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

Contract number: 044409

Deliverable n° 6-3

Title:

Documentation of the contribution analysis and uncertainty assessment. Results interpretation identifying priority material flows and wastes for waste prevention, recycling and choice of waste treatment options. Policy recommendations.

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Contents:

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 6-3 is to present a contribution analysis, an uncertainty assessment, the results of identifying priority material flows and wastes for waste prevention, recycling and choice of waste treatment options as well as policy recommendations.

2 Contribution analysis and interpretation: Waste flows

The waste generation in EU-27 in year 2003 and in year 2035 in nine different scenarios is presented in deliverable D6-2: ‘25-year forecasts of the cumulated physical stocks, waste generation, and environmental impacts for each scenario for EU-27 and for the case study countries’. This section further analyses and interprets these results.

2.1 Contribution analysis: waste quantities and generating activities in year 2003

Table 2.1 presents the total quantity of generated waste of 19 different waste fractions in EU-27 in year 2003 and its distribution on 11 groups of activities in the economy that generate the waste. In the following each of the 19 waste fractions are explained, and the generating activities are identified.

Waste generation in:
Region: EU27
Year: 2003

			Sector											
Waste category	**Waste fraction**	**Quantity, dry weight (Million t)**	Agriculture and fishery	Forestry	Ressource extraction	Food industry	Industry	Construction	Refineries and gas	Electricity and heat	Service	Waste treatment	Household	All sectors
Organic	Food waste	526	4%	0%	0%	32%	3%	0%	0%	0%	11%	1%	50%	100%
	Food waste to WWT	4	0%	0%	0%	1%	2%	0%	0%	0%	18%	0%	77%	100%
	Manure	157	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
	Wood waste	82	1%	12%	1%	2%	25%	21%	0%	11%	9%	2%	16%	100%
Textile	Textile waste	18	1%	0%	0%	1%	16%	2%	0%	0%	11%	2%	68%	100%
Paper	Paper waste	113	0%	0%	0%	8%	27%	1%	0%	0%	39%	3%	20%	100%
Plastic	Plastic waste	167	2%	0%	0%	8%	24%	24%	1%	0%	19%	3%	19%	100%
Glass	Glass waste	60	2%	0%	2%	27%	22%	23%	0%	0%	12%	6%	5%	100%
Construction and inert	Sand, stone, clay	1,657	1%	0%	6%	1%	23%	50%	0%	0%	10%	6%	2%	100%
	Cement, concrete, asphalt	566	0%	0%	0%	2%	10%	75%	0%	0%	5%	2%	5%	100%
	Bricks waste	38	0%	0%	0%	0%	8%	73%	0%	0%	8%	2%	8%	100%
	Ash and slag waste	762	0%	0%	1%	0%	3%	0%	1%	7%	2%	83%	2%	100%
	Metal ore waste	90	0%	0%	3%	0%	80%	2%	0%	0%	14%	1%	0%	100%
Metal	Iron waste	218	2%	0%	1%	2%	46%	19%	1%	0%	16%	5%	9%	100%
	Aluminium waste	20	2%	0%	1%	3%	44%	17%	1%	0%	17%	5%	10%	100%
	Copper waste	6	1%	0%	0%	2%	53%	12%	0%	0%	18%	3%	11%	100%
	Metals nec waste	7	2%	0%	1%	2%	38%	16%	1%	0%	21%	6%	12%	100%
	Other materials (non metal)	34	0%	0%	0%	1%	17%	7%	0%	1%	30%	3%	42%	100%
Special fractions	Special fractions	378	11%	0%	0%	1%	28%	2%	17%	0%	12%	2%	26%	100%
Total		**4,904**												

Table 2.1: Waste generation in the EU-27 in 2003.

2.1.1 Food waste

The total quantity of food waste in EU-27 in year 2003 was 526 million tonne (dry weight). Inputs of food/feed products to an activity becomes:

- Supply of products, e.g. inputs of rapeseed to an oil mill becomes supply of vegetable oil and animal feed
- Emissions, when food/feed is digested it becomes respiratory emissions – mainly CO_2, H_2O and some CH_4
- Waste: Human excretion and urine, i.e. originating from digested food by humans. This fraction belongs to the waste fraction 'Food waste to WWT', see section 2.1.2
- Waste: Manure, i.e. originating from digested feed by animals. This fraction belongs to the waste fraction 'Manure', see section 2.1.3
- Waste: All outputs that are not included in the above bullets, i.e. non-digested food residuals. This fraction belongs to the waste fraction '2.1.1' which is further described below

Since the waste fraction 'Food waste to WWT' is calculated based on the human metabolism and the number of inhabitants in the EU countries, only excretion and urine are included in this fraction. Thus, no non-digested food is present in the 'Food waste to WWT' fraction. Since this does not fully reflect reality, too much food waste is present in 'Food waste' and too little is present in 'Food waste to WWT'.

Food waste originates from the uses of the following products:

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

50% of the food waste occurs in the households, 32% in the food industry, and 11% in service activities (mainly hotels and restaurants). It should be noted that the quantity of food waste does not say anything about the potential for minimising loss because it includes usable wastes (e.g. food that has expired its shelf life) as well as non usable wastes (e.g. non-edible parts of food).

2.1.2 Food waste to WWT

The total quantity of ‘food waste to WWT’ in EU-27 in year 2003 was 4 million tonne (dry weight). The characteristics of the waste fraction is described in section 2.1.1. ‘Food waste to WWT’ occurs in the activities where food is eaten, i.e. mainly in the households and in service (hotels and restaurants).

2.1.3 Manure

The total quantity of ‘manure’ in EU-27 in year 2003 was 157 million tonne (dry weight). The characteristics of the waste fraction is described in section 2.1.1. ‘Manure’ occurs in animal production activities in agriculture; ‘Bovine meat and milk’, ‘Pigs’ and ‘Poultry and animals nec.’.

2.1.4 Wood waste

The total quantity of ‘wood waste’ in EU-27 in year 2003 was 82 million tonne (dry weight). Wood waste originates from the use of the following products:

- Forestry products (except waste of forestry products occurring in pulp manufacturing, this is partly discarded with waste water, partly landfilled, and partly incinerated; these wastes are included in the ‘Special fractions’, see Table 2.1)
- Tobacco products (insignificant, but included here to ensure that it is included)
- Wood products, except furniture

In addition, a part of the waste fraction ‘Other materials (non metal)’ in Table 2.1 (total quantity at 34 million tonne) is wood waste contained in waste of:

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

However, since the total quantity of ‘Other materials (non metal)’ is 34 million tonne (compared to total wood waste at 82 million tonne), and since only a small fraction of the above mentioned products is non-metal materials, this additional quantity of wood waste is considered as being insignificant.

Wood waste includes both waste of wood products and ash from combusted wood (biomass). Thus, wood waste in the electricity activity is mainly ash.

Wood waste mainly occurs in industry (wood products manufacturing, pulp manufacturing, and manufacturing of furniture).

2.1.5 Textile waste

The total quantity of 'textile waste' in EU-27 in year 2003 was 18 million tonne (dry weight). Textile waste originates from the use of the following products:

- Textiles
- Wearing apparel and furs
- Leather products, footwear

In addition, a minor part of the waste fraction 'Other materials (non metal)' in Table 2.1 (34 million tonne) is textile waste. See description in section 2.1.4. However, this is considered as insignificant compared to the quantity of textile waste at 18 million tonne.

Textile waste mainly occurs in households (clothing and housing – the latter includes textiles such as floor carpets etc.).

2.1.6 Paper waste

The total quantity of 'paper waste' in EU-27 in year 2003 was 113 million tonne (dry weight). Paper waste originates from the use of the following products:

- Pulp, virgin (except waste of pulp occurring in pulp and paper manufacturing, this is partly discarded with waste water, partly landfilled, and partly incinerated; these wastes are included in the 'Special fractions', see Table 2.1)
- Paper and paper products
- Printed matter and recorded media

It should be noted that a minor share of the last bullet above includes CDs, DVDS etc. This has not been separated from the 'paper waste' fraction.

Waste originating from the use of paper products in the household activity 'hygiene' is not included as 'paper waste' since this waste is regarded as being discarded via waste water. In Table 2.1, this tissue paper in waste water is included in the waste fraction 'Special fractions'.

In addition, a minor part of the waste fraction 'Other materials (non metal)' in Table 2.1 (34 million tonne) is paper waste. See description in section 2.1.4. However, this is considered as insignificant compared to the quantity of paper waste at 113 million tonne.

Paper waste mainly occurs in service industry (mainly in 'Business services nec.', wholesale and retail), industry (mainly in 'Printed matter and recorded media' and 'Paper and paper products'), and households (mainly leisure).

2.1.7 Plastic waste

The total quantity of 'plastic waste' in EU-27 in year 2003 was 167 million tonne (dry weight). Plastic waste originates from the use of the following products:

- Plastics basic, virgin
- Rubber and plastic products

In addition, a minor part of the waste fraction 'Other materials (non metal)' in Table 2.1 (34 million tonne) is plastic waste. See description in section 2.1.4. However, this is considered as insignificant compared to the quantity of plastic waste at 167 million tonne.

Plastic waste mainly occurs in households (waste of plastic products), construction (in construction materials), service (mainly packaging waste in wholesale and retail), and industry (mainly in packaging material in 'Chemicals nec.' and plastic industry). Also note that 8% of the plastic waste occurs in the food industry (Table 2.1); this is mainly packaging waste.

2.1.8 Glass waste

The total quantity of 'glass waste' in EU-27 in year 2003 was 60 million tonne (dry weight). Glass waste originates from the use of the following products:

- Glass, mineral wool and ceramic goods, virgin

In addition, a minor part of the waste fraction 'Other materials (non metal)' in Table 2.1 (34 million tonne) is glass waste. See description in section 2.1.4. However, this is considered as insignificant compared to the quantity of glass waste at 60 million tonne.

Glass waste mainly occurs in the food industry (packaging waste), construction (window glass), and industry (motor vehicles and the glass manufacture industry.

2.1.9 Sand, stone, clay waste

The total quantity of 'sand, stone, clay waste' in EU-27 in year 2003 was 1,657 million tonne (dry weight). 'Sand, stone, clay waste' originates from the use of the following products:

- Sand, gravel and stone from quarry
- Clay and soil from quarry
- Minerals from mine n.e.c.

In addition, a minor part of the waste fraction 'Other materials (non metal)' in Table 2.1 (34 million tonne) is 'sand, stone, clay waste'. See description in section 2.1.4. However, this is considered as insignificant compared to the quantity of 'sand, stone, clay waste' at 1,657 million tonne.

'Sand, stone, clay waste' mainly occurs in the construction industry (sand and stone used as foundation, and sand and stone mixed with cement to produce concrete on site or mixed with asphalt), and various other activities where sand, stone if used for construction purposes.

2.1.10 Cement, concrete asphalt waste

The total quantity of ‘cement, concrete asphalt waste’ in EU-27 in year 2003 was 566 million tonne (dry weight). ‘Cement, concrete asphalt waste’ originates from the use of the following products:

- Cement, virgin
- Concrete, asphalt and other mineral products

In addition, a minor part of the waste fraction ‘Other materials (non metal)’ in Table 2.1 (34 million tonne) is ‘cement, concrete asphalt waste’. See description in section 2.1.4. However, this is considered as insignificant compared to the quantity of ‘cement, concrete asphalt waste’ at 566 million tonne.

‘Cement, concrete asphalt waste’ mainly occurs in the construction industry (waste of construction materials). 75% of the ‘cement, concrete asphalt waste’ occurs in the construction sector. The remaining originates from other activities’ uses of construction materials.

2.1.11 Bricks waste

The total quantity of ‘bricks waste’ in EU-27 in year 2003 was 38 million tonne (dry weight). ‘Bricks waste’ originates from the use of the following products:

- Bricks

‘Bricks waste’ mainly occurs in the construction industry (waste of construction materials). 73% of the ‘bricks waste’ occurs in the construction sector. The remaining originates from other activities’ uses of bricks.

2.1.12 Ash and slag waste

The total quantity of ‘ash and slag waste’ in EU-27 in year 2003 was 762 million tonne (dry weight). ‘Slag and ash waste’ originates from the use of the following products:

- Coal, lignite, peat

and from the supply of the following services:

- Incineration of waste: Food
- Incineration of waste: Paper
- Incineration of waste: Plastic
- Incineration of waste: Metals
- Incineration of waste: Glass/inert
- Incineration of waste: Textiles
- Incineration of waste: Wood
- Incineration of waste: Oil/Hazardous waste

It should be noted that slag and ash from the burning of other materials than coal and waste, e.g. biomass, is included in the model as e.g. waste of forest products in case of ash from burning of biomass.

‘Slag and ash waste’ mainly occurs in the waste incineration activities (mainly incineration of inert materials, metals and food waste) and ‘electricity, steam and hot water’. It should be noted that the amount of slag and ash waste from waste incineration may be overestimated due to a too high share of waste sent to incineration. The shares of waste fractions sent to waste incineration is based on an weighted average of the 20 EU countries for which data collection has been available for inclusion for the calculation of model results. Especially, the shares of inert wastes may be overestimated because, the share of waste sent to incineration may be calculated based on the actual quantity incinerated divided by an underestimated total amount of inter waste. The shares can be seen in the so-called J matrix (see chapter 4 in deliverable D6-1 ‘Documentation of the data consolidation and calibration exercise, and the scenario parameterisation’). See section 4.10 for further details on the uncertainties relating to the J matrix.

