **chapters 5.1** to **5.3**, is that the stock formation accounts can be detailed according to the inputs present in the product. The information embodied in the transfer coefficients combined with the matrices of the inputs of materials (natural resources, materials for treatment and products) can trace the material composition of equipment.

5.4.3 Waste treatment activities; allocation of materials for treatment and by-products

Input of materials for treatment, accounted in $\mathbf{W_U}$, concerns the waste treatment activities. All supply of materials for treatment is accounted for (used in) the use of materials for treatment matrix. Also import and export of materials for treatment should be accounted for. However, as a default/starting point trade with materials for treatment is not included in the CREEA project due to limited data availability and challenging balancing exercises regarding a balanced trade-linking for materials for treatment (which also has to be consistent with the supply and use of products). Hence we have:

$$(\mathbf{W_V} \cdot \mathbf{i})' \cdot \mathbf{i} = (\mathbf{W_U}' \cdot \mathbf{i})' \cdot \mathbf{i} \quad \textbf{(17)}$$

The format of the $\mathbf{W_U}$ matrix is different from the supply of materials for treatment matrix $\mathbf{W_V}$. The columns in $\mathbf{W_V}$ and $\mathbf{W_U}$ are the same; they represent activities. The rows in the $\mathbf{W_V}$ matrix have same classification as the products in the supply (**V'**) and use (**U**) tables (due to the calculation in **(13)**). This classification is not used in the $\mathbf{W_U}$ matrix. This is because some of the materials for treatment in the $\mathbf{W_V}$ table are composed of different materials, e.g. machinery waste may be composed by iron, alu, copper and plastics. The waste treatment activities are defined for homogeneous waste fractions, and hence the classification of the rows of $\mathbf{W_V}$ does not fit with the waste treatment services of the waste treatment activities. In order to achieve correspondence between the defined waste treatment activities (which treat homogenous waste fractions), the composite wastes (e.g. machinery) are disaggregated and same wastes appearing in different product classifications (e.g. meat waste and other food wastes will both be treated as just food waste) are aggregated.

For the purpose of the reclassification of the supply of materials for treatment, the correspondence matrix **Q** is defined. The **Q** matrix has format materials for treatment (same as products in use table) by re-classified homogeneous materials for treatment. The sums of the rows in **Q** are 1. The reclassification of materials for treatment in $\mathbf{W_V}$ and $\mathbf{W_U}$ is illustrated in **Figure 5.3** and in **(18)**.

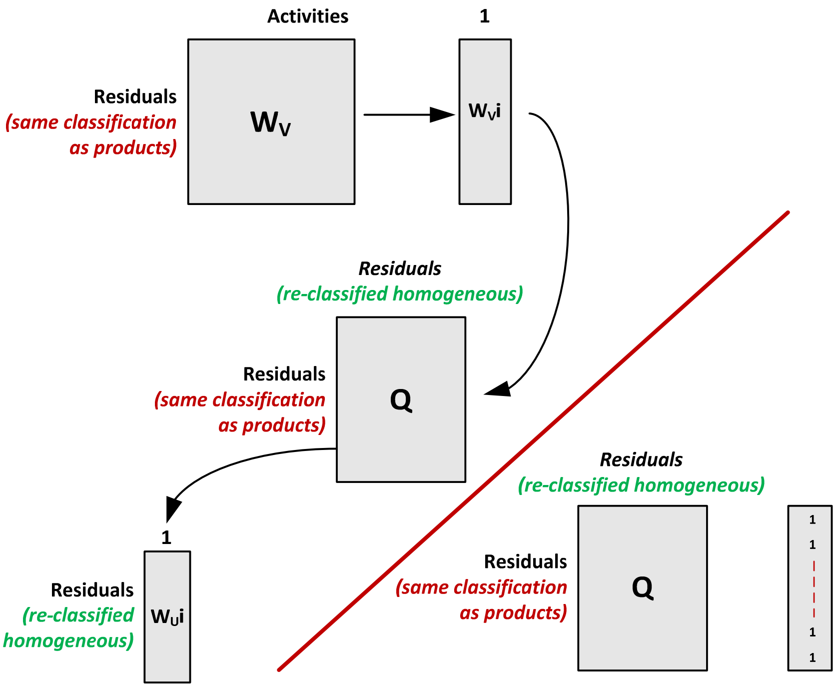

Figure 5.3: Re-classification of the materials for treatment in $\mathbf{W_V}$ to homogeneous materials for treatment in $\mathbf{W_U}$ by use of **Q**. In lhe lower right corner it is illustrated that the row sums of **Q** are 1.

$$\mathbf{W_U} \cdot \mathbf{i} = [\mathbf{Q}' \cdot \mathrm{mdiag}(\mathbf{W_V} \cdot \mathbf{i})] \cdot \mathbf{i} \qquad \textbf{(18)}$$

The next step in creating $\mathbf{W_U}$ is to distribute the re-classified materials for treatment ($\mathbf{W_U}$·**i**) into the use of materials for treatment matrix ($\mathbf{W_U}$). This distribution is carried out in a two step procedure. First, some of the total supply of materials for treatment is estimated based on information in the framework combined with ancillary information (e.g. human metabolism can be used to estimate urine and excretion in sewage water). The second step is to allocate the remaining materials for treatment, which are not specified in the first step, to a default waste treatment activity, e.g. landfill.

This can also be explained by an example: Imagine that we have calculated the total supply of paper waste as 1000 tonne. Then from the data collection for the supply table (**V'**) we know that the 'Re-processing of secondary paper into new pulp' activity supplies 500 tonne pulp. We also know that the proportion of ingoing waste paper ending up in the final product ($\mathbf{e_0}$) for this activity is 0.85. Hence, we can calculate that the 'Re-processing of secondary paper into new pulp' activity treats 500 tonne pulp divided by 0.85 tonne pulp per tonne paper waste. This equals 588 tonne paper waste used by the 'Re-processing of secondary paper into new pulp' activity. For some other waste treatment activities we may use other information to estimate the quantity of materials for treatment used by these activities. And then the remaining paper waste is allocated to landfill of paper waste.

5.5 Mass balance check and consolidated calculation of $\Delta\mathbf{S}+\mathbf{W_V}$

In the precedent chapters the procedures to calculate supply of materials for treatment plus stock additions as well as how to derived the use of materials for treatment matrix have been described. This has included a description of the role of resource-, materials for treatment- and product- transfer coefficients matrices. These procedures are the foundation of the mass balance approach in order to generate waste and stock change accounts.

The scope of the rest of this chapter is to present the iterative procedure that will be applied to the default PSUTs based on the approach explained above to ensure mass balance and consistency within the framework.

The first step in determining the waste accounts is to calculate the supply of materials for treatment ($\mathbf{W_V}$) plus stock additions ($\Delta\mathbf{S}$). For productive activities, this is carried out by using **formulas (7)**, **(11)** and **(13)**. Correspondingly, for households and for stock formation **formulas (8)** and **(14)** used.

In this way a first construction of matrix $\Delta\mathbf{S}+\mathbf{W_V}$ is carried out. However, experiences from the FORWAST project (Schmidt et al. 2010) show that this first calculation implies several inconsistencies depending on the quality of the input data. If the physical supply and use tables are created based on a default assumption of constant prices, the calculated inputs of feedstock may be less than the sum of the output of the associated supply of products and emissions. This leads to negative values in matrix $\Delta\mathbf{S}+\mathbf{W_V}$ which is inconsistent; activities do not generate negative quantities of waste. Another aspect of the inconsistency appears when some of the calculated product transfer coefficients in $\mathbf{D_0}$ show values outside the interval [0;1]. Again, this is inconsistent; if entries in $\mathbf{D_0}$>1 it means that activities produce more product output than input of feedstock. Correspondingly, if entries in $\mathbf{D_0}$<1 it means that some feedstocks cause negative supply of products.

