SIXTH FRAMEWORK PROGRAMME

PRIORITY [policy-oriented research priority SSP 5A]

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

FORWAST

Overall mapping of physical flows and stocks of resources to forecast waste quantities in Europe and identify life-cycle environmental stakes of waste prevention and recycling

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Documentation of the data consolidation and calibration exercise, and the scenario parameterisation.

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1 Introduction

The overall objective of the FORWAST project is to:

1. Provide an inventory of the historically cumulated physical stock of materials in EU-27 and to forecast the expected amounts of waste generated, per material category, in the next 25 years.
2. Provide an assessment of the life-cycle wide environmental impacts from different scenarios of waste prevention, recycling and waste treatment in the EU-27.

These inventory and assessment results are provided as an output of a Leontief-type environmentally extended, quasi-dynamic, physical input-output model covering the EU-27, including raw material extraction and processing of imported materials and waste treatment of exported wastes.

The fundamental concept behind the model is that of mass balances ("what comes in must go out"), implying that the resource input (R) minus emissions (B) and stock changes (ΔS) determines the potential waste amounts ($W=R-B-\Delta S$). To determine *where* and *when* the materials in the resource inputs come out as waste, it is also necessary to trace the materials in the resource inputs through the different activities of the economy, which is done in the input-output model, and to determine the lifetime of the material stocks.

The objective of the present Deliverable 6-1 is to document the data consolidation and calibration exercise, and the scenario parameterisation.

2 Data consolidation – country level

The data collection at the country level includes detailed data collection for some selected countries with good data availability (work package 3) and coverage data collection for other countries (work package 4). The difference between the two levels of detail is the level of aggregation. The detailed data collection include country supply and use tables (SUT) for 117 products by 117 activities, and the coverage data collection include SUTs for 59 products by 59 activities. Both types of data include the same emissions outputs and resource inputs. The data collection and processing are further described in deliverable 3-1 and 4-1 (http://forwast.brgm.fr/).

It should be noted that the total number of product and activity categories in the final model is 145. This number is higher than the above mentioned 117 because some additional 24 waste treatment activities and 4 household activities are added after the data collection. A full list of included products/activities is provided in the appendix.

2.1 Monetary supply-use tables

The starting point of the detailed data collection is the Eurostat 60x60 supply-use tables. For some countries more detailed supply-use tables are available. Firstly, the supply-use tables converted to basic prices. This is done using a standardized basic price converter tool developed as part of the project; the procedure is described in deliverable 6-4 'Documentation of the final model used for the scenario analyses'.

For the countries where detailed data are collected, the 60x60 tables are disaggregated into 117x117 tables. For this purpose, an Excel based macro tool is used. The tool is developed as part of the project; the procedure is described in deliverable 6-4 'Documentation of the final model used for the scenario analyses'. The basic inputs are monetary supply and use tables in basic prices, a specification of which activities/products to be disaggregated, and a specification of the total supply of the 117 products. By use of this, a dummy/default disaggregated supply-use table can be obtained. Using this default disaggregation, the production function of all disaggregated activities are the same. Then, manual changes are made on the supply table and on the use table to reflect differences in the production function. The disaggregation tool ensures that product and activity balances are maintained throughout the exercise.

The balanced monetary supply-use table is illustrated below.

Balanced MSUT	Activities (a)	Import	Needs fulfilment	Export	Total
Products (c)	**V'**	N_c			**q**
Total	**g'**				
Products (c)	**U**		**y**	E_c	**q**
Primary inputs	Labour				
	Taxes				
	Profit				
Total	**g'**				

Figure 2.1: Balanced monetary supply and use tables (MSUTs). **V'** (supply table), **U** (use table).

2.2 Physical supply-use tables

2.2.1 Supply-use

Data on physical product flow are collected for the 59 (low detail level countries in WP4) and 117 (high detail level countries in WP3) products, i.e. domestic production, import and export. For this purpose several data sources are used, e.g. resource statistics, agricultural statistics, energy statistics, production statistics, trade statistics etc. Service products, such as retail, marketing, education, consulting etc. have no physical weight. All flows are given in dry weight. Typically, data in statistics are provided in actual/wet weight. This is converted to dry weight using product material composition given in the $\mathbf{K_c}$ tables (available from http://forwast.brgm.fr/)

Default physical supply-use tables are constructed using the monetary tables for distributing the physical flows (total domestic supply/use and import/export) of products. Then more detailed information from statistics, e.g. data on agriculture, energy etc. are used to redistribute the default tables. Once this exercise is finished, we have supply-use tables in monetary as well as physical units.

By nature, the supply and use of products balance. But a physical balance for activities is not yet established; inputs of resources and waste and outputs of emissions and waste are not accounted for.

2.2.2 Resource table

A resource table is created specifying the resource inputs to the resource extracting activities. Distinction is made between 13 material categories:

1. Al (Aluminium)

2. BI (Fibre carbon)
3. BO (Food carbon, including tobacco)
4. CC (Coal carbon)
5. CH (Crude oil and natural gas carbon)
6. CO (Carbonate carbon)
7. Cu (Copper)
8. Fe (Iron)
9. ME (Metals, n.e.c.)
10. MI (Minerals and other balancing element, n.e.c., including nitrogen and hydrogen)
11. O (Oxygen in oxidised products)
12. SO (Clay and soil)
13. ST (Sand, gravel and stone)

The resource table is typically constructed based on the supply table and a resource composition obtained as composition data in $\mathbf{K_c}$ for resource extracting activities (resource table and composition data are available from http://forwast.brgm.fr/).

2.2.3 Emissions tables

Two types of emission tables are created:

1) traditional format as environmental extension to IO-tables (emissions x activities); this table is called **B**
2) products x activities format specifying the origin of the emissions from an activity; this table consists of three sub tables called $\mathbf{G_c}$, $\mathbf{G_w}$, and $\mathbf{G_R}$, where the subscript specify the origin of the emission: c (products), w (waste), and R (resource input).

The second emissions table is used for the calculation of specific waste outputs from activities, e.g. input of 1 kg feed to the 'bovine meat and milk' activity leads to approx 0.08 kg product output and 0.71 kg emission. Now, the waste originating from feed (this is manure) can be calculated as 1 – 0.08 – 0.71 = 0.21 kg manure.

If no detailed NAMEA is available, the two emissions tables above are created from UNFCCC country submissions (UNFCCC 2009). For this purpose an 'emissions machine' (Excel based tool) have been developed as part of the project. The physical use table is used for distribution of emissions, when data are not at the desired level of detail in the UNFCCC data.

Conventions regarding included emissions in **B** and **G** are described in deliverable 6-4 'Documentation of the final model used for the scenario analyses'. An important convention for the **G** table is, that the use of 1 kg fuel (in the use table) must correspond to the emission of 1 kg fuel (in the **G** table). Thus, in order to enable the mass balance principle for fuels and associated emissions, the emission of hydrogen in H_2O is also included. This is determined based on the hydrogen content in fuels (chemical formula).

Another example of conventions is; In **B** CO_2 is included with full weight, but in **G** only the weight of the carbon in CO_2 is included. This is because simultaneous resource inputs and emissions outputs of oxygen in combustion processes is not included.

2.2.4 Waste and stock addition tables

The remaining inputs and outputs to establish balanced activities are the outputs of waste + stock additions and the inputs of waste. It is only the waste treatment and recycling activities that have inputs of waste. The waste generation (W_v) + stock addition (ΔS) tables have the same format as the supply and use table, and *each flow* is calculated based on a mass balance:

$$W_v + \Delta S = U - D^*U - G$$

The use (**U**) is obtained from the use table, the emission (G) is obtained from the second emissions table **G** (described above), and D is a feedstock efficiency transfer coefficient, which specifies how much of the current input of a product (use) is becoming part of the supply. The D coefficients are calculated in order to maintain balance: the feedstock products in the use table are specified in the $\mathbf{D_1}$ table, and then the sum of these are divided by the supply of the activity. It is possible to specify different D coefficients for different feedstock inputs to an activity (The applied $\mathbf{D_1}$ table and implied **D** tables are available from http://forwast.brgm.fr/).