2.1.13 Metal ore waste

The total quantity of ‘metal ore waste’ in EU-27 in year 2003 was 90 million tonne (dry weight). ‘Metal ore waste’ originates from the use of the following products:

- Iron ores from mine
- Bauxite from mine
- Copper from mine
- Metals from mine n.e.c.

‘Metal ore waste’ mainly occurs in industry (manufacture of basic metals).

2.1.14 Iron waste

The total quantity of ‘iron waste’ in EU-27 in year 2003 was 218 million tonne (dry weight). ‘Iron waste’ originates from the use of the following products:

- Iron basic, virgin
- Iron, after first processing
- *Iron contained in:* Fabricated metal products, except machinery
- *Iron contained in:* Machinery and equipment n.e.c.
- *Iron contained in:* Office machinery and computers
- *Iron contained in:* Electrical machinery n.e.c.
- *Iron contained in:* Radio, television and communication equipment
- *Iron contained in:* Instruments, medical, precision, optical, clocks
- *Iron contained in:* Furniture; other manufactured goods n.e.c.

The seven last bullets above concern products which are composed of different waste fractions. In the model, disassembly is applied, see description in section 4 in deliverable D6-1 ‘Documentation of the data consolidation and calibration exercise, and the scenario parameterisation’.

‘Iron waste’ mainly occurs in industry (mainly in iron processing and transport vehicles), construction (iron in construction materials), and service activities (iron in machinery and equipment etc.).

2.1.15 Aluminium waste

The total quantity of 'aluminium waste' in EU-27 in year 2003 was 20 million tonne (dry weight). 'Aluminium waste' originates from the use of the following products:

- Aluminium basic, virgin
- Aluminium, after first processing
- *Aluminium contained in:* Fabricated metal products, except machinery
- *Aluminium contained in:* Machinery and equipment n.e.c.
- *Aluminium contained in:* Office machinery and computers
- *Aluminium contained in:* Electrical machinery n.e.c.
- *Aluminium contained in:* Radio, television and communication equipment
- *Aluminium contained in:* Instruments, medical, precision, optical, clocks
- *Aluminium contained in:* Furniture; other manufactured goods n.e.c.

The seven last bullets above concern products which are composed of different waste fractions. In the model, disassembly is applied, see description in section 4 in deliverable D6-1 'Documentation of the data consolidation and calibration exercise, and the scenario parameterisation'.

'Aluminium waste' mainly occurs in industry (mainly in aluminium processing and transport vehicles), construction (aluminium in construction materials), and service activities (aluminium in machinery and equipment etc.).

2.1.16 Copper waste

The total quantity of 'copper waste' in EU-27 in year 2003 was 5.9 million tonne (dry weight). 'Copper waste' originates from the use of the following products:

- Copper basic, virgin
- Copper, after first processing
- *Copper contained in:* Fabricated metal products, except machinery
- *Copper contained in:* Machinery and equipment n.e.c.
- *Copper contained in:* Office machinery and computers
- *Copper contained in:* Electrical machinery n.e.c.
- *Copper contained in:* Radio, television and communication equipment
- *Copper contained in:* Instruments, medical, precision, optical, clocks
- *Copper contained in:* Furniture; other manufactured goods n.e.c.

The seven last bullets above concern products which are composed of different waste fractions. In the model, disassembly is applied, see description in section 4 in deliverable D6-1 'Documentation of the data consolidation and calibration exercise, and the scenario parameterisation'.

'Copper waste' mainly occurs in industry (mainly in copper processing and transport vehicles), construction (copper in construction materials), and service activities (copper in machinery and equipment etc.).

2.1.17 Metals nec. waste

The total quantity of 'metals nec. waste' in EU-27 in year 2003 was 7.0 million tonne (dry weight). 'Metals nec. waste' originates from the use of the following products:

- Metals nec. basic, virgin
- Metals nec., after first processing
- *Metals nec. contained in:* Fabricated metal products, except machinery
- *Metals nec. contained in:* Machinery and equipment n.e.c.
- *Metals nec. contained in:* Office machinery and computers
- *Metals nec. contained in:* Electrical machinery n.e.c.
- *Metals nec. contained in:* Radio, television and communication equipment
- *Metals nec. contained in:* Instruments, medical, precision, optical, clocks
- *Metals nec. contained in:* Furniture; other manufactured goods n.e.c.

The seven last bullets above concern products which are composed of different waste fractions. In the model, disassembly is applied, see description in section 4 in deliverable D6-1 'Documentation of the data consolidation and calibration exercise, and the scenario parameterisation'.

'Metals nec. waste' mainly occurs in industry (mainly in metals nec. processing and transport vehicles), construction (metals nec. in construction materials), and service activities (metals nec. in machinery and equipment etc.).

2.1.18 Waste of other materials (non metal)

This waste fraction represents all non-metal materials contained in:

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

The waste fraction includes plastic parts, glass parts, textiles, paper/cardboard parts, wooden parts, mineral parts etc. Since this waste fraction covers many different materials not classified elsewhere in the results, it is less interesting describing where in economy it occurs.

2.1.19 Special waste fractions

Special waste fractions includes:

- Hazardous waste (waste of fertilisers and chemicals)
- Oil waste (waste of crude oil and refined petroleum products)
- Residue of wood recycling
- Residue of paper recycling
- Residue of recycling of waste oil
- Residue of plastic recycling
- Residue of recycling of slag and ash
- Residue of recycling of inert materials and metals
- Paper waste to WWT from pulp/paper manufacturing
- Paper waste to WWT (tissue paper) in households: hygiene
- Wood waste: Residues from pulp manufacturing waste to Landfill

Since this waste fraction covers many different materials not classified elsewhere in the results, it is less interesting describing where in economy it occurs.

2.2 Waste flows in the FORWAST model versus waste flows in statistics

The model output on waste flows of the FORWAST model can be compared with national waste statistics on waste generation. Appropriate statistics for this purpose have been identified for Denmark (Miljøstyrelsen 2005). The FORWAST model outputs on waste generation in Denmark is based on the Danish data collection, see deliverable D3-1 'Report describing data processing and validation'. Figure 2.1 below shows the comparison for which appropriate data are available in the Danish waste statistics.

Waste fraction	Model results 1000 tonnes (dry weight)	Waste statistics 1000 tonnes (dry weight)
Food waste, MSW	8,337	
Food waste, Waste water	100	211
Wood waste	745	74
Ash and slag waste	5,541	2,182
Inert waste (sand, stone, cl	32,743	3,785
Oil waste	785	
Textile waste	211	
Paper waste	1,948	1,367
Plastic waste	3,163	
Hazardous waste	2,384	
Glass waste	665	219
Bricks waste	386	228
Metal waste	2,797	788

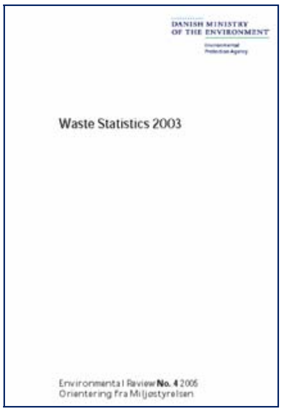

Figure 2.1: Comparison of FORWAST model results on waste generation (left) with Danish waste statistics (right) in year 2003.

In the following, each of the items for which comparison has been possible in Figure 2.1 is commented.

2.2.1 Food waste, waste water

The comparison shows that the FORWAST results corresponds to approximately 50% of the quantities in the waste statistics. As described in section 2.1.2 the reason for this is that no non-digested food is present in the ‘Food waste to WWT’ fraction. Since this does not fully reflect reality, too much food waste is present in ‘Food waste’ and too little is present in ‘Food waste to WWT’.

2.2.2 Wood waste

It appears from Figure 2.1 that the model results on wood waste generation are a factor 10 higher than the figures reported in Danish waste statistics. The main reason for the difference is related to differences in definitions of wastes. In the FORWAST model all uses of forest products and wood products in activities, that is not present in the supply of products or in emissions, will become waste. Since the supply of wood chips from saw mills is not recorded as supply of products in the FORWAST model (it is wood waste), whereas wood chips are not recoded as waste in waste statistics, the model results show higher figures. Another explanation of the difference is related to the life time expectancy of wood products in the model. If the actual life time is longer, the waste generation is lower than calculated in the model.

2.2.3 Ash and slag waste

The generation of ash and slag waste is a factor 2.5 higher in the model results than in the waste statistics. The main reason for this difference is the fact that waste treatment information on the share of especial construction waste that is sent to incineration may be overestimated, see section 2.1.12.

2.2.4 Inert waste (sand stone, clay, concrete etc.)

Inert waste is a factor 10 higher in the FORWAST results compared to waste statistics. The main cause of the difference is estimated to be related to what is recorded in waste statistics, e.g. when roads and buildings reach the end of their lifetimes, most of the foundation material will remain on the ground and not be recorded in waste statistics. When leaving such material on the ground this can be seen as a kind of landfill not recorded in waste statistics. Another reason for the difference may be that the lifetimes of construction materials in the model is underestimated.

2.2.5 Paper waste

The comparison in Figure 2.1 shows that paper waste generation in the FORWAST model is approx 42% higher than what is recorded in waste statistics. It is estimated that the difference is related to underestimation of the life time of paper products as well as underestimated figures in waste statistics on the amount of paper waste present in mixed municipal solid waste.

2.2.6 Glass waste

Glass waste generation in the model results is approx a factor 3 higher than the recorded quantity in waste statistics. The explanation of this significant difference is that glass bottles sent to direct reuse is recorded as waste in the FORWAST model whereas it is not in waste statistics. A mass flow analysis of glass in Denmark 1999 (Holm et al. 2002, p 93) shows that the total glass waste was 845,000 tonnes of which 689,000 tonnes is sent to direct reuse. Thus, the amount of glass waste, excluding glass waste to direct reuse, is 156,000 tonnes. According to Figure 2.1, this amount has grown to 211,000 tonnes in year 2003.

2.2.7 Bricks waste

The quantity of bricks waste in the model results is a factor 1.7 higher than what is reported in the statistics. The most likely reason for the difference is related to the estimation of product life time of bricks. But also the fact that not all bricks waste is registered in statistics may contribute to the difference.

2.2.8 Metal waste

Metal is a factor 3.5 higher in the FORWAST results compared to waste statistics. The main causes of the difference are estimated to be related to:

- lifetimes of metal products in the model is underestimated
- waste statistics have insufficient information on metal waste sent to municipal incineration and landfill
- corrosion (emissions of iron) is not taken into account

2.2.9 Conclusion of the comparison with statistics

The comparison of FORWAST results with waste statistics showed significant differences, in almost all cases the FORWAST results shows significant higher waste quantities. The main causes of the differences are identified as flows which are not registered/recorded in the statistics and uncertainties in the estimation of product life times. For some waste fractions it has been possible to identify the specific causes of the difference, e.g. the glass waste fraction, where the difference between FORWAST results and statistics can be explained by the fact that used glass bottles for direct reuse is not recorded in waste statistics.

3 Contribution analysis and interpretation: Environmental impacts

This section presents a contribution analysis of the environmental impacts caused by EU-27 production and consumption. It should be noted that the results are calculated in a life cycle perspective including environmental impacts caused by emissions outside the EU-27.

3.1 Methodology and data used for the calculation of environmental impacts

This section analyses the environmental impact from EU-27 production and consumption which is presented in deliverable D6-2 '25-year forecasts of the cumulated physical stocks, waste generation, and environmental impacts for each scenario for EU-27 and for the case study countries'. The functional unit of the results on environmental impacts is the final demand (household uses and export), see dark grey boxes in Figure 3.1. This is also referred to as 'EU-27 production and consumption'.

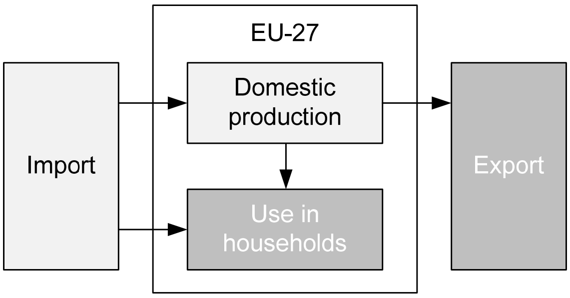

Figure 3.1: Illustration of major commodity flows. Total supply (output of import and domestic production) is equal to total use (input to use in households and export). The latter is used as functional unit (driving vector) in the model.

It should be noted that the impact per imported products is presumed to be equal to domestically produced products. Further, it should be noted that the model results are based on data collection from 20 out of the 27 EU-27 countries, and subsequently the ratio between domestic supply and imported products is also based on these 20 countries. Therefore, uncertainties in the environmental impact outside and inside the EU-27 are present. Uncertainties are further described in section 4 'Uncertainty assessment'.