In the FORWAST project, the data collection for supply and use of products was carried out independently of the data collection for emissions and natural resources (Schmidt 2010a). This implied that inconsistent relationships between inputs of fuels and fuel related emissions appeared. Correspondingly, inconsistencies between inputs of natural resources and supplied products of resource extracting activities appeared. These inconsistencies will not be present in the CREEA project because the emissions and resource matrices are interlinked with the supply and use tables via coefficients, e.g. emission factors.

The inconsistent values of $\mathbf{D_0}$ and of $\mathbf{\Delta S}+\mathbf{W_v}$ will be eliminated by:

1. Redistribute the entries in the rows with the relevant feedstocks in the use table (**U**)
2. Scale the production volume and associated inputs and outputs of products, natural resources, emissions and materials for treatment. This option will only be used if the production volume of an activity appears to be too big compared with the available feedstocks.

Option 1) above can be implemented in an automated optimization procedure which is defined to ensure consistency and to maximise the agreement with some defined criteria on expected production functions. An example of the latter could be that approximately 1.1 kg DM wood is used to produce 1 kg DM pulp in the pulp manufacturing activity.

Redistribution of the entries in the rows in the use table is equivalent to differentiate the prices over activities.

Option 2) will be used when the automated procedure explained above fails to produce satisfactory agreement with the defined criteria expected production functions.

6 Limitations of the approach

The main limitation of the approach is related to the level of aggregation of products and activities and to the quality of input data. Aggregated product categories reduces the ability to distinguish potentially different important flows, e.g. the calculated waste flows originating from the inputs of 'chemicals nec' may be anything from harmless inert materials to hazardous chemical waste.

When the accounting period is only one year and when time series are not run, then we have to assume that $\Delta\mathbf{S}$ is equal to degradation of stock accumulated in the economy in previous years; i.e. we assume a steady-state economy.

Then we have $\mathbf{W_V} + \Delta\mathbf{S} = \mathbf{W_V}$. And the quantities in $\mathbf{W_V}$ are what has to be distributed (via $\mathbf{J}$) in $\mathbf{W_U}$. In general we have a positive economic growth, i.e. it can be expected that $\Delta\mathbf{S}$ > degradation of stock accumulated in the economy in previous years. Hence, the approach overestimates $\mathbf{W_V}$.

When time series are run, then the assumption of constant product material composition may be problematic.

7 Definitions used in the CREEA framework

7.1 Definition of used terms

Technosphere:
Space where human activities take place.

Environment:
The surroundings of the technosphere.

Physical flow:
Movement of material between different human activities or from/to the environment.

Activity:
Disaggregated category of the technosphere. The sum of industry and household activities represent all human activities. Industry activities are productive activities that aim at selling the resulting products to another activity, while the remaining human activities are household activities.

Productive activity:
Industry activity. To indicate a productive activity the subscript *a* is used.

Accumulation and final uses:
Household activies and accumulation categories. To indicate a accumulation and final uses the subscript *a* is used

Waste treatment activity:
Human activity using materials for treatment. Waste treatment activities are service activities, i.e. their principal product is a service. For landfill and waste incineration, this service is to take care of the treatment and disposal of materials for treatment. For recycling and re-processing activities, the service is to process materials for treatment into by-products.

Product:
Output flow from a human activity with a positive either market or non-market value. {An example of a product with a non-market value can be household childcare. Products from industry and household activities are denoted 'industry products' and 'household products' respectively. } Further distinction of the products can be made according the role of products in the productive process in terms of princiapal products and by-products:

Principal product:
Product for which the production volume changes in response to changes in demand. The principal product triggers the productive activities.

By-product:
Non-principal product that directly (i.e. without further processing) is used in place of other products.

Another distinction is pursued according to the lifetime and the user of the products:

Durables products:
A durable product may be used repeatedly or continuously by consumers over a period of more than a year.

Non-durables products:
A non-durable product may be not used repeatedly or by consumers continuously over a period of more than a year but it is completely used in the accounting period.

Fixed assets
Fixed assets are produced products (such as machinery, equipment, buildings or other structures) that are used repeatedly or continuously in production over several accounting periods (more than one year).

Intermediate products
Intermediate products are products completely used up in the accounting period within productive activities.

Material for treatment:
Output flows of a human activity that remains in the technosphere and cannot directly (i.e. without further processing or emissions) displace another principal product of an activity. After processing in a waste treatment (re-processing or recycling) activity, the recovered materials for treatment may displace other products.

Natural resources inflow:
Material inflows from the environment to the technosphere.

Emission:
Output flow from a human activity that directly enters the environment. NOTE: The term 'Environmental indicators' covers also emissions.

7.2 Definitions of vectors and matrices

Supply *of products* matrix (V):
Product supply per {human} productive activity within a specified period and geographical area
The standard dimension of supply tables in literature (e.g. Hoekstra 2005, Kop Jansen and ten Raa 1990, ten Raa and Rueda-Cantuche 2003) is activities by products. This corresponds to the transpose format of the use table. Throughout this report, we use the standard dimension for V, but in figures and formulas, the
supply table will always appear as V' (transpose of V) in order to have the same dimension as the use table of products (U).
Dimension: activities by products.

Sub-sets of **V** (same format as **V**, the sum of the sub-sets equals **V**):
- $\mathbf{V_C}$ represents supply of products which are produced from feedstock of products, i.e. inputs in the use table (**U**)
- $\mathbf{V_R}$ represents supply of products which are produced from feedstock of resource

inputs, i.e. inputs in the resource table (**R**)

- V_W represents supply of products which are produced from feedstock of materials for treatment, i.e. inputs in the use of materials for treatment table (W_U)

Use of products matrix (U):
Products used per {human} productive activity within a specified period and geographical area.
Dimension: products by activities

Stock formation and change of inventories (S^+):
Stock formation and change of inventories. Also referred to as accumulation.
Note that S^+ should not be confused with ∆**S**. S^+ is the stock formation and change of inventories as of the original accounting systems (on the use side) whereas ∆**S** is a calculated balancing item on the supply side.
Dimension: Products by one (or by types of stock formation and change of inventories)

Final consumption matrix (Y):
Products used by individual households or the community to satisfy their individual or collective needs or wants within a specified period and geographical area.
Dimension: products by final consumption categories

Import of products (N_c) and materials for treatment (N_w):
Import of products and materials for treatment for a specified period and importing geographical area. Nc and Nw represent import of products and materials for treatment, respectively.
Dimension of each of N_c and N_w: products by importing countries.

Export of products (E_c) and materials for treatment (E_w):
Export of products and materials for treatment for a specified period and exporting geographical area. Ec and Ew represent export of products and materials for treatment, respectively.
Dimension of each of E_c and E_w: products by importing countries

Product transfer coefficient matrix (D_0):
For each product input used by an activity, the proportion of the input which is present in the products supplied by the activity, i.e: (real use of a product present in the supplied products) / (total input of that product). Allowed values fall in the interval [0,1]. D_0 also includes those products that have a shorter lifetime than the product they enter into (e.g. windows in a building, typically exchanged several times during the life time of a building). This implies that the materials for treatment and stock changes of these products will appear as materials for treatment and stock changes of the composite product industry (e.g. the building industry) rather than of the activity using the composite products (e.g. the use of buildings).
Dimension: Products by activities

Input data for product transfer coefficients (D_1):
For each product input used by an activity, a specification whether the product will be present in the products supplied by the activity (**V'**). Allowed values fall in the interval [0,1]. The value = 0 means that the product is not present in **V'**, the value = 1 means that the product will be present in **V'** but the proportion is unknown, and a value ∈]0,1[

means that the product will be present in **V'** in the specified proportion. $\mathbf{D_1}$ is used in the calculation of $\mathbf{D_0}$.
Dimension: Products by activities

Activities output/input vector (g):
Sum of the output (supplied products, materials for treatment and emissions) or input (used natural resources, products, materials for treatment, and primary factors) per human activity within a specified period and geographical area.