In the FORWAST model, distinction is made between waste and stock additions. Time series of supply-use tables enables this. Any stock will leave the economy as waste at a given time when the product reaches the end of its life time. Thus, by use of product life times, the $\mathbf{W_V}+\mathbf{\Delta S}$ can be separated into $\mathbf{W_V}$ and $\mathbf{\Delta S}$.

The balanced physical supply-use table is illustrated below. It should be noted that waste treatment/recycling activities are not balanced here because special detailed waste modules have been constructed, see chapter 4.3.

Balanced PSUT	Activities (a)	Import		Needs fulfilment	Export		Total
Products (c)	**V'**	$\mathbf{N_c}$	$\mathbf{N_w}$				**q**
Total	**g'**						
Products (c)	**U**			**y**	$\mathbf{E_c}$	$\mathbf{E_w}$	**q**
Stock changes	**-ΔS**						
Supply of residuals	$\mathbf{-W_V}$						
Use of residuals	$\mathbf{W_U}$						
Resources	**R**						
Emissions	**-B**						
Total	**g'**						

Figure 2.2: Balanced physical supply and use tables (PSUTs). In the table the meaning of 'residuals' is the same as waste.

2.3 Data consolidation exercise

Before the country SUTs can be used as model inputs, data consistency is checked via a consolidation exercise.

2.3.1 Balance check: Total supply and use

Firstly, the **g** and **q** vectors in **Figure 1** and q in **Figure 2** are checked for balance; it is required that the tables must balance with a maximum discrepancy of 0.5% between total supply and total use.

2.3.2 Balance check: Two emissions tables

The sum of the emissions in the two types of emissions tables described above; **B** and **G**, are compared. These totals must be the same.

2.3.3 Consistency check: Negative waste is not allowed

When constructing the physical SUTs, the data processing includes assumption of same prices of products over many activities (if no specific information is available). It is clear that ‘chemicals nec’ used by agriculture (this mainly covers pesticides) is not the same as ‘chemicals nec’ used by the food industry (this mainly covers food additives and cleaning agents) is not the same. Therefore, the assumption of same prices over activities does not hold in all cases. The effect of this is that the use of products is overestimated for some activities and underestimated for other activities. When these over/under-estimated uses are feedstocks to the supply of the activity, then in cases with underestimation of feedstocks, there will be less feedstock than supply. Since waste outputs are calculated, this leads to negative waste output. This is of course not possible in real world, and the causes of the negative waste have to be identified and corrected. The following three parameters are typically adjusted when negative waste occurs:

- the use of feedstock products is increased so that the sum of all feedstoks exceeds supply, and so that an appropriate feedstock efficiency is achieved. When a specific use is increased, the other uses of the same product by other activities are reduced accordingly in order to maintain balance between total supply and use of products
- the resource input is increased (this option is only used for resource extracting activities)
- the emissions of the specific product, that leads to negative waste, are adjusted; e.g. if the plastics industry supplies 10 kg plastic, it uses 15 kg oil and gas, and it emits 6 kg emissions originating from oil and gas; here waste = 15 – 10 – 6 = -1

The selection of an appropriate option above is based on common knowledge of the processing within the activities.

3 Data consolidation – EU-27 level

Each of the country SUT provided as data collection input to the table must fulfil some consistency and mass balance requirements. However, there are still a number balancing issues to be addressed and solved as well as some new imbalances caused by the data aggregation from country level to EU-27 level to be solved. This exercise is described in the following.

3.1 Data input to the model from data collection year 2003

The data collection includes detailed data collection for some countries with good data availability and coverage data collection for other countries. The difference between the two levels of detail is the level of aggregation. The detailed data collection include country supply and use tables (SUT) for 117 products by 117 activities, and the coverage data collection include SUTs for 59 products by 59 activities.

3.2 Aggregation of the two types of SUTs to one EU-27 117x117 SUT

Firstly, the SUTs belonging to each type of aggregation (117x117 or 59x59) are added to achieve one accumulated 117x117 table and one accumulated 59x59 table. The structure of 117x117 table is then used to disaggregate the 57x57 table. After that the two tables are added to form one 117x117 table representing EU-27’s economy.

3.3 Product balance

When using the accumulated 117x117 table to disaggregating the accumulated 59x59 table, differences in import/export shares may cause that all the disaggregated supplies does not balance with the disaggregated uses. Therefore, imbalances for the product balance occur within the disaggregated product categories. These imbalances are adjusted via import/export.

3.4 Resource alignment

In order to ensure consistency, the resource input minus emissions and waste from resources must be equal to the supply for resource extracting activities. Some example of resource activities where resources are lost as emissions and/or waste are 1) Crude petroleum and natural gas where some of the extracted resource is flared, and 2) Bovine meat and milk where some of the resource input (grass and ensilage) is lost as respiratory emissions and manure.

3.5 Elimination of investment column in use table

The column 'Capital formation' in the use table (this is not shown in Figure 2.1) describes the use of products that are capitalised because they have a life time of more than one year, i.e. they are used in production for more than one period. Since these capitalised products are part of the production function of the activities, they should be incorporated in the use table, in the same way as use of other products. The procedure for distributing the investment column into the use table is described in deliverable D6-4 'Documentation of the final model used for the scenario analyses'.

3.6 Human metabolism balance

In order to ensure consistency in all inputs and outputs relating to human and animal metabolism, the EU-27 supply use table is aligned using the mass balances given below. The flows which are corrected as part of the alignment exercise, are also specified below.

The human metabolism is included in the model in order to ensure that materials contained in food is coming out of the model as the correct flows: emissions, urine and faeces in waste water and food waste. The balance is based on Ortiz et al. (2007). Below, the balance is shown for one average person for one year. To have the total metabolism for the Swedish population in 2003, the figures in the table are multiplied with 10,355,844 persons.

Human metabolism (per person year)	DM (kg)
Inputs	
Food	202.2
Body growth	0.55
Total	**202.7**
Outputs	
Urine (CH_4ON_2)	27.4
Faeces (C_2H_4O)	13.7
Respiration: C in CO_2	71.2
Respiration: CH_4	0.083
Respiration: H_2O	89.9
Total	**202.2**
Balance (input - output)	**0.5**

Table 3.1: Carbon and dry mass balance for human metabolism for one person in one year.

When aligning the supply-use tables with the human metabolism given in Table 3.1, the sum of the respiratory emissions are first calculated using the mass balance in the table, and then next distributed in the $\mathbf{G_c}$ emissions table using the food products in the use table (dry weight) as distribution key. However, some activities use food as a feedstock and not for direct human consumption; these are:

- Bovine meat and milk
- Pigs
- Poultry and animals n.e.c.
- Fish
- Meat and fish products
- Dairy products
- Fruits and vegetables, processed
- Vegetable and animal oils and fats
- Flour
- Sugar
- Animal feeds
- Food preparations n.e.c.
- Beverages

The use of food in these activities are not related to the human metabolism.

3.7 Animal metabolism balance

Correspondingly to the human metabolism, it is ensured that materials contained in animal feed is coming out of the model as the correct flows: animal products at farm gate, emissions, and manure. Also, the balance is used to align the uses of feed inputs when knowing the output of animal products. In the tables below, the animal balances are shown normalised by the dry weight of animal products at farm gate (live weight + milk + egg + fur). The balance is based on physical information in the detailed Danish supply-use tables and figures in the National Environmental Research Institute's (NERI) reporting to the UNFCCC (Illerup et al. 2005). Swedish data are used for representing the number of animals and meat and milk outputs in EU-27 (Jordbruksverket 2007).