When calculating the environmental impacts, the following emissions have been included:

- Carbon dioxide (CO_2), fossil as well as biogenic
- Resource extraction of biogenic carbon
- Nitrogen oxides (NO_x)
- Methane (CH_4)
- Sulphur dioxide (SO_2)
- Dinitrogen monoxide (N_2O)
- Carbon monoxide (CO)
- Non-methane volatile organics (NMVOC)

The LCIA-method, Stepwise 2006 method, version 1.2, has been used for calculating environmental indicators per midpoint impact category and as aggregated, monetarised values. The method is described and documented in Weidema et al. (2007) and Weidema (2009). The method can be downloaded as a CSV-file for import in the LCA software SimaPro at: http://www.lca-net.com/projects/stepwise_ia/. It should be noted that 1 kg fossil and 1 kg biogenic CO_2 emission cause the same impact. Resource extraction of 1 kg biogenic carbon causes an impact of -3.66 kg CO_2-eq. Thus, the growing of an agricultural crop containing 1 kg carbon will cause the effect 3.66 kg CO_2-eq, and when it is digested or disposed of it will cause the effect of 3.66 kg CO_2-eq (if we assume that all carbon contained in the product is released as CO_2).

3.2 Contribution analysis: EU-27 production and consumption year 2003

3.2.1 Identification of significant environmental impact categories and contributing emissions

The total monetarised impact from EU-27 production and consumption in 2003 is 1,162 GEUR. The contributions to this total impact from individual impact categories is given in Table 3.1 below.

Impact category	Mid-point impact	Unit	End-point impact	Unit
Global warming	9,467	million tonne CO2-eq	786	GEUR
Respiratory inorganics	4.74	million tonne PM2.5-eq	320	GEUR
Photochemical ozone, vegetat.	104,545	billion m2*ppm*hours	39.0	GEUR
Eutrophication, terrestrial	799	billion m2UES	10.0	GEUR
Acidification	544	billion m2UES	4.21	GEUR
Respiratory organics	10.8	billion pers*ppm*h	2.76	GEUR
Eutrophication, aquatic	1.70	million tonne NO3-eq	0.172	GEUR
Total			**1,162**	**GEUR**

Table 3.1: Environmental impacts related to the EU-27 final uses in 2003. The impacts are given in mid-point units (characterised results) as well as end-point units (weighted results).

It appears from **Table 3.1** that the most significant impact categories are global warming (68% of the total impact) and respiratory inorganics (28% of the total impact). The other impact categories account for the remaining 4% of the total impact.

In the following, more attention is given to the contributing to the total impacts in Table 3.1 above.

Global warming

The total contribution to global warming is caused by the emissions shown in Table 3.2. It should be noted that GHG-emissions related to land use change (direct and indirect) are not included.

Substance	Amount (million tonne CO2-eq)	Compartment
Carbon dioxide, crude oil and natural gas carl	5,294	Emission to air
Carbon dioxide, coal carbon	2,397	Emission to air
Carbon dioxide, food carbon	1,856	Emission to air
Methane	1,791	Emission to air
Dinitrogen monoxide	737	Emission to air
Carbon dioxide, fibre carbon	572	Emission to air
Carbon dioxide, carbonate	216	Emission to air
Carbon monoxide	88	Emission to air
Fibre carbon	-1,177	Carbon sequestration from air
Food carbon	-2,307	Carbon sequestration from air
Total	**9,467**	

Table 3.2: Emissions contribution to global warming.

It appears from Table 3.2 that the most significant GHG-emissions are CO_2 originating from combustion of oil, gas and coal (these account for 101% of the total), also methane and dinitrogen monoxide are important; 19% and 8% respectively. It also appears that, in a 100 year perspective, extraction of biogenic carbon contributes to a net carbon sequestration. For biogenic carbon, the balances are as follows:

- Food carbon: Sequestration (-2,307 million tonne CO2-eq) + emission (1,856 million tonne CO2-eq) = -451 million tonne CO2-eq, i.e. only 80% of the carbon in agricultural products is released again during 100 years
- Fibre carbon: Sequestration (-1,177 million tonne CO2-eq) + emission (572 million tonne CO2-eq) = -605 million tonne CO2-eq, i.e. only 49% of the carbon in fibre products (wood, paper and textile) is released again during 100 years

The figures given in the two bullets above do not take into account that some carbon is released as methane. The release of carbon as methane during the first 100 years after landfill are: food waste (7%), paper waste (5%), textile waste (3%), and wood waste (0.4%). These figures are calculated based on carbon content in wastes, waste degradability during 100 years (see Table 3.3) and emission factors obtained from Doka et al. (2007).

The high figures on net carbon sequestration above are mainly due to long degradation times in landfills, and consequently, the figures are subject to the uncertainties that are related to the degradation times of food and fibre products in landfills. The applied waste degradation times for food and fibre wastes are obtained from data provided by Johann Fellner, Technical University of Vienna. The data are given in Table 3.3 below.

Waste fraction	Share that is degraded during 100 years
Landfill of food waste	27%
Landfill of paper waste	27%
Landfill of textile waste	12%
Landfill of wood waste	1.6%

Table 3.3: Waste degradation times of food and fibre carbon containing waste fractions.

Respiratory inorganics

The total contribution to respiratory inorganics is caused by the emissions shown in Table 3.4.

Substance	Amount (million tonne PM2.5-eq)	Compartment
Nitrogen dioxide	3.08	Emission to air
Sulfur dioxide	1.60	Emission to air
Carbon monoxide	0.0586	Emission to air
Total of all compartments	**4.74**	

Table 3.4: Emissions contribution to respiratory inorganics.

The most significant emission contributing to respiratory, inorganics is nitrogen dioxide. In this respect, it should be noted that the probably most significant emission has not been included in the FORWAST emissions inventories; namely emissions of particles (Weidema 2009; Jolliet et al. 2003; Goedkoop and Spriensma 2001). Therefore, it may be expected that the monetarised impact related to respiratory effects is more significant than specified in Table 3.1.

Photo chemical ozone

The total contribution to photochemical ozone formation is caused by the emissions shown in Table 3.5.

Substance	Amount (billion m2*ppm*hours)	Compartment
Nitrogen dioxide	38,751	Emission to air
Carbon monoxide	34,229	Emission to air
Methane	24,145	Emission to air
NMVOC	7,421	Emission to air
Total	**104,545**	

Table 3.5: Emissions contribution to photochemical ozone formation.

Eutrophication, terrestrial

The only contributing emissions is nitrogen dioxide.

Acidification

The total contribution to acidification is caused by the emissions shown in Table 3.6.

Substance	Amount (billion m2 UES)	Compartment
Sulfur dioxide	389	Emission to air
Nitrogen dioxide	155	Emission to air
Total	**544**	

Table 3.6: Emissions contribution to acidification.

Respiratory, organics

The total contribution to respiratory organics is caused by the emissions shown in Table 3.7.

Substance	Amount (billion pers*ppm*h)	Compartment
Carbon monoxide	4.26	Emission to air
Methane	2.96	Emission to air
Nitrogen dioxide	2.66	Emission to air
NMVOC	0.925	Emission to air
Total	**10.8**	

Table 3.7: Emissions contribution to respiratory, organics.

Eutrophication, aquatic

The only contributing emissions is nitrogen dioxide.

3.2.2 Identification of significant causes of environmental impacts

The final uses (functional unit of the study) includes uses by 10 categories of household activities and export of the remaining 135 product categories included in the model. A full list of the 145 included product categories in the model is provided in the appendix 1.

In the following the cause of the total impact is traced, i.e. following the significant flows in Figure 3.2.

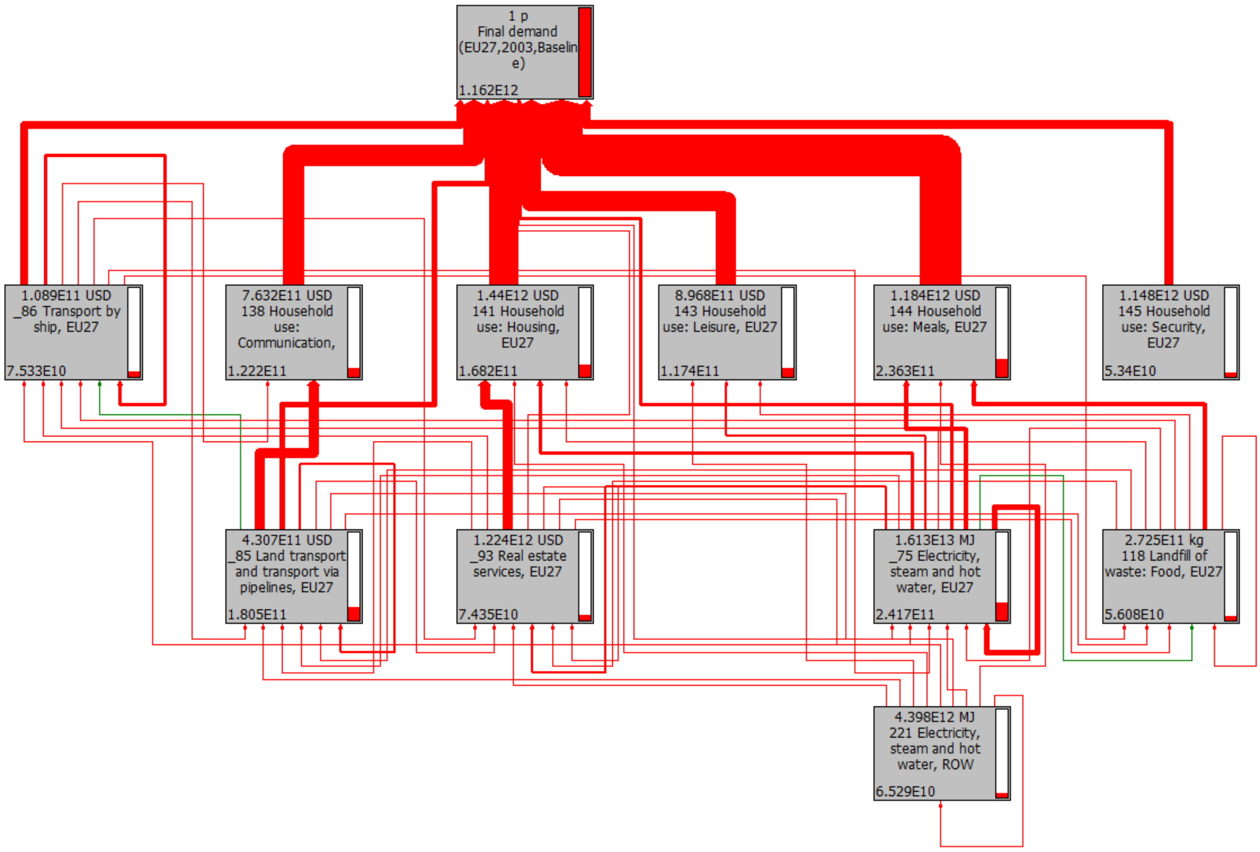

Figure 3.2: Illustration of the major causes of the total monetarised impact at 1,162 GEUR. The thickness of the arrows represents the significant of the flows. The value in the top of the boxes show the quantity of the flows measured in the hybrid units used in the model. The values in the bottom of the boxes show the monetarised impact of each product plus all upstream (in the product life cycle) impacts.

When focussing on the environmental impacts caused by the final uses (household uses and export), the most significant impacts are caused by household uses (74% of total monetarised impact) and the remaining is caused by the production of exported products (26% of total monetarised impact), see Table 3.8 for more details.

EU-27 final uses: household uses and exports			
Causes of the total monetarised impact (GEUR)		**Causes of the total GHG-emissions (million tonne CO2-eq)**	
Households	**75%**	**Households**	**78%**
- Meals	21%	- Meals	24%
- Housing	15%	- Housing	16%
- Communication	11%	- Leisure	10%
- Leisure	11%	- Communication	10%
- Security	4.8%	- Security	4.8%
- Other household uses	12%	- Other household uses	12%
Exports	**25%**	**Exports**	**22%**
- Transport by ship	3.9%	- Land transport and transport via pipeli	2.3%
- Land transport and transport via pipelines	2.8%	- Transport by ship	2.1%
- Electricity, steam and hot water	1.8%	- Electricity, steam and hot water	1.8%
- Wholesale trade	1.5%	- Wholesale trade	1.4%
- Iron basic, virgin	1.1%	- Iron basic, virgin	1.2%
- Other exports	14%	- Other exports	13%
Total (%)	**100%**	**Total (%)**	**100%**
Total (GEUR)	**1,162**	**Total (million tonne CO2-eq)**	**9,467**

Table 3.8: Causes of the total impact related to EU-27 final uses (household uses and export) both as monetarised total environment impact and as GHG-emissions (mid-point impact).

It appears that the most significant activity causing environmental impacts is the household activity 'Meals' followed by the activity housing. The causes of the environmental impacts from these two products/services are illustrated in Table 3.9 and Table 3.10.

EU-27 Household activity: Meals			
Causes of the monetarised impact (GEUR)		**Causes of the GHG-emissions (million tonne CO2-eq)**	
Hotels and restaurants	13%	Landfill of waste: Food	15%
Electricity, steam and hot water	12%	Dairy products	12%
Landfill of waste: Food	12%	Hotels and restaurants	12%
Dairy products	11%	Electricity, steam and hot water	11%
Meat and fish products	8.2%	Incineration of waste: Food	10%
Beverages	7.2%	Meat and fish products	8.2%
Food preparations n.e.c.	7.0%	Food preparations n.e.c.	6.8%
Incineration of waste: Food	6.9%	Beverages	6.7%
Other inputs	21%	Other inputs	17%
Household, meals: Direct emissions	1.5%	Household, meals: Direct emissions	1.8%
Total (%)	**100%**	**Total (%)**	**100%**
Total (GEUR)	**236**	**Total (million tonne CO2-eq)**	**2,176**

Table 3.9: Causes of the impact related to EU-27 household use group 'meals', both as monetarised total environment impact and as GHG-emissions (mid-point impact).