Sub-set division of **g** based on activities:
- $\mathbf{g_a} \cup \mathbf{g_f} = \mathbf{g}$
- $\mathbf{g_a}$: activities input/output for productive activities (see **Figure 3.2**)
- $\mathbf{g_f}$: activities input/output for accumulation and final uses categories (see **Figure 3.2**)

Product output/input vector (q):
Sum of supplied products (domestic and exported) or used products (domestic and imported) for all human activities within a specified period and geographical area

Stock additions matrix (ΔS):
Additions to stocks of products and materials for treatment per human activity within a specified period and geographical area. In final waste treatment activities, the stocks are stocks of materials for treatment. All other stock changes refer to stocks of products. Small temporary changes in inventories are not covered by the stock concept of our model, but are taken up as use in the **U** matrix.
Note that $\mathbf{W_V}+\Delta\mathbf{S}$ is a calculated balancing item. $\Delta\mathbf{S}$ should not be confused with $\mathbf{S^+}$. $\mathbf{S^+}$ is the stock formation and change of inventories as of the original accounting systems (on the use side) whereas $\Delta\mathbf{S}$ is a calculated balancing item on the supply side.
Dimension: Products by activities plus final consumption categories.

Sub-set division of $\Delta\mathbf{S}$ based on activities:
- $\Delta\mathbf{S_a} \cup \Delta\mathbf{S_f} = \Delta\mathbf{S}$
- $\Delta\mathbf{S_a}$: stock additions in the productive activities (see **Figure 3.2**)
- $\Delta\mathbf{S_f}$: stock additions in the accumulation and final uses categories (see **Figure 3.2**)

Sub-set division of $\Delta\mathbf{S}$ based on inputs:
- $\Delta\mathbf{S_C} + \Delta\mathbf{S_R} + \Delta\mathbf{S_W} = \Delta\mathbf{S}$
- $\Delta\mathbf{S_C}$ represents stock additions which originates from inputs of products, i.e. inputs in the use table (**U**), stock formation ($\mathbf{S^+}$) and final consumption (**Y**)
- $\Delta\mathbf{S_R}$ = mdiag($\Delta\mathbf{s_R}$) represents stock additions which originates from inputs of natural resources, i.e. inputs in the resource table (**R**)
- $\Delta\mathbf{S_W}$ = mdiag($\Delta\mathbf{s_W}$) represents stock additions which originates from inputs of materials for treatment, i.e. inputs in the use of materials for treatment table ($\mathbf{W_U}$)

Materials for treatment supply matrix ($\mathbf{W_V}$):
Materials for treatment supplied per human activity within a specified period and geographical area.
Dimension: Materials for treatment by activity

Sub-set division of $\mathbf{W_V}$ based on activities:

- $\mathbf{W_{V,a} \cup W_{V,f} = W_V}$
- $\mathbf{W_{V,a}}$: supply of materials for treatment in the productive activities (see **Figure 3.2**)
- $\mathbf{W_{V,f}}$: supply of materials for treatment in the accumulation and final uses categories (see **Figure 3.2**)

Sub-set division of $\mathbf{W_V}$ based on inputs:

- $\mathbf{W_{V,C}} + \mathbf{W_{V,R}} + \mathbf{W_{V,W}} = \mathbf{W_V}$
- $\mathbf{W_{V,C}}$ represents supply of materials for treatment which originates from inputs of products, i.e. inputs in the use table (**U**)
- $\mathbf{W_{V,R}}$ = mdiag($\mathbf{w_{V,R}}$) represents supply of materials for treatment which originates from inputs of natural resources, i.e. inputs in the resource table (**R**)
- $\mathbf{W_{V,W}}$ = mdiag($\mathbf{w_{V,W}}$) represents supply of materials for treatment which originates from inputs of materials for treatment, i.e. inputs in the use of materials for treatment table ($\mathbf{W_U}$)

Note that the supply of materials for treatment originating from resource inputs and inputs of materials for treatment are accounted as vectors, i.e. $\mathbf{w_{V,R}}$ and $\mathbf{w_{V,W}}$. These are diagonalised to fit with the square format of the $\mathbf{W_V}$ matrix.

Materials for treatment use matrix ($\mathbf{W_U}$):
Materials for treatment used per waste treatment activity within a specified period and geographical area.
Dimension: Materials for treatment by activity

Materials for treatment distribution (J):
For each type of materials for treatment, the proportion of the supply of the materials for treatment used by each waste treatment activity (as defined by hi and hf) including export. The sum of each row in J is = 1. Since only waste treatment activities (and export) receive materials for treatment, the columns in J representing non-waste treatment activities contain only zeros.
Dimension: Materials for treatment by activities plus importing countries.

Material for treatment transfer coefficient vector ($\mathbf{e_0}$):
For each waste treatment activity, the proportion of the total material for treatment input to the activity present in the supplied products, i.e: (materials for treatment present in products) / (total materials for treatment input to activity). Allowed values fall in the interval [0,1].
Dimension: Activities by one.

Natural resources matrix (R):
Input of natural resources per human activity within a specified period and geographical area.
Dimension: Natural resources by activity plus final consumption categories

Sub-set division of **R** based on activities:

- $\mathbf{R_a \cup R_f = R}$

- $\mathbf{R_a}$: input of natural resources for productive activities (see **Figure 3.2**)
- $\mathbf{R_f}$: input of natural resources for accumulation and final uses categories (see **Figure 3.2**)

Resource transfer coefficient vector ($\mathbf{f_0}$):
For each activity, the proportion of the total resource input to the activity present in the supplied products, i.e: (natural resources present in products) / (total resource input to activity). Allowed values fall in the interval [0,1].
Dimension: Activities by one.

Emissions matrix (B):
Emissions output per human activity within a specified period and geographical area.
Dimension: Emission type by activity plus final consumption categories

Sub-set division of **B** based on activities:
- $\mathbf{B_a} \cup \mathbf{B_f} = \mathbf{B}$
- $\mathbf{B_a}$: emissions for productive activities (see **Figure 3.2**)
- $\mathbf{B_f}$: emissions for accumulation and final uses categories (see **Figure 3.2**)

Sub-set division of **B** based on inputs:

For each product, material for treatment and resource input to an activity, the emissions that originate from that specific product, material for treatment or resource input.