Bovine metabolism (per kg dry product output: milk and meat live weight)	DM (kg)
Inputs	
Grass+silage+Cereals/conc.	12.3
Total	**12.3**
Outputs	
Milk+ Meat live weight	1.00
Manure	2.61
Respiration: C in CO_2	3.74
Respiration: CH_4	0.25
Respiration: O in H_2O	4.21
Respiration: H in H_2O	0.53
Total	**12.3**
Balance (input - output)	**-0.01**

Table 3.2: Carbon and dry mass balance for bovine metabolism. The balance is given per 1 kg dry meat (live weight) and milk.

Pig metabolism (per kg dry product output: meat live weight)	DM (kg)
Inputs	
Silage+Cereals/conc.	3.42
Total	**3.42**
Outputs	
Milk+ Meat live weight	1.00
Manure	1.26
Respiration: C in CO_2	0.58
Respiration: CH_4	0.015
Respiration: O in H_2O	0.50
Respiration: H in H_2O	0.063
Total	**3.42**

Table 3.3: Carbon and dry mass balance for pig metabolism. The balance is given per 1 kg dry meat live weight.

Other animals metabolism (per kg dry product output: live weight)	DM (kg)
Inputs	
Grass+silage+Cereals/conc.	6.71
Total	**6.71**
Outputs	
Meat live weight+eggs+furs+milk	1.00
Manure	1.55
Respiration: C in CO_2	1.81
Respiration: CH_4	0.033
Respiration: O in H_2O	2.06
Respiration: H in H_2O	0.258
Total	**6.71**

Table 3.4: Carbon and dry mass balance for 'other animals' metabolism. The balance is given per 1 kg dry meat live weight. 'Other animals' mainly include poultry. The category also include fur animals, horses, goats etc.

When aligning the animal producing activities in the supply-use tables with the animal metabolism given in Table 3.2 - Table 3.4, the determining flow is the supply of animal products. Then the use of feed and respiratory emissions follow the ratio given in the tables.

To align/correct the use of feed in the animal producing activities, the uses of the following product categories + resource input (grass and silage) are scaled proportionally to balance with the feed input in the tables above:

- Resource table (**R**):
  - Resource input (grass and silage)
- Use table (**U**):
  - Grain crops
  - Crops nec.
  - Fish
  - Meat and fish products
  - Dairy products
  - Fruits and vegetables, processed
  - Vegetable and animal oils and fats
  - Flour
  - Sugar
  - Animal feeds
  - Food preparations n.e.c.
  - Beverages

To align/correct the respiratory emissions in the animal producing activities, the following emissions are corrected to balance with the emissions in the tables above. In the **B** table C in CO_2 is entered with a factor

44/12 to account for the oxygen in CO_2. In the $\mathbf{G_c}$ and $\mathbf{G_R}$ tables it is the sum of C in CO_2, CH_4, O in H_2O, and H in H_2O that is distributed using the use of feed+resource (dry mass) listed above as distribution key

- Emissions table (**B**):
  - Carbon dioxide, food carbon
  - Methane
  - Oxygen (O in H_2O)
  - Minerals, n.e.c. (H in H_2O)
- Emission distribution table ($\mathbf{G_c}$):
  - Grain crops
  - Crops nec.
  - Fish
  - Meat and fish products
  - Dairy products
  - Fruits and vegetables, processed
  - Vegetable and animal oils and fats
  - Flour
  - Sugar
  - Animal feeds
  - Food preparations n.e.c.
  - Beverages
- Emission distribution table ($\mathbf{G_R}$):
  - Bovine meat and milk (this represents grass and silage)

3.8 Fuel emissions balance

In the country level data collection, it is not ensured that the use of fuels (use table **U**) is aligned with the emissions tables (**B** and $\mathbf{G_c}$). Therefore, consistency between the use table and emissions tables is not ensured, i.e. it is not ensured that use of fuel = emission of fuel (+possible minor slag/ash/oil waste waste).

Since the emissions data used in the country level SUTs generally are based on official emissions data (UNFCCC submissions), these data are regarded as being of higher quality than the collected data on the physical use of fuels. Therefore, the uses of fuels in the use table (**U**) are aligned/corrected so that they follow the figures in the **G** and **B** tables.

For coal and biomass, the corrected use of fuel for each activities is calculated as follows:

If the supply of waste of the fuel is negative
then
    If the use of fuel is a feedstock
    then
        $U_{corrected} = G_c/(1\text{-}D)$ = emissions / (1 – feedstock efficiency)
        (the corrected use of fuel is calculated using the relationship $W_v + \Delta S = U - D*U - G$)
    else
        $U_{corrected} = -W_v + G_c$ = -waste generation + emissions
        (here the negative waste is added in order to ensure that the new waste generation is >0)
else
    $U_{corrected} = U_{old}$

The waste of coal has been cross checked with the EU-27 average content of ash in coal at 11% (based on survey by GIG).

For oil fuels, the corrected use has been calculated assuming an average waste generation at 1% of the use (oil waste), and for gas, 0% of the used gas is assumed to become waste.

3.9 Household uses

The final demand vector in the use table is integrated in ten household activities:

- Household use: Clothing
- Household use: Communication
- Household use: Education
- Household use: Health care
- Household use: Housing
- Household use: Hygiene
- Household use: Leisure
- Household use: Meals
- Household use: Security
- Household use: Social care

The distribution of the final demand vector into the household uses is based on Weidema et al. (2005) and the detailed Danish SUT (described in the chapter on Denmark in deliverable D3.1 'Report describing data processing and validation'). The distribution is specified in the tables below.

Product		Household activity									
		Clothing	Commu-nication	Education	Health care	Housing	Hygiene	Leisure	Meals	Security	Social care
1	Bovine meat and milk	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
2	Pigs	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
3	Poultry and animals n.e.c.	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
4	Grain crops	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
5	Crops n.e.c.	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
6	Agricultural services n.e.c.	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
7	Forest products	0%	0%	0%	0%	72%	25%	0%	3%	0%	0%
8	Recycling of waste wood	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9	Fish	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
10	Coal, lignite, peat	0%	0%	0%	0%	72%	25%	0%	3%	0%	0%
11	Crude petroleum and natural gas	0%	0%	0%	0%	72%	25%	0%	3%	0%	0%
12	Iron ores from mine	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
13	Bauxite from mine	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
14	Copper from mine	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
15	Metals from mine n.e.c.	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
16	Sand, gravel and stone from quarry	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
17	Clay and soil from quarry	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
18	Minerals from mine n.e.c.	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
19	Meat and fish products	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
20	Dairy products	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
21	Fruits and vegetables, processed	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
22	Vegetable and animal oils and fats	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
23	Flour	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
24	Sugar	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
25	Animal feeds	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
26	Food preparations n.e.c.	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
27	Beverages	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
28	Tobacco products	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
29	Textiles	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
30	Wearing apparel and furs	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
31	Leather products, footwear	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
32	Wood products, except furniture	0%	0%	0%	0%	72%	25%	0%	3%	0%	0%
33	Pulp, virgin	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
34	Recycling of waste paper	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
35	Paper and paper products	0%	0%	0%	0%	22%	9%	62%	7%	0%	0%
36	Printed matter and recorded media	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
37	Refined petroleum products and fuels	0%	21%	0%	0%	11%	4%	50%	14%	0%	0%
38	Recycling of waste oil	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
39	Fertiliser, N	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
40	Fertiliser, other than N	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
41	Plastics basic, virgin	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
42	Recycling of plastics basic	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
43	Chemicals n.e.c.	6%	7%	0%	12%	24%	4%	23%	23%	0%	0%
44	Rubber and plastic products	0%	12%	0%	0%	67%	17%	4%	0%	0%	0%
45	Glass, mineral wool and ceramic goods, virgin	0%	0%	0%	0%	52%	0%	0%	48%	0%	0%
46	Recycling of glass, mineral wool and ceramic goods	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
47	Cement, virgin	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
48	Recycling of slags and ashes	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
49	Concrete, asphalt and other mineral products	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
50	Recycling of concrete, asphalt and other mineral products	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
51	Bricks	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
52	Recycling of bricks	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
53	Iron basic, virgin	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
54	Recycling of iron basic	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
55	Aluminium basic, virgin	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
56	Recycling of aluminium basic	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
57	Copper basic, virgin	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
58	Recycling of copper basic	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 3.5: Distribution of final demand vector in use table into ten household activities. The table is continued on the next page...