It appears from the table that the most significant causes of the impact related to the household activity 'meals' are related to 'hotels and restaurants' (primary dining), electricity (for food preparation and storage), landfill of food waste (mainly methane emissions). It also appears that the use of meat and dairy products together is the main cause of environmental impacts relating to the household activity 'meals'.

EU-27 Household activity: Housing			
Causes of the monetarised impact (GEUR)		**Causes of the GHG-emissions (million tonne CO2-eq)**	
Real estate services	49%	Real estate services	50%
Electricity, steam and hot water	19%	Electricity, steam and hot water	19%
Textiles	3.5%	Textiles	3.6%
Furniture and other manufactured goods n.e.c.	2.8%	Gas	3.0%
Gas	2.7%	Chemicals n.e.c.	2.6%
Chemicals n.e.c.	2.6%	Plastics basic, virgin	2.6%
Plastics basic, virgin	2.5%	Incineration of waste: Oil/Hazardous waste	2.5%
Incineration of waste: Oil/Hazardous waste	2.3%	Furniture and other manufactured goods n.e.c.	2.4%
Other inputs	13%	Other inputs	9%
Household, meals: Direct emissions	3.2%	Household, meals: Direct emissions	4.4%
Total (%)	**100%**	**Total (%)**	**100%**
Total (GEUR)	**168**	**Total (million tonne CO2-eq)**	**1,483**

Table 3.10: Causes of the impact related to EU-27 household use group 'housing', both as monetarised total environment impact and as GHG-emissions (mid-point impact).

It appears from the table that the most significant causes of the impact related to the household activity 'housing' are related to 'real estate services'. The impacts related to real estate services are mainly caused by the use of buildings, energy and construction materials in this activity. Other significant causes of the environmental impact related to housing are direct emissions (when fuels are burned for heating in the households), energy (electricity and district heating) and textiles and furniture.

3.3 Contribution analysis: per product in the hybrid IO-model

This section presents the environmental impact per unit of product in a cradle to gate perspective. Environmental impacts are presented as monetarised impacts in EUR2003 (end-point impact) and GHG-emissions in kg CO_2-eq (mid-point impact). These impacts can be compared with results of traditional LCA-studies.

It should be noted that the environmental impacts in the FORWAST model are calculated without distinguishing between fossil CO_2 and biogenic CO_2. I.e. the emission of 1 kg fossil CO_2 contributes the same as the emissions of 1 kg biogenic CO_2. In addition, plant or animal uptake of atmospheric CO_2 contributes with minus CO_2 emissions (removal of CO_2 from the atmosphere).

In the Kyoto accounting system (UNFCCC) as well as in many LCAs and carbon footprint studies, annual uptake of atmospheric carbon in standing forests, agricultural products and fishery are not included (the effect of this carbon uptake is a negative contribution to GHG-emissions). Also the emissions of biogenic CO_2 are not included, i.e. respiratory CO_2 from humans and animals, CO_2 from burning of biomass, and CO_2 from other degradation of organic material (the effect of these CO_2 emissions is a positive contribution to GHG-emissions). In life cycle assessment and carbon footprint, it is often assumed that the two above mentioned effects equals each other out. However, this is not always a good assumption, especially not regarding degradation of organic materials in landfills (also see Table 3.2). In the time horizon for which emissions are included from landfill sites in the FORWAST model (100 years after the waste is landfilled), not all of the carbon contained in the wastes is released. Therefore, given time horizon at 100 years, the Kyoto approach is likely to overestimate the total GHG emissions.

Another difference between 1) not distinguishing between fossil and biogenic CO_2, and 2) presume that biogenic CO_2 is not associated with impacts on global warming, is the environmental impact per product. This is present for activities that are associated with burning/other degradation of organic material, and for activities that are associated with uptake of atmospheric carbon.

If biogenic carbon is included in the calculation of GHG emissions, especially agricultural crops, fish and forestry products will show a negative contribution to global warming (this is also valid for products where agricultural crops, fish and forestry products are present upstream in the product system). Also waste treatment services which are typically regarded as being not associated with CO_2 emissions will appear as having a significant larger contribution to global warming (due to emissions of biogenic CO_2); e.g. waste incineration of organic material, waste water treatment, composting, land application of manure, landfill of organic waste.

To facilitate comparison with other LCAs and carbon footprint studies, the environmental impacts per product is shown using both of the abovementioned approaches in the two subsections below. In section 3.3.1 the impacts using the FORWAST approach are shown, and in section 3.3.2 the impacts using the Kyoto approach are shown.

The tables below specifies the impacts for 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

In the tables, the product type is indicated with colour codes, see below:

Product type
Physical
Service
Waste treatment
Household

3.3.1 Environmental impacts per unit of products

In the table below the environmental impacts (monetarised and GHG-emissions) are shown per unit for all products in the FORWAST model. GHG-emissions are calculated without distinguishing between biogenic and fossil CO_2, and plant uptake of atmospheric carbon is included as CO_2 emission with negative sign.

Product no.	Product name	Product type	Unit	Monetarised environmental impact per unit pf product (EUR2003)	GHG-emissions per unit of product (kg CO2-eq)
1	Bovine meat and milk	Physical	kg (dry weight)	1.51	15.56
2	Pigs	Physical	kg (dry weight)	0.83	8.00
3	Poultry and animals n.e.c.	Physical	kg (dry weight)	1.21	11.40
4	Grain crops	Physical	kg (dry weight)	-0.08	-1.11
5	Crops n.e.c.	Physical	kg (dry weight)	0.02	-0.15
6	Agricultural services n.e.c.	Service	EUR2003	0.24	1.83
7	Forest products	Physical	kg (dry weight)	-0.13	-1.58
8	Recycling of waste wood	Waste treatment	kg waste (dry weight)	0.14	1.68
9	Fish	Physical	kg (dry weight)	1.37	8.34
10	Coal, lignite, peat	Physical	kg (dry weight)	0.01	0.09
11	Crude petroleum and natural gas	Physical	kg (dry weight)	0.01	0.13
12	Iron ores from mine	Physical	kg (dry weight)	0.01	0.05
13	Bauxite from mine	Physical	kg (dry weight)	0.04	0.36
14	Copper from mine	Physical	kg (dry weight)	0.03	0.21
15	Metals from mine n.e.c.	Physical	kg (dry weight)	0.02	0.19
16	Sand, gravel and stone from quarry	Physical	kg (dry weight)	0.00	0.01
17	Clay and soil from quarry	Physical	kg (dry weight)	0.00	0.01
18	Minerals from mine n.e.c.	Physical	kg (dry weight)	0.00	0.02
19	Meat and fish products	Physical	kg (dry weight)	1.98	18.15
20	Dairy products	Physical	kg (dry weight)	1.91	18.86
21	Fruits and vegetables, processed	Physical	kg (dry weight)	0.43	3.46
22	Vegetable and animal oils and fats	Physical	kg (dry weight)	0.14	0.95
23	Flour	Physical	kg (dry weight)	-0.02	-0.54
24	Sugar	Physical	kg (dry weight)	0.14	0.94
25	Animal feeds	Physical	kg (dry weight)	0.10	0.55
26	Food preparations n.e.c.	Physical	kg (dry weight)	1.02	9.00
27	Beverages	Physical	kg (dry weight)	1.40	12.08
28	Tobacco products	Physical	kg (dry weight)	0.75	6.15
29	Textiles	Physical	kg (dry weight)	1.10	9.33
30	Wearing apparel and furs	Physical	kg (dry weight)	2.07	17.48
31	Leather products, footwear	Physical	kg (dry weight)	2.19	18.83
32	Wood products, except furniture	Physical	kg (dry weight)	-0.04	-0.98
33	Pulp, virgin	Physical	kg (dry weight)	-0.02	-0.77
34	Recycling of waste paper	Waste treatment	kg waste (dry weight)	0.08	1.24
35	Paper and paper products	Physical	kg (dry weight)	0.17	0.98
36	Printed matter and recorded media	Physical	kg (dry weight)	0.51	3.73
37	Refined petroleum products and fuels	Physical	kg (dry weight)	0.05	0.41
38	Recycling of waste oil	Waste treatment	kg waste (dry weight)	-0.04	-0.37
39	Fertiliser, N	Physical	kg (dry weight)	0.39	3.63
40	Fertiliser, other than N	Physical	kg (dry weight)	0.15	1.29
41	Plastics basic, virgin	Physical	kg (dry weight)	0.37	3.11
42	Recycling of plastics basic	Waste treatment	kg waste (dry weight)	-0.23	-2.00
43	Chemicals n.e.c.	Physical	kg (dry weight)	0.25	2.06
44	Rubber and plastic products	Physical	kg (dry weight)	0.86	7.19
45	Glass, mineral wool and ceramic goods, vi	Physical	kg (dry weight)	0.23	1.87
46	Recycling of glass, mineral wool and ceran	Waste treatment	kg waste (dry weight)	-0.13	-1.03
47	Cement, virgin	Physical	kg (dry weight)	0.09	0.88
48	Recycling of slags and ashes	Waste treatment	kg waste (dry weight)	-0.07	-0.74
49	Concrete, asphalt and other mineral produ	Physical	kg (dry weight)	0.02	0.20
50	Recycling of concrete, asphalt and other n	Waste treatment	kg waste (dry weight)	0.02	0.14

Table 3.11 (part 1 of 3): Environmental impact (monetarised and GHG-emissions) per unit of all products in the FORWAST model. GHG-emissions are calculated without distinguishing between biogenic and fossil CO_2, and plant uptake of atmospheric carbon is included as CO_2 emission with negative sign.

Product no.	Product name	Product type	Unit	Monetarised environmental impact per unit pf product (EUR2003)	GHG-emissions per unit of product (kg CO2-eq)
51	Bricks	Physical	kg (dry weight)	0.04	0.32
52	Recycling of bricks	Waste treatment	kg waste (dry weight)	-0.04	-0.31
53	Iron basic, virgin	Physical	kg (dry weight)	0.23	2.06
54	Recycling of iron basic	Waste treatment	kg waste (dry weight)	-0.07	-0.63
55	Aluminium basic, virgin	Physical	kg (dry weight)	0.98	8.15
56	Recycling of aluminium basic	Waste treatment	kg waste (dry weight)	-0.65	-5.22
57	Copper basic, virgin	Physical	kg (dry weight)	0.79	6.76
58	Recycling of copper basic	Waste treatment	kg waste (dry weight)	-0.21	-2.20
59	Metals basic, n.e.c., virgin	Physical	kg (dry weight)	0.36	2.29
60	Recycling of metals basic, n.e.c.	Waste treatment	kg waste (dry weight)	-0.22	-1.28
61	Iron, after first processing	Physical	kg (dry weight)	0.34	3.03
62	Aluminium, after first processing	Physical	kg (dry weight)	1.80	14.87
63	Copper, after first processing	Physical	kg (dry weight)	0.96	8.14
64	Metals n.e.c., after first processing	Physical	kg (dry weight)	1.72	12.70
65	Fabricated metal products, except machin	Physical	kg (dry weight)	0.53	4.51
66	Machinery and equipment n.e.c.	Physical	kg (dry weight)	0.77	6.40
67	Office machinery and computers	Physical	kg (dry weight)	3.55	29.24
68	Electrical machinery n.e.c.	Physical	kg (dry weight)	0.65	5.45
69	Radio, television and communication equip	Physical	kg (dry weight)	1.22	10.03
70	Instruments, medical, precision, optical, cl	Physical	kg (dry weight)	2.91	23.41
71	Motor vehicles and trailers	Service	EUR2003	0.10	0.81
72	Transport equipment n.e.c.	Service	EUR2003	0.07	0.56
73	Furniture and other manufactured goods n.	Physical	kg (dry weight)	0.40	2.80
74	Recycling services	Service	EUR2003	0.54	4.29
75	Electricity, steam and hot water	Physical	kWh	0.06	0.51
76	Gas	Physical	kg (dry weight)	0.05	0.46
77	Water, fresh	Service	EUR2003	0.15	1.24
78	Buildings, residential	Service	EUR2003	0.11	0.97
79	Buildings, non-residential	Service	EUR2003	0.10	0.87
80	Infrastructure, excluding buildings	Service	EUR2003	0.18	1.51
81	Trade and repair of motor vehicles and serv	Service	EUR2003	0.07	0.54
82	Wholesale trade	Service	EUR2003	0.07	0.52
83	Retail trade and repair services	Service	EUR2003	0.06	0.51
84	Hotels and restaurants	Service	EUR2003	0.10	0.90
85	Land transport and transport via pipelines	Service	EUR2003	0.53	3.64
86	Transport by ship	Service	EUR2003	1.05	4.56
87	Air transport	Service	EUR2003	0.28	2.01
88	Cargo handling, harbours and travel agenci	Service	EUR2003	0.13	0.96
89	Post and telecommunication	Service	EUR2003	0.05	0.39
90	Financial intermediation	Service	EUR2003	0.03	0.26
91	Insurance and pension funding	Service	EUR2003	0.04	0.32
92	Services auxiliary to financial intermediatio	Service	EUR2003	0.03	0.29
93	Real estate services	Service	EUR2003	0.08	0.64
94	Renting of machinery and equipment etc.	Service	EUR2003	0.03	0.29
95	Computer and related services	Service	EUR2003	0.05	0.42
96	Research and development	Service	EUR2003	0.07	0.56
97	Business services n.e.c.	Service	EUR2003	0.05	0.44
98	Public service and security	Service	EUR2003	0.06	0.46
99	Education services	Service	EUR2003	0.05	0.38
100	Health and social work	Service	EUR2003	0.05	0.41

Table 3.11 (part 2 of 3): Environmental impact (monetarised and GHG-emissions) per unit of all products in the FORWAST model. GHG-emissions are calculated without distinguishing between biogenic and fossil CO_2, and plant uptake of atmospheric carbon is included as CO_2 emission with negative sign.