- $\mathbf{B_C}$ refers to emissions that originate from the use of products (e.g. when an input of coal is burned)
  Dimension $\mathbf{B_c}$: Products by activities plus final consumption categories
- $\mathbf{b_W}$ refers to emissions that originate from the use of materials for treatment (e.g. emissions from waste incineration)
  Dimension $\mathbf{b_w}$: vector with activities plus final consumption categories components
- $\mathbf{b_R}$ refers to emissions that originate from the use of natural resources (e.g. emissions from flaring in oil and gas extraction). Thus, for each activity, the sum of all emissions categories in **B** are distributed either on the products, materials for treatment or resource inputs to the activity.
  Dimension $\mathbf{b_R}$: vector with activities plus final consumption categories components

Stock degradation matrix ($\mathbf{L_S}$):
For each type of stocks of products, the proportion of the initial stock that becomes material for treatment in year u. Allowed values fall in the interval [0,1]. In the model calculations only one row of $\mathbf{L_s}$ is used at the time. We use the notation $\mathbf{L_{s,u}}$=1 to signify the row vector represented by the first row of $\mathbf{L_s}$.
$\mathbf{L_s}$ may be determined by the lifetime of products and/or possibly other factors.
Dimension: Age of stocks by products

Materials for treatment degradation matrix ($\mathbf{L_W}$):
For each type of material for treatment, the proportion of the net supply of the material for treatment that becomes emissions in year u.
Net supply of a material for treatment is the supply of the material for treatment minus the use of the material for treatment. Allowed values fall in the interval [0,1]. For materials for treatment from waste treatment activities, the sum of each column = 1,

and for the materials for treatment from non-waste treatment activities the columns are empty (contain only zeros). $\mathbf{L_w}$ may be determined by the decomposition function of waste in landfills or similar.
Dimension: Age of stocks by materials for treatment

8 Classifications used in the CREEA project

8.1 Industry classification

See **Appendix 1: CREEA industry classification**.

8.2 Product classification

See **Appendix 2: CREEA product classification**.

8.3 Natural resources classification

The following list of natural resources represents a recommended minimum list of resources to be included. This can easily be adjusted without having any effect on the MFA and waste accounts. However, it is a requirement, that the natural resources are defined according to the 'ecosystem approach' (versus the 'harvest approach'), see **chapter 2.3.1**. The minimum list is:

- Aluminium
- Carbon, biogenic
- Carbon, fossil
- Copper
- Iron
- Metals, n.e.c.
- Minerals, n.e.c. (including hydrogen and nitrogen)
- Oxygen
- Sand, gravel, stone, clay and soil
- Zinc

The criteria for defining the minimum list are that it enables for tracking the major resource inputs and for balancing with combustion and respiratory oxygen and water. The reason for distinguishing between different metals is that this facilitates the balancing of resource beneficiation.

8.4 Emissions classification

The following list of emissions represents a recommended minimum list of emissions to be included. This can easily be adjusted without having any effect on the MFA and waste accounts. The minimum list is:

- Ammonia
- Carbon dioxide, biogenic
- Carbon dioxide, fossil
- Carbon monoxide
- Dinitrogen monoxide
- Methane
- Nitrogen dioxide
- NMVOC, non-methane volatile organic compounds, unspecified origin
- Other emissions
- Sulfur dioxide
- Water

The criteria for defining the minimum list are that it enables for tracking some typical major pollutants for which data are available in emissions accounts and for balancing with combustion and respiratory water.

8.5 Waste account classification

The calculated supply materials for treatment ($\mathbf{W_V}$) and use of materials for treatment ($\mathbf{W_U}$) constitute the basis from which waste accounts are derived.

The final classification of the waste accounts is not defined here since this will be affected by the quality of the data inputs to the calculations of materials for treatment and on the applied definition of waste for the waste accounts. Instead the classification for the data basis from which the waste accounts will be derived is defined here.

The classification (i.e. dimension) of $\mathbf{W_V}$ is similar to the supply table, and the classification (i.e. dimension) of $\mathbf{W_U}$ is re-classified homogeneous materials for treatment by activities. Hence the supply and use tables for materials for treatment provide information on the type of material for treatment that is generated or treated, and information on which activities that generate and treat the materials for treatment.

The data basis from which waste accounts are derived involves the following classifications:

- Industry and final use categories classification (see **chapter 8.1**)
- Product classification (see **chapter 8.2**)
- Re-classified homogenous materials for treatment classification (see below)

The re-classified homogenous materials for treatment are carried out using the following classification:

- Aluminium
- Copper
- Food/feed including urine and excretion
- Inert
- Lead
- Paper
- Plastics
- Preciuos metals
- Oil/hazardous
- Steel
- Wood

The criterion for defining this list of re-classified homogenous materials for treatment is that it satisfies the subdivision of materials to correctly direct the materials for treatment to the waste treatment activities in the included industry classification. An example is that the waste treatment activity 'Re-processing of secondary lead into new lead' requires that a homogenious material for treatment consisting of lead can be identified.

9 Examples of data sources for data collection

The precedent chapters have described the general framework of MFA, the procedure for the generation of materials for treatment accounts and the disaggregations necessary for a proper accountability of the waste treatment activities. This chapter provides an overview of examples of central data sources to complete data sets in order to produce the tables in the CREEA MFA and waste account framework.

9.1 Production volumes and trade

The first step in the data collection to create the PSUTs and waste accounts as of **chapters 3** to **5** is to obtain physical (dry matter mass) data on the total domestic production volumes of the products included in the CREAA product classification. In addition to that, data on the import and export of the same products are obtained.

For products which are supplied partly from virgin production and partly from secondary production, the total product volumes are differentiated per activity, i.e. total supply per activity.

The information referred to above (together with price data and specific coefficients for some key uses, e.g. fuels and energy per supply) are used as input data to the disaggregation procedure for the monetary supply-use tables carried out in work package 7 of the CREEA project (creea.eu). These data as well as are then used in order to disaggregate the monetary tables. For the specific coefficients, general data can be used if not country/region specific data exists, for instance from LCI databases, e.g. the ecoinvent database (ecoinvent.org).

The disaggregated monetary tables provided by work package 7 of the CREEA project are used to distribute the total physical (dry matter mass) production over the activities, final use categories and trade categories. This first draft/default construction of physical supply table and use table is carried out by assuming constant prices over activities. At a later stage, this is revised as described in **chapter 5.5**.

Examples of data sources/databases of production volumes are:

- EUROSTAT database provides statistics for EU Member States and some other European countries;
  Website: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home

- Food and Agriculture Organization of United Nations - FAOSTAT provides agricultural data of world countries;
  Website: http://faostat.fao.org/default.aspx

- Food and Agriculture Organization of United Nations - Yearbooks of Fishery Statistics Summary Tables for data on fishery and aquaculture;
  Website: ftp://ftp.fao.org/fi/stat/summary/default.htm

- British Geological Survey, 'MineralsUK' Centre - European Mineral Statistics provides statistical information about minerals and metals in Europe;
  Website: http://www.bgs.ac.uk/mineralsuk/

- United States Geological Survey - Minerals Yearbook provides statistical data and information;
  Website: http://minerals.usgs.gov/minerals/pubs/commodity/myb/

- Swiss Centre for Life Cycle Inventories - Ecoinvent provides life cycle inventories data for many products;
  Website: http://www.ecoinvent.ch/

- International Energy Agency provides statistical energy-related data
  Website: http://www.iea.org/stats/index.asp

- United Nations Statistics Division provides industrial commodity productions and commodity trade statistics for many world countries, including trade of waste and scraps in monetary as well as physical units;
  Website: http://data.un.org/Browse.aspx?d=ICS

- World Steel Association - Steel Statistical Yearbook provides information on the production of steel from primary and secondary sources:
  Website: http://www.worldsteel.org/

- International Copper Study Group – Statistical yearbook provides data on copper production;
  Website: http://www.icsg.org/

9.2 Transfer coefficient matrices

The transfer coefficient matrix for resource inputs (**f_0**) is created based on:

- **Crop cultivation:** This is generally considered as 100%, i.e. the removed crops are equivalent to the extracted natural resources
- **Animal production:** This is based on animal metabolism balances; inputs of feed is balanced with outputs of animals, manure/urine/excretion, and respiratory CO_2, H_2O and CH_4
- **Forest production:** This is generally considered as 100%, i.e. the removed forest products are equivalent to the extracted natural resources
- **Minerals mining activities:** This is based on information on ore concentration of crude ores and the ores after beneficiation
- **Oil and gas extraction:** This is based on information on the amount of flared oil and gas

The transfer coefficient matrix for the use of materials for treatment (**e_0**) is based on various information on recycling efficiency, e.g. kg paper waste required per kg pulp.