Product		Household activity									
		Clothing	Commu-nication	Education	Health care	Housing	Hygiene	Leisure	Meals	Security	Social care
59	Metals basic, n.e.c., virgin	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
60	Recycling of metals basic, n.e.c.	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
61	Iron, after first processing	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
62	Aluminium, after first processing	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
63	Copper, after first processing	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
64	Metals n.e.c., after first processing	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
65	Fabricated metal products, except machinery	0%	0%	0%	0%	36%	3%	48%	12%	0%	0%
66	Machinery and equipment n.e.c.	20%	0%	0%	0%	8%	5%	5%	61%	0%	0%
67	Office machinery and computers	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
68	Electrical machinery n.e.c.	0%	4%	0%	0%	91%	0%	6%	0%	0%	0%
69	Radio, television and communication equipment	0%	19%	0%	0%	0%	0%	81%	0%	0%	0%
70	Instruments, medical, precision, optical, clocks	0%	0%	0%	59%	0%	0%	41%	0%	0%	0%
71	Motor vehicles and trailers	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
72	Transport equipment n.e.c.	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
73	Furniture; other manufactured goods n.e.c.	0%	0%	0%	0%	62%	0%	38%	0%	0%	0%
74	Recycling services	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
75	Electricity, steam and hot water	12%	0%	0%	0%	32%	8%	14%	34%	0%	0%
76	Gas	0%	0%	0%	0%	72%	25%	0%	3%	0%	0%
77	Water, fresh	16%	0%	0%	0%	0%	69%	0%	16%	0%	0%
78	Buildings, residential	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
79	Buildings, non-residential	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
80	Infrastructure, excluding buildings	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
81	Trade and repair of motor vehicles; service stations	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
82	Wholesale trade	4%	5%	8%	9%	17%	3%	16%	16%	9%	12%
83	Retail trade and repair services	4%	5%	8%	9%	17%	3%	16%	16%	9%	12%
84	Hotels and restaurants	0%	0%	0%	0%	0%	0%	10%	90%	0%	0%
85	Land transport; transport via pipelines	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
86	Transport by ship	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
87	Air transport	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
88	Cargo handling, harbours; travel agencies	0%	17%	0%	0%	0%	0%	83%	0%	0%	0%
89	Post and telecommunication	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
90	Financial intermediation	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
91	Insurance and pension funding	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
92	Services auxiliary to financial intermediation	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
93	Real estate services	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
94	Renting of machinery and equipment etc.	0%	17%	0%	0%	52%	0%	31%	0%	0%	0%
95	Computer and related services	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
96	Research and development	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
97	Business services n.e.c.	0%	0%	0%	0%	41%	0%	33%	0%	2%	24%
98	Public service and security	0%	0%	0%	0%	0%	0%	0%	0%	99%	1%
99	Education services	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
100	Health and social work	0%	0%	0%	42%	0%	0%	0%	0%	0%	58%
109	Membership organisations	0%	0%	0%	0%	1%	0%	30%	0%	50%	20%
110	Recreational and cultural services	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
111	Services n.e.c.	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%

Table 3.6: ... Table on previous page continued. Distribution of final demand vector in use table into ten household activities.

4 Hybrid IO-table incl. waste flows for EU-27

4.1 Hybrid supply use table (HSUT)

The first step in constructing a hybrid IO-table, is to construct a hybrid supply-use table. This is done by using the rows from the physical supply and use table for all physical products, and the rows from the monetary supply and use table for all service products. The rows representing waste treatment services, are left empty in the hybrid supply-use table; these are filled in the hybrid IO-table.

4.2 Hybrid input-output table (HIOT)

The HIOT is created from the HSUT using the by-product technology model which is equivalent to the commodity technology model (Suh et al. 2010). The direct requirement coefficient matrix **A** and environmental intervention coefficient matrix **E** using the by-product-technology model are determined as follows:

$$\mathbf{A} = (\mathbf{U} - \mathbf{V}'_{\mathbf{od}})\mathbf{V}'^{-1}_{\mathbf{d}}$$

$$\mathbf{E} = \mathbf{B}\mathbf{V}'^{-1}_{\mathbf{d}}$$

respectively, where the supply table **V** is split into $\mathbf{V_d}$ (diagonal entries in **V**) and $\mathbf{V_{od}}$ (off-diagonal entries in **V**). Other matrices are: **U** (hybrid use table) and **B** (all extensions: monetary primary inputs, emissions, supply of waste, stock additions, and resources)

The calculated **A** and **E** are normalised, i.e. all columns are per one unit of supply. To have **A** and **E** in a non-normalised version, the columns in **A** and **E** are scaled with the scaling factors in **s**:

$$\mathbf{s} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$$

where **I** (identity matrix) and **y** (needs fulfilment vector).

4.3 Integration of waste module

The only waste treatment activities included in the supply-use tables are recycling activities. These are included there because activities producing basic materials are disaggregated into a) activity that supplies virgin material, and b) activity that supplies the service to treat waste and recovered material. Supply and use data on all other waste treatment activities are obtained as normalised data per kg treated waste. The waste module is obtained from deliverable D5-4 ‘Description of the environmental pressures from waste treatment’. The normalised waste treatment activities in D5-4 are balanced ensuring that inputs of waste and products equals outputs of products (recycled waste), emissions, waste, and stock additions (stocks of products and stocks of waste in landfills).

4.4 Integration of waste flows in the hybrid IO-model

Based on the physical supply and use tables the supply of waste (one type of waste per physical product) is calculated for each activity. The waste types in this supply of waste table ($\mathbf{W_V}$), i.e. the rows in the $\mathbf{W_V}$, is aggregated into the following waste fractions:

- Food waste
- Wood waste
- Ash and slag waste
- Oil waste
- Textile waste
- Paper waste
- Plastic waste
- Hazardous waste
- Glass waste
- Bricks waste
- Other inert waste (sand, stone, clay, cement, concrete, asphalt)
- Iron waste
- Aluminium waste
- Copper waste
- Metals nec waste

Waste of the following products are composed of more than one of the above mentioned waste fractions:

- Fabricated metal products, except machinery waste
- Machinery and equipment n.e.c. waste
- Office machinery and computers waste
- Electrical machinery n.e.c. waste
- Radio, television and communication equipment waste
- Instruments, medical, precision, optical, clocks waste
- Furniture; other manufactured goods n.e.c. waste

Waste of these composite products undergo a disassembly process which allows to allocate the wastes to the waste fractions above. The residuals distribution table (**J**) specify the fraction of the composite products sent to recycling, incineration, landfill etc. The **J** table for year 2003 for EU-27 is presented in Table 4.1 below. In the J table below, the fraction of wastes of composite products sent to recycling is specified in the 'disassembly' column. Wastes exported for recycling abroad are specified in the 'export' column (export of slag and ash is landfilled abroad).