Product no.	Product name	Product type	Unit	Monetarised environmental impact per unit pf product (EUR2003)	GHG-emissions per unit of product (kg CO2-eq)
101	Incineration of waste: Food	Waste treatment	kg waste (dry weight)	0.14	1.76
102	Incineration of waste: Paper	Waste treatment	kg waste (dry weight)	0.09	1.21
103	Incineration of waste: Plastic	Waste treatment	kg waste (dry weight)	0.13	1.74
104	Incineration of waste: Metals	Waste treatment	kg waste (dry weight)	0.01	0.12
105	Incineration of waste: Glass/inert	Waste treatment	kg waste (dry weight)	0.01	0.12
106	Incineration of waste: Textiles	Waste treatment	kg waste (dry weight)	0.13	1.70
107	Incineration of waste: Wood	Waste treatment	kg waste (dry weight)	0.13	1.68
108	Incineration of waste: Oil/Hazardous waste	Waste treatment	kg waste (dry weight)	0.35	3.01
109	Manure treatment, conventional storage	Waste treatment	kg waste (dry weight)	0.34	4.08
110	Manure treatment, biogas	Waste treatment	kg waste (dry weight)	0.23	3.13
111	Biogasification of food waste	Waste treatment	kg waste (dry weight)	-0.03	0.14
112	Biogasification of paper	Waste treatment	kg waste (dry weight)	0.04	0.88
113	Biogasification of sewage slugde	Waste treatment	kg waste (dry weight)	-0.03	0.14
114	Composting of food waste	Waste treatment	kg waste (dry weight)	0.18	2.11
115	Composting of paper and wood	Waste treatment	kg waste (dry weight)	0.17	2.04
116	Waste water treatment, food	Waste treatment	kg waste (dry weight)	0.29	3.05
117	Waste water treatment, other	Waste treatment	kg waste (dry weight)	0.24	2.43
118	Landfill of waste: Food	Waste treatment	kg waste (dry weight)	0.21	2.34
119	Landfill of waste: Paper	Waste treatment	kg waste (dry weight)	0.15	1.73
120	Landfill of waste: Plastic	Waste treatment	kg waste (dry weight)	0.02	0.17
121	Landfill of waste: Iron	Waste treatment	kg waste (dry weight)	0.01	0.07
122	Landfill of waste: Alu	Waste treatment	kg waste (dry weight)	0.01	0.07
123	Landfill of waste: Copper	Waste treatment	kg waste (dry weight)	0.01	0.07
124	Landfill of waste: Metals nec	Waste treatment	kg waste (dry weight)	0.01	0.07
125	Landfill of waste: Glass/inert	Waste treatment	kg waste (dry weight)	0.01	0.07
126	Landfill of waste: Mine waste	Waste treatment	kg waste (dry weight)	0.01	0.07
127	Landfill of waste: Textiles	Waste treatment	kg waste (dry weight)	0.09	1.05
128	Landfill of waste: Wood	Waste treatment	kg waste (dry weight)	0.02	0.21
129	Landfill of waste: Oil/Hazardous waste	Waste treatment	kg waste (dry weight)	0.01	0.07
130	Landfill of waste: Slag/ash	Waste treatment	kg waste (dry weight)	0.01	0.07
131	Land application of manure	Waste treatment	kg waste (dry weight)	0.08	1.15
132	Land application of compost	Waste treatment	kg waste (dry weight)	0.14	1.76
133	Membership organisations	Service	EUR2003	0.08	0.67
134	Recreational and cultural services	Service	EUR2003	0.07	0.58
135	Services n.e.c.	Service	EUR2003	0.07	0.64
136	Household use: Clothing	Household	EUR2003	0.18	1.57
137	Household use: Communication	Household	EUR2003	0.18	1.33
138	Household use: Education	Household	EUR2003	0.05	0.40
139	Household use: Health care	Household	EUR2003	0.06	0.49
140	Household use: Housing	Household	EUR2003	0.13	1.17
141	Household use: Hygiene	Household	EUR2003	0.38	3.62
142	Household use: Leisure	Household	EUR2003	0.15	1.21
143	Household use: Meals	Household	EUR2003	0.23	2.09
144	Household use: Security	Household	EUR2003	0.05	0.43
145	Household use: Social care	Household	EUR2003	0.05	0.43

Table 3.11 (part 3 of 3): Environmental impact (monetarised and GHG-emissions) per unit of all products in the FORWAST model. GHG-emissions are calculated without distinguishing between biogenic and fossil CO_2, and plant uptake of atmospheric carbon is included as CO_2 emission with negative sign.

3.3.2 Environmental impacts per unit of products (special case where biogenic CO2 is regarded having no impacts)

In the table below the environmental impacts (monetarised and GHG-emissions) are shown per unit for all products in the FORWAST model. GHG-emissions are calculated without inclusion of negative impacts from plant uptake of atmospheric carbon and positive impacts from emissions of biogenic CO_2.

Note: Impacts from plant uptake of atmospheric carbon and emissions of biogenic CO2 are excluded					
Product no.	**Product name**	**Product type**	**Unit**	**Monetarised environmental impact per unit pf product (EUR2003)**	**GHG-emissions per unit of product (kg CO2-eq)**
1	Bovine meat and milk	Physical	kg (dry weight)	1.88	20.07
2	Pigs	Physical	kg (dry weight)	1.06	10.68
3	Poultry and animals n.e.c.	Physical	kg (dry weight)	1.51	15.07
4	Grain crops	Physical	kg (dry weight)	0.06	0.59
5	Crops n.e.c.	Physical	kg (dry weight)	0.16	1.57
6	Agricultural services n.e.c.	Service	EUR2003	0.24	1.88
7	Forest products	Physical	kg (dry weight)	0.01	0.07
8	Recycling of waste wood	Waste treatment	kg waste (dry weight)	0.00	-0.01
9	Fish	Physical	kg (dry weight)	1.51	10.03
10	Coal, lignite, peat	Physical	kg (dry weight)	0.01	0.09
11	Crude petroleum and natural gas	Physical	kg (dry weight)	0.01	0.13
12	Iron ores from mine	Physical	kg (dry weight)	0.01	0.05
13	Bauxite from mine	Physical	kg (dry weight)	0.04	0.38
14	Copper from mine	Physical	kg (dry weight)	0.03	0.23
15	Metals from mine n.e.c.	Physical	kg (dry weight)	0.02	0.20
16	Sand, gravel and stone from quarry	Physical	kg (dry weight)	0.00	0.01
17	Clay and soil from quarry	Physical	kg (dry weight)	0.00	0.02
18	Minerals from mine n.e.c.	Physical	kg (dry weight)	0.00	0.02
19	Meat and fish products	Physical	kg (dry weight)	2.34	22.54
20	Dairy products	Physical	kg (dry weight)	2.30	23.58
21	Fruits and vegetables, processed	Physical	kg (dry weight)	0.61	5.71
22	Vegetable and animal oils and fats	Physical	kg (dry weight)	0.29	2.84
23	Flour	Physical	kg (dry weight)	0.14	1.34
24	Sugar	Physical	kg (dry weight)	0.30	2.93
25	Animal feeds	Physical	kg (dry weight)	0.27	2.58
26	Food preparations n.e.c.	Physical	kg (dry weight)	1.34	12.80
27	Beverages	Physical	kg (dry weight)	1.70	15.66
28	Tobacco products	Physical	kg (dry weight)	0.97	8.85
29	Textiles	Physical	kg (dry weight)	1.19	10.42
30	Wearing apparel and furs	Physical	kg (dry weight)	2.20	19.06
31	Leather products, footwear	Physical	kg (dry weight)	2.36	20.92
32	Wood products, except furniture	Physical	kg (dry weight)	0.11	0.80
33	Pulp, virgin	Physical	kg (dry weight)	0.13	1.00
34	Recycling of waste paper	Waste treatment	kg waste (dry weight)	-0.05	-0.25
35	Paper and paper products	Physical	kg (dry weight)	0.28	2.32
36	Printed matter and recorded media	Physical	kg (dry weight)	0.63	5.20
37	Refined petroleum products and fuels	Physical	kg (dry weight)	0.05	0.41
38	Recycling of waste oil	Waste treatment	kg waste (dry weight)	-0.04	-0.37
39	Fertiliser, N	Physical	kg (dry weight)	0.40	3.74
40	Fertiliser, other than N	Physical	kg (dry weight)	0.15	1.30
41	Plastics basic, virgin	Physical	kg (dry weight)	0.37	3.16
42	Recycling of plastics basic	Waste treatment	kg waste (dry weight)	-0.25	-2.14
43	Chemicals n.e.c.	Physical	kg (dry weight)	0.26	2.24
44	Rubber and plastic products	Physical	kg (dry weight)	0.87	7.40
45	Glass, mineral wool and ceramic goods, vi	Physical	kg (dry weight)	0.23	1.92
46	Recycling of glass, mineral wool and cerar	Waste treatment	kg waste (dry weight)	-0.13	-1.07

Table 3.12 (part 1 of 3): Environmental impact (monetarised and GHG-emissions) per unit of all products in the FORWAST model. GHG-emissions are calculated without inclusion of negative impacts from plant uptake of atmospheric carbon and positive impacts from emissions of biogenic CO_2.

Note: Impacts from plant uptake of atmospheric carbon and emissions of biogenic CO2 are excluded					
Product no.	**Product name**	**Product type**	**Unit**	**Monetarised environmental impact per unit pf product (EUR2003)**	**GHG-emissions per unit of product (kg CO2-eq)**
47	Cement, virgin	Physical	kg (dry weight)	0.09	0.88
48	Recycling of slags and ashes	Waste treatment	kg waste (dry weight)	-0.07	-0.73
49	Concrete, asphalt and other mineral produ	Physical	kg (dry weight)	0.02	0.21
50	Recycling of concrete, asphalt and other n	Waste treatment	kg waste (dry weight)	0.02	0.15
51	Bricks	Physical	kg (dry weight)	0.04	0.34
52	Recycling of bricks	Waste treatment	kg waste (dry weight)	-0.04	-0.32
53	Iron basic, virgin	Physical	kg (dry weight)	0.23	2.08
54	Recycling of iron basic	Waste treatment	kg waste (dry weight)	-0.07	-0.63
55	Aluminium basic, virgin	Physical	kg (dry weight)	1.00	8.30
56	Recycling of aluminium basic	Waste treatment	kg waste (dry weight)	-0.66	-5.33
57	Copper basic, virgin	Physical	kg (dry weight)	0.80	6.87
58	Recycling of copper basic	Waste treatment	kg waste (dry weight)	-0.21	-2.25
59	Metals basic, n.e.c., virgin	Physical	kg (dry weight)	0.36	2.32
60	Recycling of metals basic, n.e.c.	Waste treatment	kg waste (dry weight)	-0.22	-1.29
61	Iron, after first processing	Physical	kg (dry weight)	0.34	3.06
62	Aluminium, after first processing	Physical	kg (dry weight)	1.82	15.17
63	Copper, after first processing	Physical	kg (dry weight)	0.97	8.28
64	Metals n.e.c., after first processing	Physical	kg (dry weight)	1.75	13.07
65	Fabricated metal products, except machin	Physical	kg (dry weight)	0.54	4.62
66	Machinery and equipment n.e.c.	Physical	kg (dry weight)	0.79	6.64
67	Office machinery and computers	Physical	kg (dry weight)	3.63	30.20
68	Electrical machinery n.e.c.	Physical	kg (dry weight)	0.66	5.63
69	Radio, television and communication equip	Physical	kg (dry weight)	1.26	10.53
70	Instruments, medical, precision, optical, cl	Physical	kg (dry weight)	3.01	24.64
71	Motor vehicles and trailers	Service	EUR2003	0.10	0.84
72	Transport equipment n.e.c.	Service	EUR2003	0.07	0.59
73	Furniture and other manufactured goods n.	Physical	kg (dry weight)	0.53	4.33
74	Recycling services	Service	EUR2003	0.56	4.51
75	Electricity, steam and hot water	Physical	kWh	0.06	0.51
76	Gas	Physical	kg (dry weight)	0.05	0.47
77	Water, fresh	Service	EUR2003	0.15	1.27
78	Buildings, residential	Service	EUR2003	0.12	1.04
79	Buildings, non-residential	Service	EUR2003	0.11	0.95
80	Infrastructure, excluding buildings	Service	EUR2003	0.19	1.64
81	Trade and repair of motor vehicles and ser	Service	EUR2003	0.07	0.57
82	Wholesale trade	Service	EUR2003	0.07	0.56
83	Retail trade and repair services	Service	EUR2003	0.06	0.55
84	Hotels and restaurants	Service	EUR2003	0.11	1.03
85	Land transport and transport via pipelines	Service	EUR2003	0.53	3.68
86	Transport by ship	Service	EUR2003	1.05	4.59
87	Air transport	Service	EUR2003	0.28	2.03
88	Cargo handling, harbours and travel agenci	Service	EUR2003	0.13	1.00
89	Post and telecommunication	Service	EUR2003	0.05	0.41
90	Financial intermediation	Service	EUR2003	0.03	0.28
91	Insurance and pension funding	Service	EUR2003	0.04	0.34
92	Services auxiliary to financial intermediatio	Service	EUR2003	0.04	0.31
93	Real estate services	Service	EUR2003	0.08	0.68
94	Renting of machinery and equipment etc.	Service	EUR2003	0.03	0.31
95	Computer and related services	Service	EUR2003	0.05	0.45
96	Research and development	Service	EUR2003	0.07	0.59
97	Business services n.e.c.	Service	EUR2003	0.06	0.47
98	Public service and security	Service	EUR2003	0.06	0.48
99	Education services	Service	EUR2003	0.05	0.40
100	Health and social work	Service	EUR2003	0.05	0.43

Table 3.12 (part 2 of 3): Environmental impact (monetarised and GHG-emissions) per unit of all products in the FORWAST model. GHG-emissions are calculated without inclusion of negative impacts from plant uptake of atmospheric carbon and positive impacts from emissions of biogenic CO_2.