The transfer coefficient matrix for products is calculated based on the feedstock specification matrix (**D_1**) and other information within the framework, i.e. supply table, use table, emissions tables, resource table and the transfer coefficient tables for natural resources and materials for treatment. Information to fill the **D_1** matrix is obtained from:

- **$D_{1ij<1}$:** Production specific data, e.g. life cycle inventories
- **$D_{1ij=1}$:** General knowledge of which feedstocks are used in which activities. Data are available from the FORWAST project.

9.3 Emission factors

Emission tables are calculated via emission factors which links to elements within the PSUT framework, i.e.:

- the use table (e.g. the use of fuels)
- the supply table (e.g. animal metabolism balances and process emissions of nitrous oxides from fertiliser production)
- the use of materials for treatment matrix (e.g. the input of paper waste to incineration of waste paper)

Emissions factors can be obtained from various sources, e.g. national inventory reports submitted within the UNFCCC framework.

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Appendix 1: CREEA industry classification

Productive activities are listed from no. 1 to 163. Waste treatment activities are marked with grey. In addition to the productive activities six waste treatment activities for the Uncontrolled disposal of waste are defined. These activities are not linked via any product transactions to the other productive activities. The only purpose of the the six special waste treatment activities are: 1) to have somewhere to place uncontrolled disposal of waste in the framework, and 2) to have some activities where emissions of uncontrolled disposed waste can be included.

No	Name	Code	Code
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
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
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 vehicles and motorcycles (51)	i51	A_TDWH
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
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

	Household consumption		

164	Uncontrolled disposal of waste: Food
165	Uncontrolled disposal of waste: Paper
166	Uncontrolled disposal of waste: Plastic
167	Uncontrolled disposal of waste: Inert/metal/hazardous
168	Uncontrolled disposal of waste: Textiles
169	Uncontrolled disposal of waste: Wood

Appendix 2: CREEA product classification

Products and materials for treatment classification. Producs are shown as whte rows whereas materials for treatment are marked with grey.

No	Name	Code	Code
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
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
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
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 pension funding services (65)	p65	C_FINT
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

201	Food waste for treatment: non-registered waste
202	Paper for treatment: non-registered waste
203	Plastic waste for treatment: non-registered waste
204	Inert/metal/hazardous waste for treatment: non-registered waste
205	Textiles waste for treatment: non-registered waste
206	Wood waste for treatment: non-registered waste

Appendix 3: ISIC Rev.4 industry classification

International Standard Industrial Classification of All Economic Activities, Rev.4
A - Agriculture, forestry and fishing
B - Mining and quarrying
C - Manufacturing
D - Electricity, gas, steam and air conditioning supply
E - Water supply; sewerage, waste management and remediation activities
F - Construction
G - Wholesale and retail trade; repair of motor vehicles and motorcycles
H - Transportation and storage
I - Accommodation and food service activities
J - Information and communication
K - Financial and insurance activities
L - Real estate activities
M - Professional, scientific and technical activities
N - Administrative and support service activities
O - Public administration and defence; compulsory social security
P - Education
Q - Human health and social work activities
R - Arts, entertainment and recreation
S - Other service activities
T - Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U - Activities of extraterritorial organizations and bodies

Source : United Nations Statistics Division, Classifications Registry

Appendix 4: CPC ver.2 product classification

Central Product Classification, Ver.2
0 - Agriculture, forestry and fishery products
1 - Ores and minerals; electricity, gas and water
2 - Food products, beverages and tobacco; textiles, apparel and leather products
3 - Other transportable goods, except metal products, machinery and equipment
4 - Metal products, machinery and equipment
5 - Constructions and construction services
6 - Distributive trade services; accommodation, food and beverage serving services; transport services; and electricity, gas and water distribution services
7 - Financial and related services; real estate services; and rental and leasing services
8 - Business and production services
9 - Community, social and personal services

Source : United Nations Statistics Division, Classifications Registry (http://unstats.un.org/unsd/cr/registry/cpc-2.asp. last accesed: January 2012)

Appendix 5: Correspondance between CPC and EWC-Stat aggregated

Below is provided a list of correpondance between the input of products (CPC) and the related potential solid waste generation (EWC-Stat).

Code CPC Ver1.1	Description	EWC aggr	EWC aggr description	Full/partial
391	Wastes from food and tobacco industry	9	Animal and vegetal wastes	Full
3911	Raw offal, inedible (including pigs' bristles, animal guts, bird skins, feathers, bones and ivory)	9	Animal and vegetal wastes	Full
3912	Bran and other residues from the working of cereals or legumes; vegetable materials and vegetable waste, vegetable residues and by-products, whether or not in the form of pellets, of a kind used in animal feeding n.e.c.	9	Animal and vegetal wastes	Full
3913	Residues of starch manufacture and similar residues	9	Animal and vegetal wastes	Full
3914	Beet-pulp, bagasse and other waste of sugar manufacture	9	Animal and vegetal wastes	Full
3915	Cocoa shells, husks, skins and other cocoa waste	9	Animal and vegetal wastes	Full
3916	Brewing or distilling dregs and waste	9	Animal and vegetal wastes	Full
3917	Wine lees; argol	9	Animal and vegetal wastes	Full
3918	Tobacco refuse	9	Animal and vegetal wastes	Full
392	Non-metal wastes or scraps	13	Other wastes	Full
3921	Miscellaneous textile wastes	13	Other wastes	Full
39211	Silk waste, not carded or combed	13	Other wastes	Full
39212	Waste of wool or of fine or coarse animal hair	13	Other wastes	Full
39213	Garnetted stock of wool or of fine or coarse animal hair	13	Other wastes	Full
39214	Cotton waste, except garnetted stock	13	Other wastes	Full
39215	Other cotton waste; garnetted stock	13	Other wastes	Full
39216	Waste of man-made fibres	13	Other wastes	Full
39217	Worn clothing and other worn textile articles	13	Other wastes	Full
39218	Rags, scrap twine, cordage, rope and cables and worn out articles of twine, cordage, rope or cables, of textile materials	13	Other wastes	Full
3922	Waste of leather, leather dust, powder and flour	13	Other wastes	Full
3923	Residual lyes from the manufacture of wood pulp, including lignin sulphonates, but excluding tall oil	7	Wood	Full
3924	Waste and scrap of paper or paperboard	5	Paper	Full
3925	Waste, parings and scrap of rubber (except hard rubber) and powders and granules obtained therefrom	13	Other wastes	Full
3926	Used pneumatic tyres of rubber	13	Other wastes	Full
3927	Waste, parings and scrap of plastics	6	Plastic	Full
3928	Sawdust and wood waste and scrap	7	Wood	Full