Waste fraction \ Activity no. / Activity name	8 Recycling of waste wood	34 Recycling of waste paper	38 Recycling of waste oil	42 Recycling of plastics basic	46 Recycling of glass, mineral wool and ceramic goods	48 Recycling of slags and ashes	50 Recycling of concrete, asphalt and other mineral products	52 Recycling of bricks	54 Recycling of iron basic	56 Recycling of aluminium basic	58 Recycling of copper basic	60 Recycling of metals basic, n.e.c.	101 Incineration of waste	103 Biogasification of waste	104 Composting of food waste	105 Waste water treatment	106 Landfill of waste	Export	Disassembly	**Sum**
Food/organic waste													43%	0.1%	8%	2%	47%			**100%**
Wood waste	24%												34%		0.1%		36%	6%		**100%**
Ash and slag waste						9%											89%	1%		**100%**
Inert waste (sand, stone, clay, cement, concrete, asphalt)							38%						10%				51%			**99%**
Oil waste			4%										37%				60%			**100%**
Textile waste													55%				44%	1%		**100%**
Paper waste		30%											15%		1%		42%	13%		**100%**
Plastic waste				19%									39%				39%	4%		**100%**
Hazardous waste													38%				62%	0.04%		**100%**
Glass waste					38%								21%				27%	14%		**100%**
Bricks waste							28%	4%					7%				61%			**100%**
Iron waste									46%				15%				19%	20%		**100%**
Alu waste										41%			22%				20%	17%		**100%**
Copper waste											40%		23%				20%	17%		**100%**
Metals nec waste												41%	22%				20%	17%		**100%**
Fabricated metal products, except machinery													25%				24%	18%	34%	**100%**
Machinery and equipment n.e.c.													23%				28%	20%	29%	**100%**
Office machinery and computers													25%				31%	20%	24%	**100%**
Electrical machinery n.e.c.													25%				30%	20%	25%	**100%**
Radio, television and communication equipment													25%				30%	20%	25%	**100%**
Instruments, medical, precision, optical, clocks													27%				33%	20%	20%	**100%**
Furniture; other manufactured goods n.e.c.													52%				37%		11%	**100%**

Table 4.1: The **J** table for year 2003 for EU-27.

The final waste treatment of each of the fractions contained in the composite products that are sent to recycling is specified in Table 4.2 below. The figures are estimated.

Fraction contained in composite waste	Composite waste / Waste treatment	Recycling of: Fabricated metal products, except machinery waste	Recycling of: Machinery and equipment n.e.c. waste	Recycling of: Office machinery and computers waste	Recycling of: Electrical machinery n.e.c. waste	Recycling of: Radio, television and communication equipment waste	Recycling of: Instruments, medical, precision, optical, clocks waste	Recycling of: Furniture; other manufactured goods n.e.c. waste
Iron	Recycling	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	Incineration	0	0	0	0	0	0	0
	Landfill	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Alu	Recycling	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	Incineration	0	0	0	0	0	0	0
	Landfill	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Copper	Recycling	0.5	0.5	0.9	0.9	0.9	0.9	0.9
	Incineration	0	0	0	0	0	0	0
	Landfill	0.5	0.5	0.1	0.1	0.1	0.1	0.1
Metals nec	Recycling	0	0	0.9	0.9	0.9	0.9	0.9
	Incineration	0	0	0	0	0	0	0
	Landfill	1	1	0.1	0.1	0.1	0.1	0.1
Plastic	Recycling	0	0	0.5	0.5	0.5	0.5	0.5
	Incineration	0	0	0	0	0	0	0
	Landfill	1	1	0.5	0.5	0.5	0.5	0.5
Wood	Incineration	0	0	1	1	1	1	1
	Landfill	1	1	0	0	0	0	0
Food/organic	Incineration	0	0	0	0	0	0	0
	Landfill	1	1	1	1	1	1	1
Inert	Landfill	1	1	1	1	1	1	1

Table 4.2: Specification of the final waste treatment of each of the fractions contained in the composite products that are sent to recycling.

The supply of each of the waste fractions per activity is distributed into the rows representing different waste treatment services in the hybrid IO-table. This distribution is determined by the **J** table.

Some waste treatments are fixed in all scenarios, and are specified separate from the **J** table. These are:

- Food waste sent to waste water treatment: This is excretion and faeces and it is determined by the human metabolism balance, see section 3.6
- Animal waste to manure treatment: This is determined by the animal metabolism balances, see section 3.7
- Paper waste to waste water treatment in pulp/paper manufacturing: All waste of pulp in pulp/paper manufacturing is sent to waste water treatment
- Paper waste to waste water treatment: All paper waste in household activity: Hygiene is sent to waste water treatment

- Wood waste to landfill: All wood waste originating from forestry products in the activity ‘pulp, virgin’ is assumed to be pulp manufacturing residuals sent to landfill
- Mine waste: All residuals originating from metals mining products is assumed to be landfilled
- Recycling residues: All recycling residues, e.g. waste originating from waste paper in activity ‘recycling of waste paper’ is assumed to be sent to landfill. This includes: Residues from wood recycling, paper recycling, recycling of waste oil, recycling of plastic, recycling of slag and ash (in cement production), and recycling of inert materials and metals

5 Scenario parameterisation

Two types of scenarios are implemented in the EU-27 hybrid IO-table:

1) macro-economic scenarios, and
2) what-if-scenarios of waste treatment

5.1 Parameterisation of macro-economic scenarios

Three different future macro-economic scenarios are implemented in the model:

1) Low growth scenario
2) Baseline scenario
3) High growth scenario

The differentiation between scenarios is based on Mantzos and Capros (2006). Due to lack of information, the developments of energy efficiency are assumed to be similar in the three macro economic scenarios. A general description of the three macro-economic scenarios can be found in deliverable 5.2 ‘Description of the three chosen macro-economic scenarios for EU-27 until 2035’.

5.1.1 Scaling of the economy representing different scenarios

The macro-economic scenarios are implemented in the hybrid supply-use tables. First, developments in GDP and TMR are established (index 100 = year 2003). Historical figures on GDP are obtained from Eurostat (2009), and future figures are from Mantzos and Capros (2006). The latter provides differentiated information for a range of different activities/sectors. Historical TMR data are represented by EU-27 direct resource extraction of:

- Energy resources: IEA (2004) and IEA (2008)
- Agricultural products and fish: FAOSTAT (2009a)
- Forest products: FAOSTAT (2009b)
- Metals and mineral mining: USGS (2009)
- Aggregates: Koziol et al. (2008)

Projections of future TMR developments are based on the historical relationship between GDP and TMR, see **Figure 5.1**. Differentiation between activities is not taken into account for historical developments, i.e. for years before 2003. Differentiation between activities for projection of future TMR is based on future differentiated projections on future GDP.