Note: Impacts from plant uptake of atmospheric carbon and emissions of biogenic CO2 are excluded					
Product no.	Product name	Product type	Unit	Monetarised environmental impact per unit pf product (EUR2003)	GHG-emissions per unit of product (kg CO2-eq)
101	Incineration of waste: Food	Waste treatment	kg waste (dry weight)	-0.02	-0.14
102	Incineration of waste: Paper	Waste treatment	kg waste (dry weight)	-0.02	-0.15
103	Incineration of waste: Plastic	Waste treatment	kg waste (dry weight)	0.13	1.75
104	Incineration of waste: Metals	Waste treatment	kg waste (dry weight)	0.02	0.13
105	Incineration of waste: Glass/inert	Waste treatment	kg waste (dry weight)	0.02	0.13
106	Incineration of waste: Textiles	Waste treatment	kg waste (dry weight)	-0.02	-0.14
107	Incineration of waste: Wood	Waste treatment	kg waste (dry weight)	-0.02	-0.18
108	Incineration of waste: Oil/Hazardous waste	Waste treatment	kg waste (dry weight)	0.35	3.04
109	Manure treatment, conventional storage	Waste treatment	kg waste (dry weight)	0.24	2.84
110	Manure treatment, biogas	Waste treatment	kg waste (dry weight)	0.13	1.96
111	Biogasification of food waste	Waste treatment	kg waste (dry weight)	-0.19	-1.73
112	Biogasification of paper	Waste treatment	kg waste (dry weight)	-0.07	-0.53
113	Biogasification of sewage slugde	Waste treatment	kg waste (dry weight)	-0.19	-1.73
114	Composting of food waste	Waste treatment	kg waste (dry weight)	0.02	0.20
115	Composting of paper and wood	Waste treatment	kg waste (dry weight)	0.01	0.11
116	Waste water treatment, food	Waste treatment	kg waste (dry weight)	0.27	2.78
117	Waste water treatment, other	Waste treatment	kg waste (dry weight)	0.22	2.24
118	Landfill of waste: Food	Waste treatment	kg waste (dry weight)	0.18	2.09
119	Landfill of waste: Paper	Waste treatment	kg waste (dry weight)	0.14	1.54
120	Landfill of waste: Plastic	Waste treatment	kg waste (dry weight)	0.02	0.18
121	Landfill of waste: Iron	Waste treatment	kg waste (dry weight)	0.01	0.08
122	Landfill of waste: Alu	Waste treatment	kg waste (dry weight)	0.01	0.08
123	Landfill of waste: Copper	Waste treatment	kg waste (dry weight)	0.01	0.08
124	Landfill of waste: Metals nec	Waste treatment	kg waste (dry weight)	0.01	0.08
125	Landfill of waste: Glass/inert	Waste treatment	kg waste (dry weight)	0.01	0.08
126	Landfill of waste: Mine waste	Waste treatment	kg waste (dry weight)	0.01	0.08
127	Landfill of waste: Textiles	Waste treatment	kg waste (dry weight)	0.08	0.94
128	Landfill of waste: Wood	Waste treatment	kg waste (dry weight)	0.02	0.20
129	Landfill of waste: Oil/Hazardous waste	Waste treatment	kg waste (dry weight)	0.01	0.08
130	Landfill of waste: Slag/ash	Waste treatment	kg waste (dry weight)	0.01	0.08
131	Land application of manure	Waste treatment	kg waste (dry weight)	-0.05	-0.34
132	Land application of compost	Waste treatment	kg waste (dry weight)	-0.02	-0.19
133	Membership organisations	Service	EUR2003	0.08	0.70
134	Recreational and cultural services	Service	EUR2003	0.07	0.63
135	Services n.e.c.	Service	EUR2003	0.08	0.70
136	Household use: Clothing	Household	EUR2003	0.19	1.61
137	Household use: Communication	Household	EUR2003	0.18	1.36
138	Household use: Education	Household	EUR2003	0.05	0.42
139	Household use: Health care	Household	EUR2003	0.06	0.52
140	Household use: Housing	Household	EUR2003	0.14	1.22
141	Household use: Hygiene	Household	EUR2003	0.39	3.66
142	Household use: Leisure	Household	EUR2003	0.16	1.34
143	Household use: Meals	Household	EUR2003	0.26	2.45
144	Household use: Security	Household	EUR2003	0.06	0.46
145	Household use: Social care	Household	EUR2003	0.05	0.45

Table 3.12 (part 3 of 3): Environmental impact (monetarised and GHG-emissions) per unit of all products in the FORWAST model. GHG-emissions are calculated without inclusion of negative impacts from plant uptake of atmospheric carbon and positive impacts from emissions of biogenic CO_2.

4 Uncertainty assessment

In this section limitations of the model and uncertainties are assessed. This includes a specification of the sources of uncertainty in the model, and an assessment of each of these sources.

4.1 Sources of uncertainty

Throughout the following deliverables, uncertainties has been described when they are present relating to the specific issues covered in these reports:

- D3-1 'Report describing data processing and validation': 4 countries
- D4-1 'Report describing data processing and validation': 23 countries
- D6-1 'Documentation of the data consolidation and calibration exercise, and the scenario parameterisation'
- D6-2 '25-year forecasts of the cumulated physical stocks, waste generation, and environmental impacts for each scenario for EU-27 and for the case study countries'
- D6-3 'Documentation of the contribution analysis and uncertainty assessment. Results interpretation identifying priority material flows and wastes for waste prevention, recycling and choice of waste treatment options. Policy recommendations'
- D6-4 'Documentation of the final model used for the scenario analyses'

The list below summarises the main sources of uncertainty in the FORWAST model:

1. Limitations in data collection
2. National monetary supply-use tables
3. Conversion to basic prices
4. Data on physical domestic supply and trade
5. Disaggregation of monetary SUTs
6. Data on the physical use of products
7. Emissions
8. Resources
9. Waste treatment mix for different waste fractions
10. Scenario implementation: Physical and non-physical products
11. Scenario implementation: Energy efficiencies
12. Waste module
13. Life time of products
14. Level of aggregation

4.2 Limitations in data collection

The model calculations are based on data collection for 20 of the 27 EU-27 countries, see Table 4.1.

Country code	Country	Included (x)	Data level	GDP share
AT	Austria		117x117	2%
BE	Belgium	x	57x57	3%
BG	Bulgaria	x	57x57	0.2%
CY	Cyprus	x	57x57	0.1%
CZ	Czech Republic	x	57x57	1%
DE	Germany		117x117	21%
DK	Denmark	x	117x117	2%
EE	Estonia	x	57x57	0%
ES	Spain		117x117	8%
FI	Finland	x	57x57	1%
FR	France	x	117x117	16%
GR	Greece	x	117x117	2%
HU	Hungary	x	57x57	1%
IE	Ireland		57x57	1%
IT	Italy		57x57	13%
LT	Lithuania	x	57x57	0.2%
LU	Luxembourg	x	57x57	0.3%
LV	Latvia	x	57x57	0.1%
MT	Malta	x	57x57	0.04%
NL	Netherlands	x	117x117	5%
PL	Poland	x	117x117	2%
PT	Portugal	x	57x57	1%
RO	Romania	x	57x57	1%
SE	Sweden	x	117x117	3%
SI	Slovenia		117x117	0.3%
SK	Slovakia	x	57x57	0.3%
UK	United Kingdom		117x117	16%
38% of EU27 GDP is included				100%

Table 4.1: Overview of the data used for the creation of the EU-27 supply-use table used in the model calculations.

The effect of this limitation in the data used for the creation of the EU-27 supply-use table used in the model calculations has the following effects on uncertainties in the model:

- The ratio between domestic production (in EU-27) and import (to EU-27) is based on the data available for the 20 of the EU-27 countries on which the EU-27 is created. These countries only represent 38% of the EU-27 GDP. Therefore, large uncertainties on the split between domestic production and import are present; the volume of domestic production and related wastes and emissions is therefore uncertain
- The representativeness of results (waste and emissions) is based on 38% of EU-27 economy

4.3 National monetary supply-use tables

The starting point for the data collection for most countries is national supply-use tables (SUT) from Eurostat at level 60 products x 60 activities. Some SUTs were not available for the reference year 2003. In these cases the nearest year has been chosen, and the SUTs are scaled due to GDP for that year relative to year 2003. Other SUTs from Eurostat are not complete, i.e. some columns or rows are empty. These missing data have been filled using data from other countries combined with other data concerning the specific products/activities.

Generally, the 60x60 SUTs have been complete and available for 2003. Therefore, the uncertainties related to the above mentioned operations are assessed as being insignificant.

4.4 Conversion to basic prices

The procedure for converting the use table in purchasers prices to basic prices is described in deliverable D6-4. The procedure is a generalised method which does not take into account that margins and taxes may be different over activities. Therefore, uncertainties in the transactions in the monetary use table may occur. This may affect the use of service products (monetary) as well as it may indirectly affect the use of physical products because the monetary uses to some extent are used to distribute the physical use into the physical use table. In this respect it should be noted that uncertainties in the use of service products does only have an effect on the environmental impacts – not the generation of waste and accumulated stocks. The use of physical products is further adjusted as part of ensuring consistency in physical SUTs. The uncertainties related to the conversion to basic prices are assessed as not being significant.

4.5 Data on physical domestic supply and trade

Physical SUTs are created based on data on physical domestic supply and trade. Data on trade with physical products is generally good. For domestic production, data availability and data quality is assessed as being good for the following product categories:

- Agriculture
- Forestry
- Fishery
- Mining of metals
- Extraction of energy resources (coal, gas and crude oil)
- Refined petroleum products
- Electricity
- Pulp and paper
- Cement
- Basic metals

Data on the following product categories are assessed of being on a poorer level of quality, and often these data are not available for domestic production:

- Extraction of sand, gravel and non-metal minerals
- Food products from food industry
- Textiles
- Plastics
- Glass
- Chemicals
- Fertilisers
- Wood products
- Construction materials
- Machinery, equipment, instruments, furniture etc.

According to deliverable D6-2, the most significant environmental impacts are caused by emissions taking place within the activities for which data quality is good. Regarding waste, the most significant waste flows are related to construction waste and sand, gravel. Therefore, significant uncertainties are present in this respect.

4.6 Disaggregation of monetary SUTs

For most countries the starting point for data collection is the 60x60 monetary SUTs from Eurostat. These tables are disaggregated into 117x117 tables in order to fit with FORWAST product and activity categories. This is done for the countries which follow work package 3 (WP3) scope of data collection:

- Denmark
- France
- Greece
- Netherlands
- Poland
- Sweden

The remaining countries are disaggregated based on disaggregation factors obtained from the above mentioned scope WP3 countries.

The procedure for disaggregation is described in D6-4, and it ensures maintenance of product and activity balances and it prevents inconsistencies in economy to be introduced, e.g. that the total sum of all disaggregated products/activities is the same as the starting point and that it is prevented that some activities uses too much of certain products so that other activities would have to have negative uses.

Generally, there are three types of input data for the disaggregation of monetary SUTs:

1. Total supply (domestic production and import per product category)
2. Coefficients specifying the distribution of supplies
3. Coefficients specifying the distribution of uses

The **first type** of input data for disaggregation are the total monetary supply (domestic production + import) of all products. These disaggregation coefficients are most often based on detailed national and trade statistics as well as physical statistics combined with price information. Generally, there are good data on trade, but for some product categories information on domestic production is not available in some cases. Categories where this apply are (all the Eurostat categories that are disaggregated can be seen in Appendix 2: Disaggregation of Eurostat 60x60 SUTs):

- Food products and beverages => disaggregated to 12 categories
- Chemicals, chemical products and man-made fibres => disaggregated to 5 categories
- Other non-metallic mineral products => disaggregated to 8 categories

In some cases this lack of data has been compensated for by assuming a similar distribution of the total supply of products within the category to be disaggregated as for other countries. In other cases, physical data have been identified, and this has then been converted to monetary supplies using price information.