Code CPC Ver1.1	Description	EWC aggr	EWC aggr description	Full/partial
393	Metal wastes or scraps	3	Metallic waste	Full
3931	Slag, dross, scalings and other waste from the manufacture of iron or steel	13	Other wastes	Full
3932	Ash and residue (except from the manufacture of iron or steel), containing metals or metallic compounds, except precious metals	3	Metallic waste	Full
3933	Waste and scrap of precious metal	3	Metallic waste	Full
39331	Waste and scrap of gold or of metal clad with gold	3	Metallic waste	Full
39332	Waste and scrap of precious metal (except gold) or of metal clad with precious metal (except gold)	3	Metallic waste	Full
39333	Ash containing precious metal or precious metal compounds	3	Metallic waste	Full
3934	Ferrous waste and scrap	3	Metallic waste	Full
3935	Remelting scrap ingots of iron or steel	3	Metallic waste	Full
3936	Waste and scrap of copper, nickel, aluminium, lead, zinc and tin	3	Metallic waste	Full
3937	Vessels and other floating structures for breaking up	8	Discarded equipment and vehicles	Full
3938	Waste and scrap of primary cells, primary batteries and electric accumulators; spent primary cells, primary batteries and electric accumulators	8	Discarded equipment and vehicles	Full
399	Other wastes and scraps	13	Other wastes	Full
3991	Municipal waste	10	Household and similar wastes	Full
3992	Sewage sludge	1	Chemical and healthcare waste	Full
3993	Clinical waste	1	Chemical and healthcare waste	Full
3994	Waste organic solvents	1	Chemical and healthcare waste	Full
3995	Wastes from chemical or allied industries	1	Chemical and healthcare waste	Full
3999	Other wastes n.e.c.	13	Other wastes	Full
31921	Natural cork, debacked or roughly squared, or in blocks, plates, sheets or strip; crushed, granulated or ground cork; waste cork	7	Wood	Partial
2612	Silk waste, carded or combed	13	Other wastes	Full
2617	Jute and other textile bast fibres (except flax, true hemp and ramie), processed but not spun; tow and waste of these fibres	13	Other wastes	Partial
2619	Other vegetable textile fibres, processed but not spun; tow and waste of these fibres	13	Other wastes	Partial
2631	Silk yarn and yarn spun from silk waste; silk-worn gut	13	Other wastes	Partial
2651	Woven fabrics of silk or of silk waste	13	Other wastes	Partial
37111	Glass in the mass, in balls (except microspheres), rods or tubes, unworked; waste and scrap of glass	4	Glass	Partial
3752	Boards, blocks and similar articles of vegetable fibre, straw or wood waste agglomerated with mineral binders	7	Wood	Partial
38971	Human hair, unworked, whether or not washed or scoured; waste of human hair	13	Other wastes	Partial

Code CPC Ver1.1	Description	EWC aggr	EWC aggr description	Full/partial
416	Other non-ferrous metals and articles thereof (including waste and scrap); cermets and articles thereof; ash and residue (except from the manufacture of iron or steel), containing metals or metallic compounds	3	Metallic waste	Partial
41601	Tungsten, molybdenum, tantalum, magnesium, cobalt, cadmium, titanium, zirconium, beryllium, gallium, hafnium, indium, niobium, rhenium and thallium, unwrought, and waste and scrap and powders thereof, except powders of magnesium; cobalt mattes and other i	3	Metallic waste	Partial
41603	Bismuth, antimony, manganese, chromium, germanium and vanadium and articles thereof (including waste and scrap)	3	Metallic waste	Partial
4910	Coral and similar products, shells of molluscs, crustaceans or echinoderms and cuttle-bone	13	Other wastes	Partial
21140	Flours, meals and pellets of meat or meat offal, inedible; greaves	9	Animal and vegetal wastes	Partial
21291	Flours, meals and pellets, inedible, of fish, crustaceans, molluscs or other aquatic invertebrates	13	Other wastes	Partial
21299	Products n.e.c. of fish, crustaceans, molluscs or other aquatic invertebrates; dead fish, crustaceans, molluscs or other aquatic invertebrates unfit for human consumption	9	Animal and vegetal wastes	Partial
21830	Vegetable waxes, except triglycerides; degras; residues resulting from the treatment of fatty substances or animal or vegetable waxes	9	Animal and vegetal wastes	Partial
23310	Preparations used in animal feeding n.e.c.	9	Animal and vegetal wastes	Partial
23912	Coffee substitutes containing coffee; extracts, essences and concentrates of coffee, and preparations with a basis thereof or with a basis of coffee; roasted chicory and other roasted coffee substitutes, and extracts, essences and concentrates thereof; co	9	Animal and vegetal wastes	Partial
27991	Wadding of textile materials and articles thereof; textile fibres not exceeding 5 mm in length (flock), textile dust and mill neps	13	Other wastes	Partial
32113	Mechanical wood pulp; semi-chemical wood pulp; pulps of fibrous cellulosic material other than wood	13	Other wastes	Partial
33500	Petroleum jelly; paraffin wax, micro- crystalline petroleum wax, slack wax, ozokerite, lignite wax, peat wax, other mineral waxes, and similar products; petroleum coke, petroleum bitumen and other residues of petroleum oils or of oils obtained from bitumi	13	Other wastes	Partial
33610	Natural uranium and its compounds; alloys, dispersions, ceramic products and mixtures containing natural uranium and its compounds	2	Radioactive waste	Partial
33630	Uranium depleted in U235 and its compounds; thorium and its compounds; alloys, dispersions, ceramic products and mixtures containing uranium depleted in U235, thorium or compounds of these products	2	Radioactive waste	Partial
33720	Spent (irradiated) fuel elements (cartridges) of nuclear reactors	2	Radioactive waste	Partial
35490	Other chemical products n.e.c.	1	Chemical and healthcare waste	Partial
38230	Industrial diamonds, worked; dust and powder of natural or synthetic precious or semi-precious stones	13	Other wastes	Partial
41544	Zinc dust, powders and flakes	3	Metallic waste	Partial

Appendix 6: Correspondance between CREEA classification and the EWC-Stat

The following correspondence table show:

- in the rows the inputs of physical (mass) products in CREEA classification that will become waste (see CREEA codes in **Appendix 2: CREEA product classification**)
- in the columns the type of waste being generated in EWC-Stat classification (see EWC-Stat codes in the table after the correspondence table below)

EWC-Stat code	01.1	01.2	01.3	01.4	02	03.1	03.2	05	06	07.1	07.2	07.3	07.4	07.5	07.6	07.7	08	08.1	08.41	09	09.11	09.3	10.1	10.2	10.3	11	11.3	12.1 + 12.2 +12.3 + 12.5	12.4	12.6	13
CREEA Code																															
p01.a																				x						x					
p01.b																				x		x				x					
p01.c																				x		x				x					
p01.d																				x						x					
p01.e																				x						x					
p01.f																				x						x					
p01.g															x					x											
p01.h																				x		x				x					
p01.i																				x						x					
p01.j																				x						x					
p01.k																										x					
p01.l																				x						x					
p01.m																				x						x					
p01.n																				x		x				x					
p01.o															x					x											
p01.w.1																															
p01.w.2																															
p02														x						x						x			x		
p05																				x						x					
p10.a						x	x																					x	x		
p10.b						x	x																					x	x		
p10.c						x	x																					x	x		
p10.d						x	x																					x	x		
p10.e						x	x																					x	x		
p10.f						x	x																					x	x		
p10.g						x	x																					x	x		
p10.h						x	x																					x	x		
p11.a						x	x																						x		
p11.b																															
p11.b.1						x	x																						x		
p11.c						x	x																						x		
p12																												x			
p13.1							x		x																			x			
p13.20.11							x		x																			x			
p13.20.12							x		x																			x			
p13.20.13							x		x																			x			
p13.20.14							x		x																			x			
p13.20.15							x		x																			x			
p13.20.16							x		x																			x			
p14.1																												x			
p14.2																												x			
p14.3							x																					x			
p15.a															x					x	x					x					
p15.b															x					x	x					x					
p15.c																				x	x					x					
p15.d																				x						x					
p15.e																				x		x				x					
p15.f																				x						x					
p15.g																				x		x				x					
p15.h																				x		x				x					
p15.i																				x		x									
p15.j																				x						x					
p15.k																				x						x					
p16																								x							
p17															x																
p18															x																
p19															x																
p20														x															x		
p20.w																															
p21.1																										x					
p21.w.1																															
p21.2											x													x							
p22																															