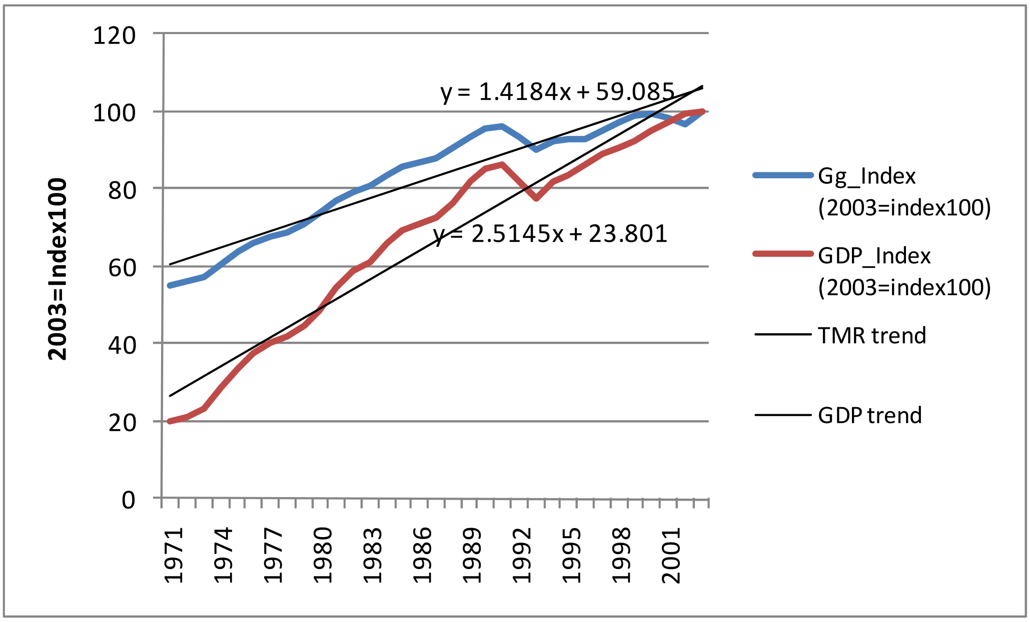

Figure 5.1: Relationship between development in GDP and TMR from 1971 to 2003. Index 100 = Year 2003.

The developments in GDP and TMR are used to scale the columns in the supply-use tables. In addition all exports of products are multiplied with the same scaling factor as for the corresponding activity. This scaling of activities and export represents the developments in the economy at the activity/sector level. Discrepancies in total supply of products and total use of products are adjusted in prioritised order 1) import 2) if adjustment causes negative import, then import is set to zero, and the remaining correction is added to export.

5.1.2 Correcting for developments in energy efficiency in the electricity activity

The scaling of activities described above does not take into account that energy efficiency may change over time. Therefore, the use of fuels and associated emissions are also adjusted to representing the changes in energy efficiencies. This is implemented in the hybrid input-output table, i.e. the use of different fuels per unit of supply as well as associated emissions in the HIOT are multiplied with a factor. This factor is calculated for each fuel (*i*) and associated emissions for activity (*j*) as:

efficiency factor for fuel (*i*) = index of supply of activity (*j*) / index for use of fuel (*i*) by activity (*j*)

The index of supply of activity (*j*) is obtained as the projected supply in a given year compared to the supply in year 2003. For activities supplying a physical product as the main product, the projected development in TMR is used, and for activities supplying a service product as the main product, the projected development in GDP is used. These data are obtained from; see section 5.1.1.

The index for use of fuel (*i*) is obtained from energy scenarios in Mantzos et al. (2003), which provides information on the projected use of different fuels for a range of different activities:

- Industry
- Services and agriculture
- Households
- Transport
- Electricity and steam

It should be noted that the projections of supply and of use of fuels are based on slightly different datasets; For projections of GDP, Mantzos and Capros (2006) have been used. This is combined with calculated ratio between development in GDP and TMR. For projections of the use of fuels, Mantzos et al. (2003) have been used. It has been possible to cross-check this with emissions from the electricity activity with data from IEA (2008), where the fuel mix in the electricity sector is specified for different years and ecoinvent (2007), where the emission per kWh electricity per fuel type is specified. See comparison in Table 5.1. Note that the emissions given in Table 5.1 are per total kWh generated (all electricity technologies), thus the emissions in Table 5.1 are a result of the fuel mix and the emission factor for each fuel (kg CO_2/kWh). The total CO_2 emission per kWh cannot be seen in the table. To have this, also emissions of CO_2-fibre should be added. There are no direct CO_2 emissions from nuclear and hydro power.

	CO_2 emission from **coal** power plants (kg CO_2/kWh)		CO_2 from **gas** power plants (kg CO_2/kWh)	
Year	Projection of fuel efficiency according to method above	Figures calculated from IEA (2008) and ecoinvent (2007)	Projection of fuel efficiency according to method above	Figures calculated from IEA (2008) and ecoinvent (2007)
2010	0.275	0.285	0.095	0.134
2015	0.301	0.260	0.101	0.124
2035	0.496	0.215	0.123	0.134

Table 5.1: Comparison of emissions of CO_2-coal and CO_2-gas in scenarios by using the method for fuel efficiency described in this section and by using projections of fuel consumption mix and efficiency in IEA (2008) and CO_2 emissions factors from ecoinvent (2007). Note that the emissions given in the table are per total kWh generated (all electricity technologies), thus the emissions in the table are a result of the fuel mix and the emission factor (kg CO_2/kWh).

The comparison in Table 5.1 shows that there is relatively good coherence between emissions calculated using the two approaches, except for emissions from coal power plants in 2035, where the projection in the method above significantly overestimates the emission. It has been chosen to apply the emissions calculated by using data from IEA (2008) and ecoinvent (2007).

5.2 Parameterisation of 'what-if-scenarios of waste treatment'

Three 'what-if-scenarios of waste treatment' have been implemented in the hybrid input-output table:

1) Waste prevention scenario
2) Waste recycling scenario
3) Waste treatment scenario

The waste treatment scenarios are comprehensively described in deliverable 5.3 'Report chapter with description of three what-if scenarios of waste treatment policies and their interplay with the macro-economic scenarios'. The following three tables (Table 5.2, Table 5.3, and Table 5.4) provide information of which parameters in the HIOT that are changed in the scenarios. Parameter values for years within the intervals given in the tables are calculated using linear interpolation.

When implementing the scenario parameterisation, it is ensured in all cases, that mass balance per column in the HIOT is maintained. Hence, the scenario parameterisation does not imply monetary or physical inconsistencies. This is also indicated in the tables below: e.g. in table Table 5.2; it is indicated that both use and waste generation are changed, i.e. reduced use of a product within an activity leads to corresponding reduced waste generation within this activity. Also, in some cases, reduced use leads to reduced emissions; this is the case for the use of fuels. When the scenarios imply a change of the amount of waste sent to recycling or incineration, a corresponding change is assumed for landfill.

Activity	Changed parameter		2003	2015	2035
Household	Use	Meat use	100	85	81
	Use	Flour use	increased correspondingly by dry mass		
Food industry	Use, waste	Fruit and veg. Use & waste	100	85	81
	Use, waste	Grain crops & waste	100	97.6	97
	Use, waste	Crops nec & waste	100	85	81
Beverages	Use, waste	Use of plastic & waste	100	90	88
	Use, waste	Use of glass & waste	100	90	88
Household	Use, waste	Textiles, wearing and apperal, leather & waste	100	94	93
All, except household	Use, waste	Printed matter	100	92	90
All, except refinery industry	Use, waste, emissions	Use of refined petroleum, waste, and emissions	100	94	93
All, except machinery product activities	Use, waste	Machinery and equipment n.e.c.	100	94	93
	Use, waste	Office machinery and computers	100	94	93
	Use, waste	Electrical machinery n.e.c.	100	94	93
	Use, waste	Radio, television and communication equipment	100	94	93
	Use, waste	Instruments, medical, precision, optical, clocks	100	94	93

Table 5.2: Specification of changed parameters and parameter values in the **waste prevention scenario**. Note that detailed scenario descriptions can be found in deliverable 5.3 'Report chapter with description of three what-if scenarios of waste treatment policies and their interplay with the macro-economic scenarios'.