The uncertainties related to the lack of data and estimates described above are generally not significant; uncertainties in the total supply will only move some products from one activity to another, and the production functions (inputs and outputs per supply of an activity) is not affected by this.

The **second type** of data input to the disaggregation are the coefficients specifying the distribution of supplies. The major role of these data are 1) within the disaggregated products, to distinguish between domestically produced products and imported products, and 2) to distinguish virgin production (diagonal supply) from recycled supply (off-diagonal supply of a product from a recycling activity). The data sources used for specifying the import of products are trade data. These data are generally of a good quality. The data sources used to distinguish virgin from recycled production are typically production statistics and waste statistics. The preferable data source is production statistics because this directly specifies the split between virgin and recycled. These data are typically available for pulp (CEPI 2004), but for other materials which are supplied both from virgin production and recycling, such data are generally not available. In these cases, data on the amount collected for recycling in waste statistics have been used. These data are then multiplied with a factor representing the efficiency of the recycling process, e.g. 0.9 means than 90% of the recycled iron scrap becomes supply of new iron. Data on collected waste for recycling is available for some waste flows in most countries; typically glass waste, plastic waste, and metal waste. Very little information exists on the recycling of wood and demolition waste as well as slag and ash waste. Hence, the latter is estimated for some countries.

The uncertainties described above influences the split between recycling and virgin product, and also indirectly how much waste is sent to other waste treatment activities (if iron waste is recycled, then it is not sent to e.g. landfill). Therefore, these uncertainties have a significant effect on the quantity of waste sent to recycling, incineration, landfill, and the derived effects of this on the environmental impacts. In traditional IO-analysis, the overall impact should not be affected, but in the FORWAST project, the waste treatment activities (incineration, landfill, biogas) are created as normalised modules, meaning that a full coherence with national emissions accounts are not ensured. However, as in the case of the first type of disaggregation data, this does not affect the production functions of the activities (inputs and outputs per supply of an activity).

The **third type** of data input to the disaggregation are the coefficients specifying the distribution of uses. The major role of these data are to specify the production function of the activities, i.e. the inputs and outputs per unit of supply. The main adjustments are carried out for the use of different feedstocks, e.g. when agriculture is disaggregated, it is ensured that ‘pigs’ use animal feed, and ‘grain crops’ do not. Also the uses of fuels and electricity is specified, e.g. when the activity virgin production of aluminium uses more electricity per unit of supply of aluminium than recycling of aluminium waste. This type of input data to the disaggregation is based on engineering/chemical/agronomic knowledge on different manufacturing processes (often obtained from life cycle assessments). The physical information obtained from engineering/chemical/agronomic knowledge is converted to monetary units using price information.

The uncertainties related to the determination of coefficients specifying the distribution of uses are significant. The data sources are seldom country specific, e.g. data on fuel uses in cement production in an LCA (ecoinvent 2007) may not correspond to the specific mix of fuels used in the different countries for which monetary SUTs are disaggregated. However, it should be noted, that the uncertainty only concerns the distribution of products within the disaggregated product categories, therefore, an underestimated use of coal in cement production will then result in an overestimation of the use of coal for glass, concrete, and bricks. Thus, the overall waste generation and environmental impacts of the model is not affected by this – the uncertainty only concerns which activities are contributing with waste generation and emissions.

4.7 Data on the physical use of products

Generally, data on the use of products are not available or they are of poor quality. Monetary uses have to some extent been used to distribute the total physical domestic use over activities in economy. The uncertainty related to this does not differ from an ordinary monetary input-output based life cycle analysis, which by definition does not take into account differences in prices over activities. Differences in prices becomes an issue when dealing with supply-use tables in physical units. This uncertainty is eliminated/minimised for all uses of feedstock products since the accounting framework described in deliverable 6-4 allows for the calculation of feedstock efficiencies (the **D** table) and the calculation of the supply of residuals ($\mathbf{W}_V$ table). For all feedstocks it is ensured that 1) no negative waste occurs, and 2) the feedstock efficiency lies within normal range, e.g. approx 10% of the feed input to bovines become bovine meat and milk. Further, it is checked whether the fuel uses and electricity uses lies within normal ranges. Normal ranges for feedstock efficiencies, fuel uses, and electricity uses are identified based on general experiences, and in various life cycle assessment studies, mainly in the ecoinvent database (ecoinvent 2007).

In most cases, the use of feedstocks and energy contributes to the most significant environmental impacts. The uncertainties related to these issues are minimised through the above mentioned procedure. Still some uncertainties may be present for environmental impacts.

For waste generation, the uncertainties relating to the distribution of physical use of products only affect where in economy the waste is generated – not the total quantity.

4.8 Emissions

For most countries, the national emissions tables (for 60 or 117 activities in economy) are created based on country submissions to the UNFCCC. The activities for which emissions data are specified in the UNFCCC national accounts are more aggregated than the FORWAST activity categories. Therefore, data on emissions within a certain aggregated activity, e.g. agriculture, have been disaggregated in to the FORWAST categories of agriculture using animal metabolism for respiratory emissions (e.g. enteric fermentation), physical uses of fuels for emissions originating from coal, refined petroleum, and gas etc. Thus, uncertainties in emissions are related to the same uncertainties as the UNFCCC emissions inventories, the physical uses of fuels in the physical use tables, as well as animal metabolism balances. Therefore, emissions data does not add new uncertainties into the model – it is rather the physical data in the model (supply-use), that determines the uncertainties in emissions.

4.9 Resources

Resource uses are obtained from production statistics and resource statistics, and resource inputs are aligned with the supply from resource extracting activities, e.g. a mining activity supplies the same amount of mining products as the activity extracts (when not taking into account the loss of resource inputs as emissions and waste).

4.10 Waste treatment mix for different waste fractions

Waste generation is a model output. All generated waste per activity is categorised into waste fractions, and the waste fractions are directed to different waste treatments; recycling, incineration landfill etc. The direction of the waste fractions is based on information in the so-called residuals distribution table (**J**-table) which is created as part of the data collection exercise for each country. For each type of waste in the model, the **J**-table specifies the waste treatment, e.g. 30% to recycling, 40% to incineration, 10% to landfill, and 20% exported for recycling. The sum is 100%. The creation of the **J**-table is based on information in national waste statistics. For many waste fractions, national waste statistics are incomplete, i.e. less waste than actual flows are reported (see section 2.2). Especially, non registered landfill of construction materials, and unauthorised disposal of food waste (home composting, and other unauthorised disposal) is lacking in national waste statistics. This means that when national statistics report that X tonne of food waste is incinerated, and that the total quantity of food waste is Y, then the percentage directed to waste incineration in the **J**-table will be too large because the denominator (Y) is underestimated. Since it is most often unauthorised landfill that is lacking in the waste statistics, then it is likely, that other waste treatment options than landfill will be overestimated, and landfill will be underestimated.

The above mentioned uncertainty only relates to the distribution between the following waste treatments:

- Incineration
- Biogasification
- Composting
- Landfill

All other waste treatments are based on either the supply table (the supply table specifies the quantity of recycled material = supply of recycled material / recycling efficiency) or the fact that 100% of a given waste fraction is directed to a certain waste treatment, e.g. 100% of manure is sent to manure treatment.

The above mentioned uncertainties are identified as being significant for the following waste fractions:

- The share of food waste sent to incineration is overestimated
- The share of chemical/hazardous waste sent to incineration is overestimated
- The share of construction/demolition waste sent to incineration is overestimated

For food waste the implication is that a significant proportion of food related products are related to incineration of food. If the **J**-table provided better information, it is expected that more food waste would be landfilled, disposed via waste water and more food waste would be disposed of unauthorised to home composting and other places (in nature).

If the **J**-table provided better information for chemical/hazardous waste, it is expected that more chemical waste would be landfilled.

The implication of the fact that the share of construction/demolition waste sent to incineration is overestimated is that the generation of slag and ash from waste incineration is significantly overestimated, e.g. see generation of slag and ash in activity ‘waste treatment’ in Table 2.1.

4.11 Scenario implementation: Physical and non-physical products

The scenario implementation of the nine scenarios in the FORWAST project is described in deliverable D6-1: ‘Documentation of data consolidation, calibration and scenario parameterisation’. In the macro-economic scenarios all physical activities are scaled with an aggregated TMR-factor (see D6-1) and all service activities are scaled with a GDP-factor. The use of the same TMR-factor for all physical activities, corresponds to assuming the all these activities have developed equally. This assumption is related to uncertainties.

4.12 Scenario implementation: Energy-efficiencies

The scenario implementation of the nine scenarios in the FORWAST project is described in deliverable D6-1. In the macro-economic scenarios, the changes in energy efficiencies for different activities over time are identified using two different data sources for the numerator (use of energy by the activity) and the denominator (supply of products by the activity) in the calculation of energy use per supply. This introduces a source of uncertainty. In D6-1 a cross check with other data sources shows relative good coherence between emissions calculated in the applied method and in the data cross check approach. However, some emissions turn out to be significant larger in the applied approach: CO_2 per kWh from coal fires power plants in year 2035. This uncertainty is estimated as being significant.

4.13 Waste module

The waste module describing all inputs and outputs for waste treatment activities is described in deliverable D5-4: ‘Description of the environmental pressures from waste treatment’. Especially two issues relating to the waste modules are regarded as being related to large uncertainties:

1. Energy efficiency of waste incineration: It is assumed that 10% of the calorific value (lower heat value) of the incinerated waste is recovered and supplied as ’75 Electricity, steam and hot water’. This is highly uncertain; Danish incineration plants utilise approx 90% of the energy content in waste while some countries have incineration plants which do not recover the energy in waste.
2. Manure treatment: It is assumed that the used technology can be represented by anaerobic pond (storage) and broad spreading for land application technique. This does apply to to the used technology in all countries. Another issue which is related to uncertainties is the dry matter content of manure. The data used for estimating emission factors from storage assume 4% DS content while the manure in the FORWAST project operates with 7-12% DS. Therefore, the emissions per wet weight which determines the emissions in the used data, are overestimated in the FORWAST project.

The uncertainties referred to above are assessed as being significant.

4.14 Life time of products

The life time of products are used to determine when uses of products become waste. Since the economic growth is increasing, underestimation of life times results in overestimation of waste generation. As described in section 2.2 many discrepancies between FORWAST results on waste generation and figures in waste statistics are assessed to be related to underestimated product life times.

4.15 Level of aggregation

The FORWAST model includes 145 product categories of which 59 are measured in physical mass, i.e. these products are sources of waste. Given the high number of waste fractions, especially for hazardous wastes, it is clear that the FORWAST categories for these wastes are not sufficient for a good description. Therefore, the FORWAST model, at the current level of detail, is only sufficient in providing information on bulk wastes (non-hazardous). And still within these bulk wastes, there are special fractions that are not described in the model, e.g. different qualities of wastes and scrap fro recycling.

4.16 Conclusion on the uncertainty assessment

Based on the description of uncertainties presented in this section, the following uncertainties are regarded as the most significant:

- Uncertainties relating to the split between EU-27 domestic production and import to the EU-27 causes uncertainties relating to figures on waste generation occurring within the EU-27 versus waste generation occurring outside the EU-27
- Uncertainties relating to disaggregation of monetary supply-use tables and data on physical uses causes uncertainties in waste and emissions per unit of supply for the product categories in the FORWAST model
- Applied waste treatment mix overestimates to share of waste sent to waste incineration (especially food and construction)
- Scenario implementation leads to overestimation of emissions related to coal based electricity in future scenarios
- Uncertainties in waste module causes overestimated emissions from manure treatment and uncertain modelling relating to energy recovery of waste incineration (large variability depending on country)
- Underestimated product life times (especially construction materials) causes overestimation of waste quantities
- The level of aggregation of the FORWAST model prevents the approach for being used for providing data on special waste fractions and hazardous waste

Significant uncertainties have been identified. But still, model results on future scenarios can be used for obtaining information on the developments in waste flows and environmental impacts given different macro-economic developments and different waste treatment strategies. Especially, the relative differences between scenarios are not affected by the major sources of uncertainties. Also information on the environmental impacts per product for year 2003 are appropriate for use in input-output and hybrid LCA. In this respect, it should be noted that the uncertainties in the FORWAST model are estimated as being less significant than in traditional economic input-output tables because the FORWAST model takes into account differences in prices over activities as well as physical inconsistencies are eliminated.

5 Identification of priority material flows

This section analyses the potential effects of different police instrument applied on different material flows. When identifying priority materials, the criteria is minimisation of the total monetarised environmental impact. This is composed of two factors:

1. Environmental impact per unit of product applying the desired technology
2. Total quantity of the material flow at which the desired technology is applied (this is a combination of the total quantity and the constraints for applying the desired technology on 100% of the material flow)

The identification of priority material flows is carried out in two sections in the following. The first section focuses on priority materials for waste treatment and recycling, and the second section focuses on priority materials for prevention.