EWC-Stat code	01.1	01.2	01.3	01.4	02	03.1	03.2	05	06	07.1	07.2	07.3	07.4	07.5	07.6	07.7	08	08.1	08.41	09	09.11	09.3	10.1	10.2	10.3	11	11.3	12.1 + 12.2 +12.3 + 12.5	12.4	12.6	13
CREEA Code																															
p23.1.a						X	X																						X		
p23.1.b						X	X																						X		
p23.1.c						X	X																						X		
p23.20.a						X	X																						X		
p23.20.b						X	X																						X		
p23.20.c						X	X																						X		
p23.20.d						X	X																						X		
p23.20.e						X	X																						X		
p23.20.f			X			X	X																						X		
p23.20.g			X			X	X																						X		
p23.20.h																													X		
p23.20.i																													X		
p23.20.j						X	X																								
p23.20.k																															
p23.20.l						X	X																						X		
p23.20.m						X	X																								
p23.20.n			X			X	X																								
p23.20.o						X	X																								
p23.20.p						X	X																								
p23.20.q						X	X																								
p23.20.r						X	X																						X		
p23.3																													X		
p24.a													X																		
p24.a.w																															
p24.b					X																										
p24.c					X																										
p24.d	X	X	X	X	X	X	X																								
p24.e						X	X																						X		
p24.f						X	X																								
p24.g						X	X																								
p24.h						X	X																						X		
p24.i						X	X																						X		
p25												X	X																		
p26.a										X																					
p26.w.1																															
p26.b																												X			
p26.c																												X			
p26.d								X																				X			
p26.d.w																															
p26.e																												X			
p27.a									X																						
p27.a.w																															
p27.41									X																						
p27.41.w																															
p27.42									X																						
p27.42.w																															
p27.43									X																						
p27.43.w																															
p27.44									X																						
p27.44.w																															
p27.45									X																						
p27.45.w																															
p27.5									X																						
p28									X																						
p29																	X														
p30																	X														
p31																	X														
p32																	X														
p33								X									X														
p34																		X													
p35																		X													
p36																								X							

EWC-Stat codes (columns in the correspondance table above):

01.1	Spent solvents
01.2	Acid, alkaline or saline wastes
01.3	Used oils Hazardous
01.4	Spent chemical catalysts
02	Chemical preparation wastes
03.1	Chemical deposits and residues
03.2	Industrial effluent sludges
05	Health care and biological wastes
06	Metallic wastes
07.1	Glass wastes
07.2	Paper and cardboard wastes
07.3	Rubber wastes
07.4	Plastic wastes
07.5	Wood wastes
07.6	Textile wastes
07.7	Waste containing PCB
08	Discarded equipment
08.1	Discarded vehicles
08.41	Batteries and accumulators wastes
09	Animal and vegetal wastes
09.11	Animal waste of food preparation and products
09.3	Animal faeces, urine and manure
10.1	Household and similar wastes
10.2	Mixed and undifferentiated materials
10.3	Sorting residues
11	Common sludges (excluding dredging spoils)
11.3	Dredging spoils
12.1 + 12.2 +12.3+12.5	Mineral wastes
12.4	Combustion wastes
12.6	Contaminated soils and polluted dredging spoils
13	Solidified, stabilised or vitrified wastes

Appendix 7: Correspondance between CREEA and SNA/SEEA definitions

CREEA definitions	**SNA/SEEA definitions**	***Notes:***
Emissions are output flows from a human activity that directly enters the environment.	**Residuals** is the single word used to cover solid waste, effluents (discharges to water) and emissions (discharges to air) (SNA 2008; para. 29.106.d). **Emissions** are releases of substances to the environment by establishments and households as a result of production, consumption and accumulation processes. Generally, emissions are analysed by type of receiving environment, i.e. emissions to air, emissions to water, emissions to soil, and by type of substance. (SEEA, 2012; para. 3.86) **Dissipative uses of products** covers products that are deliberately released to the environment as part of production processes (SEEA, 2012; para. 3.93). **Dissipative losses** are material residues that are an indirect result of production and consumption activity (SEEA, 2012; para. 3.94).	*There is not fully correspondence between CREEA and SNA/SEEA definitions. CREEA has a broder meaning of Emissions that includes all the flows from technosphere to the environment, i.e. Emissions, Dissipative uses of products and Dissipative losses*
Environment is the surroundings of the technosphere.	**Environment** is the totality of all the external conditions affecting the life, development and survival of an organism (UN Glossary*)	*The CREEA definition focuses on the productive system rather than organism.*
Industry activities are productive activities that aim at selling the resulting products to another activity	An **activity** is a process, i.e. the combination of actions that result in a certain set of products (UN, 1990; para. 29). An **institutional unit** is an economic entity that is capable, in its own right, of owning assets, incurring liabilities and engaging in economic activities and in transactions with other entities (SNA2008; para. 4.2). **Production** is an activity, carried out under the responsibility, control and management of an institutional unit, that uses inputs of labour, capital, and goods and	*The definition adopted in CREEA is a combination of the three definitions exposed.*

	services to produce outputs of goods and services. [..] (SNA2008; para. 6.2)	
Natural resources are materials from the environment to the technosphere	**Natural inputs** are all physical inputs from the environment that are moved from their location in the environment as a part of economic production processes or are directly incorporated into economic production processes. They may be (i) natural resource inputs, such as mineral and energy resources or timber resources, (ii) inputs from renewable energy sources, such as solar energy captured by economic units, or (iii) other natural inputs such as inputs from soil (e.g. soil nutrients) and inputs from air (e.g. oxygen absorbed in combustion processes) (SEEA draft, para. 2.88).	*The CREEA definition embodies resources included in the SEEA definition of natural resources and other natural inputs.*
Physical flow is a movement of material between different human activities or from/to the environment.	**Material flow accounts** measure the material "throughput" through the economy by providing information on the material input from the environment into the economy, the transformation and use of that input in economic processes (extraction, conversion, manufacturing, consumption) and its return to the natural environment as residuals (wastes) (UN glossary*).	Physical flow in the CREEA framework refers to what is accounted by material flow accounts.
Product is an output flow from a human activity with a positive either market or non-market value.	**Products** are goods and services (including knowledge capturing products) that result from a process of production. (SNA, 2008; para. 6.14). [..] In addition, solid waste may include some discarded materials exchanged between economic units, for example scrap metal, for which the discarder receives payment. In these circumstances, the solid waste is considered a product (since the solid waste has a positive value) rather than a residual *(SEEA draft, 2012; para. 3.83)*.	*CREEA and SNA definitions overlap for most of flows. Yet CREEA considers waste products as 'materials for treatment'.*
Principal product is a product for which the production volume changes in response to changes in demand.	The **principal activity** of a producer unit is the activity whose value added exceeds that of any other activity carried out within	*The CREEA definition follows a technical criteria while the SNA an economic one. For many activities*