Activity	Changed parameter		2003	2015	2035
Beveages industry	Waste to recycling	paper and paper products	20%	30%	50%
		Plastic and rubber products	25%	70%	85%
		Glass	60%	90%	95%
		Fabricated metal products	59%	80%	90%
Construction industry	Waste to recycling	Sand, gravel and stone	15%	40%	80%
		Forest products and wood products	15%	20%	40%
		Plastic and rubber products	3%	7%	14%
		Bricks	15%	40%	70%
		Fabricated metal products	20%	85%	95%
Agriculture	Waste to biogas	Manure	0%	70%	70%
All	Waste to biogas	Food waste	0%	40%	60%
All	Waste to recycling	Paper waste	59%	67%	77%
Motor vehicles and trailers	ELV to recycling	Iron waste	95%	95%	95%
		Alu waste	95%	95%	95%
		Copper waste	61%	61%	61%
		Metals nec waste	61%	61%	61%
		Fabricated metal products, except machinery waste	60%	95%	95%
		Machinery and equipment n.e.c. waste	60%	95%	95%
All	WEEE waste to trecycling	Office machinery and computers waste	24%	75%	90%
		Radio, television and communication equipment waste	25%	75%	90%
		Instruments, medical, precision, optical, clocks waste	20%	75%	90%

Table 5.3: Specification of changed parameters and parameter values in the **waste recycling scenario**. Note that detailed scenario descriptions can be found in deliverable 5.3 ‘Report chapter with description of three what-if scenarios of waste treatment policies and their interplay with the macro-economic scenarios’.

Activity	Changed parameter		2003	2015
Agriculture	Waste to biogas	Manure	0%	100%
All	Waste to incineratin	Food waste	43%	80%
		Textile waste	55%	80%
		Paper waste	15%	35%
All	Waste to recycling	Inert waste	1%	5%
All	Waste to recycling	Iron waste	46%	52%
		Alu waste	41%	50%
		Copper waste	40%	50%
		Metals nec waste	41%	50%

Table 5.4: Specification of changed parameters and parameter values in the **waste treatment scenario**. Note that detailed scenario descriptions can be found in deliverable 5.3 ‘Report chapter with description of three what-if scenarios of waste treatment policies and their interplay with the macro-economic scenarios’.

5.3 Implementation of scenario parameterisation

The scenario implementation of macro-economic scenarios and what-if-scenarios of waste treatment as described in the previous sections are implemented in an Excel spreadsheet so that the following input-parameters need to be specified:

- Scenario parameter 1: Year, allowed values ∊ [1971;2035]
- Scenario parameter 2: Macro-economic scenario, allowed values ∊ [Baseline;Low;High]
- Scenario parameter 3: Waste scenario, , allowed values ∊ [Waste prevention;Recycling;Treatment]

Based on the implemented scenarios (previous two sections) and the input-parameters (three bullets above), the HIOTs for analytical purposes are automatically derived.

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Appendix: Included product groups in the model

The table below specifies the 145 included product groups in the FORWAST model. The model contains four different types of products:

- Physical products, i.e. products that have a physical weight (mass unit, dry weight) or products being electricity/heat (energy unit)
- Service products, i.e. products that are measured in monetary units
- Waste treatment services, i.e. services to treat or recycle waste. These may be intermediate treatments (e.g. incineration that supplies ash and slag as waste) or final (e.g. landfill)
- Household uses, i.e. groups of final uses

The unit of measurement for each product group in the hybrid model is specified in the table below. The table also specifies the main by-product of each waste treatment activity (the main product/determining product is the service to treat waste). The table also specifies the NACE classification numbers relating to each product group.

No	Product type	Unit	Name	Main by-product of waste treatment services	NACE classification
1	Physical	Mass product	Bovine meat and milk		1.21
2	Physical	Mass product	Pigs		1.23
3	Physical	Mass product	Poultry and animals n.e.c.		01.24+01.25
4	Physical	Mass product	Grain crops		01.1(disaggr.)
5	Physical	Mass product	Crops n.e.c.		01.1(disaggr.)
6	Service	Monetary value	Agricultural services n.e.c.		01(disaggr.)+01.4+01.5
7	Physical	Mass product	Forest products		2 (disaggr.)
8	Waste treatment	Mass waste	Recycling of waste wood	Forest products	2 (disaggr.)
9	Physical	Mass product	Fish		5
10	Physical	Mass product	Coal, lignite, peat		10
11	Physical	Mass product	Crude petroleum and natural gas		11
12	Physical	Mass product	Iron ores from mine		13.1
13	Physical	Mass product	Bauxite from mine		13.2(disaggr.)
14	Physical	Mass product	Copper from mine		13.2(disaggr.)
15	Physical	Mass product	Metals from mine n.e.c.		13.2(disaggr.)
16	Physical	Mass product	Sand, gravel and stone from quarry		14.1+14.21
17	Physical	Mass product	Clay and soil from quarry		14.22
18	Physical	Mass product	Minerals from mine n.e.c.		14.3+14.4+14.5
19	Physical	Mass product	Meat and fish products		15.1+15.2
20	Physical	Mass product	Dairy products		15.5
21	Physical	Mass product	Fruits and vegetables, processed		15.3
22	Physical	Mass product	Vegetable and animal oils and fats		15.4
23	Physical	Mass product	Flour		15.6
24	Physical	Mass product	Sugar		15.83
25	Physical	Mass product	Animal feeds		15.7
26	Physical	Mass product	Food preparations n.e.c.		15.8(ext.)
27	Physical	Mass product	Beverages		15.9
28	Physical	Mass product	Tobacco products		16
29	Physical	Mass product	Textiles		17
30	Physical	Mass product	Wearing apparel and furs		18
31	Physical	Mass product	Leather products, footwear		19
32	Physical	Mass product	Wood products, except furniture		20
33	Physical	Mass product	Pulp, virgin		21.11(disaggr.)
34	Waste treatment	Mass waste	Recycling of waste paper	Pulp, virgin	21.11(disaggr.)
35	Physical	Mass product	Paper and paper products		21.12+21.2
36	Physical	Mass product	Printed matter and recorded media		22
37	Physical	Mass product	Refined petroleum products and fuels		23 (disaggr.)
38	Waste treatment	Mass waste	Recycling of waste oil	Refined petroleum products and fuels	23 (disaggr.)
39	Physical	Mass product	Fertiliser, N		24.15(disaggr.)
40	Physical	Mass product	Fertiliser, other than N		24.15(disaggr.)
41	Physical	Mass product	Plastics basic, virgin		24.16(disaggr.)+24.17(disaggr.)
42	Waste treatment	Mass waste	Recycling of plastics basic	Plastics basic, virgin	24.16(disaggr.)+24.17(disaggr.)
43	Physical	Mass product	Chemicals n.e.c.		24(disaggr.)
44	Physical	Mass product	Rubber and plastic products		25
45	Physical	Mass product	Glass, mineral wool and ceramic goods,		26.1(disaggr.)+26.2(disaggr.)
46	Waste treatment	Mass waste	Recycling of glass, mineral wool and ceramic goods	Glass, mineral wool and ceramic goods, virgin	26.1(disaggr.)+26.2(disaggr.)+26.3(disaggr.)
47	Physical	Mass product	Cement, virgin		26.5(disaggr.)
48	Waste treatment	Mass waste	Recycling of slags and ashes	Cement, virgin	26.5(disaggr.)
49	Physical	Mass product	Concrete, asphalt and other mineral products		26.6(disaggr.)+26.7(disaggr.)+26.8(disaggr.)
50	Waste treatment	Mass waste	Recycling of concrete, asphalt and other mineral products	Sand, gravel and stone from quarry	26.6(disaggr.)+26.7(disaggr.)+26.8(disaggr.)