	the same unit (SNA, 2008; para. 5.8).	*the two definitions are equivalent. Exception could be for multifunctional activity, e.g. for recycling activities; according to the CREEA approach, the service of recycling is assumed to be the principal activity while for SNA is the product carried out by processing secondary materials.*
By-product is a non-principal product that directly (i.e. without further processing) is used in place of other products.	**By-products** are products that are produced simultaneously with another product but which can be regarded as secondary to that product, for example gas produced by blast furnaces. **Joint products** are products that are produced simultaneously with another product that cannot be said to be secondary (for example beef and hides) (SNA, 2008; para. 28.46)	*CREEA definition includes both cases.*
Durable product is a product may be used repeatedly or continuously by consumers over a period of more than a year.	A **durable good** is one that may be used repeatedly or continuously over a period of more than a year, assuming a normal or average rate of physical usage. A consumer durable is a good that may be used for purposes of consumption repeatedly or continuously over a period of a year or more (SNA, 2008; para. 9.42).	*The two definitions are the same.*
Fixed assets are produced products (such as machinery, equipment, buildings or other structures) that are used repeatedly or continuously in production over several accounting periods (more than one year).	**Fixed assets** are produced assets that are used repeatedly or continuously in production processes for more than one year (SNA, 2008; para.10.11)	*The two definitions are the same.*
Intermediate products are products completely used up in the accounting period within productive activities.	**Intermediate consumption** consists of the value of the goods and services consumed as inputs by a process of production, excluding fixed assets whose consumption is recorded as consumption of fixed capital (SNA, 2013; para. 6.213).	*The two definitions are the same.*
Material for treatment is an output flow of a human activity that remains in the technosphere and cannot	**Solid waste** covers discarded materials that are no longer required by the owner or user. Solid waste includes materials that	*The two definitions overlap for some content. The CREEA definition is bound to technical approach and*

directly (i.e. without further processing or emissions) displace another product. After processing in a waste treatment (recycling) activity, the recovered residuals may displace other products.	are in a solid or liquid state but excludes wastewater and small particulate matter released into the atmosphere (SEEA draft, 2012; para. 3.82). **Wastewater** is discarded water that is no longer required by the owner or user. Water discharged into drains or sewers, water received by water treatment plants and water discharged direct to the environment is all considered wastewater. Wastewater includes return flows of water which are flows of water direct to the environment, with or without treatment. All water is included regardless of the quality of the water, including returns from hydro-electric power generators (SEEA draft, 2012; para. 3.84).	*considers flows to environment as emissions.*
Technosphere is the space where human activities take place.	No definition found.	
Waste treatment activity: human activity using materials for treatment. Waste treatment activities are service activities, i.e. their principal product is a service. Despite this principal product is a service, it is measured in mass unit as kg material for treatment. For landfill and waste incineration, this service is to take care of the treatment and disposal of materials for treatment. For recycling activities, the service is to process materials for treatment into by-products having a positive market value.	**Recycling** is defined as the re-introduction of residual materials into production processes so that they may be re-formulated into new products. For example, the re-introduction of old newsprint into a paper mill as an input into the production of new newsprint is considered recycling (SEEA, 2003; para. 3.51). Recycling is processing of waste and scrap and other articles, whether used or not, into secondary raw material. A transformation process is required, either mechanical or chemical. It is typical that, in terms of commodities, input consists of waste and scrap, the input being sorted or unsorted but normally unfit for further direct use in an industrial process, whereas the output is made fit for direct use in an industrial manufacturing process. The resulting secondary raw material is to be considered	*The CREEA definition of recycling (as part of waste treatment activity) includes industrial manufacturing processes such as re-processing of secondary material into new products. The SEEA definition of recycling stops at the point when a secondary material can be used in an industrial manufacturing process.*

	an intermediate good, with a value, but is not a final new product (ISIC rev.3.1, code 37).	

Appendix 8: Mathematical notation

Description	**Notation**	**Example**
Matrix containing m rows and n columns.	m × n matrix	In a matrix with dimensions “products” by “activities”, each row refer to a product and each column refer to an activity
Matrices	Bold text large case letters	Matrix **A**
Vectors	Bold text small case letters	Vector **g**
Entry of matrix **A**; row i and column j	$\mathbf{A}_{ij}$	$\mathbf{A}=\begin{bmatrix}1 & 3\\ 2 & 4\end{bmatrix}\rightarrow \mathbf{A}_{12}=3$
Row vector	Apostrophe [´]	$\mathbf{g}=\begin{bmatrix}x\\ y\end{bmatrix}\Rightarrow \mathbf{g}'=\begin{bmatrix}x & y\end{bmatrix}$
Diagonal of vector	Hat [^] or mdiag()	$\mathbf{g}=\begin{bmatrix}x\\ y\end{bmatrix}\Rightarrow \hat{\mathbf{g}}=\mathrm{mdiag}(\mathbf{g})=\begin{bmatrix}x & 0\\ 0 & y\end{bmatrix}$
Transpose of matrix	Apostrophe [´]	$\mathbf{A}=\begin{bmatrix}1 & 4\\ 2 & 5\\ 3 & 6\end{bmatrix}\Rightarrow \mathbf{A}'=\begin{bmatrix}1 & 2 & 3\\ 4 & 5 & 6\end{bmatrix}$
Identity matrix; a matrix with 1 for all diagonal entries and 0 for all other entries	**I**	$\mathbf{I}=\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}$
Vector with all entries equal to one	**i**	$\mathbf{i}=\begin{bmatrix}1\\ 1\\ 1\end{bmatrix}$
Inverted matrix or vector	Power -1 [$^{-1}$]	$\mathbf{A}^{-1}$
Off-diagonal entries of a square matrix	Tilde [˜]	$\mathbf{A}=\begin{bmatrix}k & l\\ m & n\end{bmatrix}\Rightarrow \tilde{\mathbf{A}}=\begin{bmatrix}0 & l\\ m & 0\end{bmatrix}$
Row by column multiplication of matrices	Dot [•]	$\mathbf{A}=\begin{bmatrix}a & c\\ b & d\end{bmatrix},\quad \mathbf{B}=\begin{bmatrix}e & g\\ f & h\end{bmatrix}$ $\mathbf{A}\cdot\mathbf{B}=\begin{bmatrix}ae+cf & ag+ch\\ be+df & bg+dh\end{bmatrix}$

Hadamard product of matrices Element-by-element multiplication of two matrices. The two input matrices as well as the output matrix all have the same dimension	Star [*]	$\mathbf{A}=\begin{bmatrix} a & c \\ b & d \end{bmatrix}$, $\mathbf{B}=\begin{bmatrix} e & g \\ f & h \end{bmatrix}$ $\mathbf{A} * \mathbf{B}=\begin{bmatrix} ae & cg \\ bf & dh \end{bmatrix}$
Element-by-element division of two matrices. The two input matrices as well as the output matrix all have the same dimension	slash star [/*]	$\mathbf{A}=\begin{bmatrix} a & c \\ b & d \end{bmatrix}$, $\mathbf{B}=\begin{bmatrix} e & g \\ f & h \end{bmatrix}$ $\mathbf{A} /* \mathbf{B}=\begin{bmatrix} a/e & c/g \\ b/f & d/h \end{bmatrix}$
Determinant of square matrix **A**	det(**A**)	$\mathbf{A}=\begin{bmatrix} k & l \\ m & n \end{bmatrix} \Rightarrow \det(\mathbf{A}) = kn - lm$