No	Product type	Unit	Name	Main by-product of waste treatment services	NACE classification
51	Physical	Mass product	Bricks		26.3(disaggr.)+26.4
52	Waste treatment	Mass waste	Recycling of bricks	Bricks	26.3(disaggr.)+26.4
53	Physical	Mass product	Iron basic, virgin		27.1(disaggr.)
54	Waste treatment	Mass waste	Recycling of iron basic	Iron basic, virgin	27.1(disaggr.)
55	Physical	Mass product	Aluminium basic, virgin		27.42(disaggr.)
56	Waste treatment	Mass waste	Recycling of aluminium basic	Aluminium basic, virgin	27.42(disaggr.)
57	Physical	Mass product	Copper basic, virgin		27.44(disaggr.)
58	Waste treatment	Mass waste	Recycling of copper basic	Copper basic, virgin	27.44(disaggr.)
59	Physical	Mass product	Metals basic, n.e.c., virgin		27.4(disaggr.)
60	Waste treatment	Mass waste	Recycling of metals basic, n.e.c.	Metals basic, n.e.c., virgin	27.4(disaggr.)
61	Physical	Mass product	Iron, after first processing		27.2(disaggr.)+27.3(disaggr.)+27.5(disaggr.)
62	Physical	Mass product	Aluminium, after first processing		27.2(disaggr.)+27.3(disaggr.)+27.5(disaggr.)
63	Physical	Mass product	Copper, after first processing		27.2(disaggr.)+27.3(disaggr.)+27.5(disaggr.)
64	Physical	Mass product	Metals n.e.c., after first processing		27.2(disaggr.)+27.3(disaggr.)+27.5(disaggr.)
65	Physical	Mass product	Fabricated metal products, except		28
66	Physical	Mass product	Machinery and equipment n.e.c.		29
67	Physical	Mass product	Office machinery and computers		30
68	Physical	Mass product	Electrical machinery n.e.c.		31
69	Physical	Mass product	Radio, television and communication		32
70	Physical	Mass product	Instruments, medical, precision, optical,		33
71	Service	Monetary value	Motor vehicles and trailers		34
72	Service	Monetary value	Transport equipment n.e.c.		35
73	Physical	Mass product	Furniture and other manufactured goods		36
74	Service	Monetary value	Recycling services		37
75	Physical	Energy unit	Electricity, steam and hot water		40(disaggr.)
76	Physical	Mass product	Gas		40(disaggr.)
77	Service	Monetary value	Water, fresh		41
78	Service	Monetary value	Buildings, residential		45.1(disaggr.)+45.21(disaggr.)+45.22+45.3+45.4+45.5(disaggr.)
79	Service	Monetary value	Buildings, non-residential		45.1(disaggr.)+45.21(disaggr.)+45.22+45.3+45.4+45.5(disaggr.)
80	Service	Monetary value	Infrastructure, excluding buildings		45.1(disaggr.)+45.21(disaggr.)+45.22+45.3+45.4+45.5(disaggr.)
81	Service	Monetary value	Trade and repair of motor vehicles and		50
82	Service	Monetary value	Wholesale trade		51
83	Service	Monetary value	Retail trade and repair services		52
84	Service	Monetary value	Hotels and restaurants		55
85	Service	Monetary value	Land transport and transport via pipelines		60
86	Service	Monetary value	Transport by ship		61
87	Service	Monetary value	Air transport		62
88	Service	Monetary value	Cargo handling, harbours and travel		63
89	Service	Monetary value	Post and telecommunication		64
90	Service	Monetary value	Financial intermediation		65
91	Service	Monetary value	Insurance and pension funding		66
92	Service	Monetary value	Services auxiliary to financial		67
93	Service	Monetary value	Real estate services		70
94	Service	Monetary value	Renting of machinery and equipment etc.		71
95	Service	Monetary value	Computer and related services		72
96	Service	Monetary value	Research and development		73
97	Service	Monetary value	Business services n.e.c.		74
98	Service	Monetary value	Public service and security		75
99	Service	Monetary value	Education services		80
100	Service	Monetary value	Health and social work		85

No	Product type	Unit	Name	Main by-product of waste treatment services	NACE classification
101	Waste treatment	Mass waste	Incineration of waste: Food	Electricity, steam and hot water	90(disaggr.)
102	Waste treatment	Mass waste	Incineration of waste: Paper	Electricity, steam and hot water	90(disaggr.)
103	Waste treatment	Mass waste	Incineration of waste: Plastic	Electricity, steam and hot water	90(disaggr.)
104	Waste treatment	Mass waste	Incineration of waste: Metals	none	90(disaggr.)
105	Waste treatment	Mass waste	Incineration of waste: Glass/inert	none	90(disaggr.)
106	Waste treatment	Mass waste	Incineration of waste: Textiles	Electricity, steam and hot water	90(disaggr.)
107	Waste treatment	Mass waste	Incineration of waste: Wood	Electricity, steam and hot water	90(disaggr.)
108	Waste treatment	Mass waste	Incineration of waste: Oil/Hazardous waste	none	90(disaggr.)
109	Waste treatment	Mass waste	Manure treatment, conventional storage	none	1.2(disaggr.)
110	Waste treatment	Mass waste	Manure treatment, biogas	Electricity, steam and hot water	1.2(disaggr.)
111	Waste treatment	Mass waste	Biogasification of food waste	Electricity, steam and hot water	90(disaggr.)
112	Waste treatment	Mass waste	Biogasification of paper	Electricity, steam and hot water	90(disaggr.)
113	Waste treatment	Mass waste	Biogasification of sewage slugde	Electricity, steam and hot water	90(disaggr.)
114	Waste treatment	Mass waste	Composting of food waste	none	90(disaggr.)
115	Waste treatment	Mass waste	Composting of paper and wood	none	90(disaggr.)
116	Waste treatment	Mass waste	Waste water treatment, food	none	90(disaggr.)
117	Waste treatment	Mass waste	Waste water treatment, other	none	90(disaggr.)
118	Waste treatment	Mass waste	Landfill of waste: Food	Electricity, steam and hot water	90(disaggr.)
119	Waste treatment	Mass waste	Landfill of waste: Paper	Electricity, steam and hot water	90(disaggr.)
120	Waste treatment	Mass waste	Landfill of waste: Plastic	none	90(disaggr.)
121	Waste treatment	Mass waste	Landfill of waste: Iron	none	90(disaggr.)
122	Waste treatment	Mass waste	Landfill of waste: Alu	none	90(disaggr.)
123	Waste treatment	Mass waste	Landfill of waste: Copper	none	90(disaggr.)
124	Waste treatment	Mass waste	Landfill of waste: Metals nec	none	90(disaggr.)
125	Waste treatment	Mass waste	Landfill of waste: Glass/inert	none	90(disaggr.)
126	Waste treatment	Mass waste	Landfill of waste: Mine waste	none	90(disaggr.)
127	Waste treatment	Mass waste	Landfill of waste: Textiles	Electricity, steam and hot water	90(disaggr.)
128	Waste treatment	Mass waste	Landfill of waste: Wood	Electricity, steam and hot water	90(disaggr.)
129	Waste treatment	Mass waste	Landfill of waste: Oil/Hazardous waste	none	90(disaggr.)
130	Waste treatment	Mass waste	Landfill of waste: Slag/ash	none	90(disaggr.)
131	Waste treatment	Mass waste	Land application of manure	Fertiliser, N and Fertiliser, other than N	1.2(disaggr.)
132	Waste treatment	Mass waste	Land application of compost	Fertiliser, N and Fertiliser, other than N	90(disaggr.)
133	Service	Monetary value	Membership organisations		91
134	Service	Monetary value	Recreational and cultural services		92
135	Service	Monetary value	Services n.e.c.		93
136	Household	Monetary value	Household use: Clothing		n.a.
137	Household	Monetary value	Household use: Communication		n.a.
138	Household	Monetary value	Household use: Education		n.a.
139	Household	Monetary value	Household use: Health care		n.a.
140	Household	Monetary value	Household use: Housing		n.a.
141	Household	Monetary value	Household use: Hygiene		n.a.
142	Household	Monetary value	Household use: Leisure		n.a.
143	Household	Monetary value	Household use: Meals		n.a.
144	Household	Monetary value	Household use: Security		n.a.
145	Household	Monetary value	Household use: Social care		n.a.