5.1 Identification of priority material flows for treatment and recycling

This section analyses the potential reductions in environmental impact by different means of recycling/treatment. The analysis presented in the following is based on the reduction if 100% recycling is achieved. This does not represent realistic recycling rates in reality, but the analysis indicates theoretical potentials which can be used to prioritise future policy interventions.

Table 5.1 shows the total quantity of all waste fractions for which different treatment technologies are considered within the FORWAST project. The waste fractions and their quantity are specified in the columns: ‘Waste fraction’ and ‘Quantity, dry weight (million tonne)’. The column ‘Waste treatment’ specifies the current mix of specific waste treatment options for each waste fraction in year 2003 in EU-27. The column ‘Specific impact (EUR/kg)’ specifies the monetarised impact per dry kilogram of treated waste for different waste treatment options and waste fractions. The column ‘Impact (billion EUR)’ is calculated by multiplying the following three columns:

- ‘Quantity, dry weight (million tonne)’
- ‘Waste treatment’ (%)
- ‘Specific impact (EUR/kg)’

The sum of the column ‘Impact (billion EUR)’ in the bottom of the table shows the total monetarised impact related to the treatment of the waste fractions in the table in EU-27 in year 2003.

The column ‘Impact if all waste is treated with specific waste treatment (billion EUR)’ specifies the monetarised impact if 100% of the waste fraction is treated using the treatment technology in the row, e.g. if 100% of all ‘Food waste’ is landfilled, then the impact associated with this would be 108 billion EUR. The next column ‘Potential, if all waste is treated with specific treatment minus current mix (billion EUR)’ specifies the theoretical potential environmental effect, if the current mix of treatments of a given waste fraction is displaced with the treatment in a given row. E.g. if all ‘Food waste’ is landfilled, then this would increase the current environmental impact from treatment of food waste from 53+31+7.8-0.013= 92 to 108, i.e. an increase by 16 billion EUR. Positive values represent an increase in environmental impact, and negative values represent a reduction in environmental impact. The blue arrows in the table specify, per waste fraction, which waste treatment option that is associated with the largest theoretical potential for reduction of the environmental impact.

Waste category	Waste fraction	Quantity, dry weight (million t)	Waste treatment	Specific impact (EUR/kg)	Impact (billion EUR)	Impact if all waste is treated with specific waste treatment (billion EUR)	Potential, if all waste is treated with specific treatment minus currect mix (billion EUR)
Organic	Food waste	526	49% Landfill	0.21	53	108	16
			43% Incineration	0.14	31	74	-19
			8.3% Composting	0.18	7.8	93	1.2
			0.07% Biogas	-0.035	-0.013	-18	-110
	Manure	157	100% Conventional storage	0.34	53	53	0
			0% Biogas	0.23	0	36	-18
	Wood waste	82	2.5% Recycling	0.14	0.28	11	6.2
			34% Incineration	0.13	3.6	11	5.8
			64% Landfill	0.021	1.1	1.7	-3.3
Textile	Textile waste	18	55% Incineration	0.13	1.4	2.4	0.33
			45% Landfill	0.094	0.8	1.7	-0.41
Paper	Paper waste	113	15% Recycling	0.076	1.3	8.5	-6.4
			15% Incineration	0.094	1.6	11	-4.3
			70% Landfill	0.15	12	17	2.3
Plastic	Plastic waste	167	2.6% Recycling	-0.23	-1.0	-39	-48
			39% Incineration	0.13	8.1	21	12
			59% Landfill	0.017	1.7	2.9	-5.9
Glass	Glass waste	60	4.6% Recycling	-0.13	-0.35	-8	-7.9
			21% Incineration	0.015	0.19	0.88	0.66
			74% Landfill	0.0086	0.39	0.52	0.30
Construction and inert	Construction waste	2,261	0.6% Recycling	0.016	0.21	37	17
			99% Landfill	0.0086	19	19	-0.099
	Ash and slag waste	762	3% Recycling	-0.074	-1.4	-56	-61
			98% Landfill	0.0086	6.4	6.6	1.6
Metal	Iron waste	218	46% Recycling	-0.070	-7.1	-15	-9.4
			15% Incineration	0.015	0.46	3.2	9.1
			39% Landfill	0.0086	0.73	1.9	7.8
	Aluminium waste	20	41% Recycling	-0.65	-5.3	-13	-7.8
			22% Incineration	0.015	0.064	0.29	5.5
			37% Landfill	0.0086	0.064	0.17	5.4
	Copper waste	6	40% Recycling	-0.21	-0.48	-1.2	-0.76
			23% Incineration	0.015	0.019	0.085	0.53
			37% Landfill	0.0086	0.019	0.051	0.50
	Metals nec waste	7	41% Recycling	-0.22	-0.61	-1.5	-0.94
			22% Incineration	0.015	0.022	0.10	0.67
			37% Landfill	0.0086	0.022	0.060	0.62
Total	**Total**	**4,398**			**189**		

Table 5.1: Estimation of theoretical potentials for reducing the environmental impact for different waste treatments and recycling. The figures in the table applied to EU-27 in year 2003.

The total current impact related to the treatment of all waste fractions in Table 5.1 is 189 billion EUR. This should be compared with the total EU-27 environmental impact at 1,162 billion EUR. This is a higher share of the total environmental impact caused by waste treatment than typically referred to (in national NAMEAs). The reason for the high share is that biogenic CO_2 is included in the calculation of the contribution to global warming; this makes landfilling of food waste and manure treatment to some of the most significant contributors.

For **food waste**, the largest potential for reduction of the environmental impacts is by treating the waste using biogas technology. It should be noted that it is likely that the actual potential is lower than the specified -110 billion EUR. This is because there may be some physical, logistical and financial constraints in achieving the theoretical potential. Examples of constraints are: if the food waste is mixed with other waste, it is often costly/difficult to separate it, and the fact that food waste is generated in many activities and throughout the economy, in many forms (solid, liquid etc.), and in many geographical locations makes collection and biogasification difficult and costly.

For **manure** there is a significant reduction potential at -18 billion EUR by using biogasification.

Wood waste provides a potential at -3.3 billion EUR, if the current mix of waste treatment of primarily landfill and incineration is changed to 100% landfill. The reason that landfilling of wood waste causes less environmental impacts than incineration relates to two facts: 1) the degradation rate of wood waste landfilled during 100 years in the FORWAST model is very low (only 1.6% of the landfilled wood waste degrades during 100 years), and 2) the energy recovery rate of waste incineration is relatively low; only 10% of the energy content, lower heating value, is recovered. Therefore, the reduction potential for landfill is probably overestimated, and the reduction potential for incineration of wood waste is probably underestimated.

The reduction potential for **textile waste** is insignificant.

For **paper waste** the reduction potential is largest for recycling, but also incineration provides a significant opportunity for reducing the environmental impact compared with the current treatment mix (with 70% landfill).

Plastic waste provides a significant reduction potential at -48 billion EUR if recycling is increased from 2.6% to 100%. It should be noted that the current recycling rate at 2.6% is significant lower than what is typically reported in waste statistics. The reason for this is, that waste statistics typically only focuses on packaging waste, and not plastic waste contained in products (electronic products, toys etc.) and building material (windows, wall tightening membranes etc.). Also the recycling rate at 2.6% is related to uncertainties.

For **glass waste** the potential for reductions is -7.9 billion EUR if all glass waste is sent to recycling.

Construction waste does not provide significant reduction potentials. Also recycling of construction waste shows to be related to higher environmental impacts than landfill. This mainly relates to the fact that recycling of construction waste is associated with uses of energy (transportation etc.) and that the recovered material does not displace environmentally significant virgin materials (sand, gravel). However, it should be noted that some of the main reasons for recycling construction waste are to reduce the amount of waste sent to landfill, and to reduce exploitation of new materials. These two effects are not directly monetarised in the applied impact assessment method.

The theoretical reduction potential for **ash and slag** waste is -61 billion EUR. This may be well overestimated since physical and economical constraints may be present. When recycling ash and slag waste in cement production, the ash and slag is used as a substitute for clinker, which is very energy intensive. However, not all slag (residuals from incineration of inert materials) can be used as a clinker substitute, and there are limits for how much clinker that can be substituted, and also there may be economic constraints related to the transportation of slag and ash. Further, it should be noted that the total quantity of ash and slag from waste incineration is overestimated in the model, see section 2.1.12.

For **metal wastes**, reduction potentials are present for especially **iron waste** (-9.4 billion EUR) and **aluminium waste** (-7.8 billion EUR). The potential for copper and other metals is less significant.

Summing up, the following material flows can be identified as significant regarding reduction potentials for environmental impacts (the theoretical reduction potential is given is brackets):

- Food waste (-110 billion EUR)
- Ash and slag (-61 billion EUR), Note: probably overestimated
- Plastic waste (-48 billion EUR)
- Manure (-18 billion EUR)
- Iron waste (-9.4 billion EUR)
- Glass waste (-7.9 billion EUR)
- Aluminium waste (-7.8 billion EUR)
- Paper waste (-6.4 billion EUR)

5.2 Identification of priority material flows for prevention

This section analyses the potential reductions in environmental impact by different means of Prevention. The analysis presented in the following is based on the estimated change in scenario parameters as described in deliverable D5-3: ‘Report with description of three what-if scenarios of waste treatment policies and their interplay with the macro-economic scenarios’. Therefore, the reduction potentials presented in the following are not directly comparable with the potentials presented in section 5.1 which represents 100% implementation of the analysed means (100% recycling).

Table 5.2 provides an overview of the scenario implementation of the prevention scenario. Each of the seven rows in Table 5.2 represents a means of prevention as described in deliverable D5-3. The first column specify the type of prevention, the second column specifies in which activities the prevention means are implemented. The third and fourth column species the parameters which are changed in the prevention scenario, and the changes of parameter values (year 2003 = index 100) are specified in the last two columns.

In Table 5.3, the effect of each of the means of prevention is quantified. In order to illuminate and isolate the effect of each means of prevention, all other parameters in the model are kept constant, i.e. time parameters is set to year 2003. This means that there is no effect of macro-economic parameters. The last column specifies the total reduction potential in units of monetarised environmental impacts (billion EUR). The second to the fourth columns specify the affected products and the total quantity of these products in year 2003. The fifth and sixth columns specify the total monetarised impact for the products for which prevention means are implemented without and with the prevention means. The last column is calculated as the difference between the two latter columns.

Means of prevention	Activity	Changed parameter		2003	2035
Reduce the use of meat, reduce manure	Household	Use	Meat use	100	81
		Use	Flour use	increased correspondingly by dry mass	
Reduce processing waste in food industry	Food industry	Use, waste	Fruit and veg. Use & waste	100	81
		Use, waste	Grain crops & waste	100	97
		Use, waste	Crops nec & waste	100	81
Reduce packaging waste	Beverages industry	Use, waste	Use of plastic & waste	100	88
		Use, waste	Use of glass & waste	100	88
Reduce waste of textiles, wearing and apperal, leather	Household	Use, waste	Textiles, wearing and apperal, leather & waste	100	93
Reduce paper waste	All, except household	Use, waste	Printed matter	100	90
Reduce use of petrol	All, except refinery industry	Use, waste, emissions	Use of refined petroleum, waste, and emissions	100	93
Reduce metals waste	All, except machinery product activities	Use, waste	Machinery and equipment n.e.c.	100	93
		Use, waste	Office machinery and computers	100	93
		Use, waste	Electrical machinery n.e.c.	100	93
		Use, waste	Radio, television and communication equipment	100	93
		Use, waste	Instruments, medical, precision, optical, clocks	100	93

Table 5.2: Overview of the means of prevention, and the changed parameters in the 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’.

Means of prevention	Products	Quantity of affected pool	Unit	Total impact without prevention (GEUR)	Total impact with prevention (GEUR)	Reduction potential (GEUR)
Reduce the use of meat, reduce manure	Household use: Meals	1,184	GEUR	269	263	-5.7
Reduce processing waste in food industry	Fruits and vegetables, processed	14	million tonne (dry)	5.9	5.2	-0.78
	Flour	97	million tonne (dry)	-1.8	-1.8	-0.048
	Sugar	56	million tonne (dry)	7.6	7.5	-0.10
	Food preparations n.e.c.	24	million tonne (dry)	24.2	24.1	-0.10
	Animal feeds	132	million tonne (dry)	12.9	12.8	-0.069
	Beverages	16	million tonne (dry)	22.4	22.3	-0.060
Reduce packaging waste	Beverages	16	million tonne (dry)	22	22	-0.48
Reduce waste of textiles, wearing and apperal, leather	Household use: Housing	1,440	GEUR	191	191	-0.26
	Household use: Clothing	196	GEUR	275	275	-0.73
Reduce paper waste	Printed matter and recorded media	16	million tonne (dry)	0.010	0.0062	-0.0037
Reduce use of petrol	Refined petroleum products and fuels	290	million tonne (dry)	90	83	-6.7
Reduce metals waste	Machinery and equipment n.e.c.	22	million tonne (dry)	17	16	-1.3
	Office machinery and computers	0.87	million tonne (dry)	3.1	2.9	-0.23
	Electrical machinery n.e.c.	11	million tonne (dry)	7.0	6.5	-0.53
	Radio, television and communication equipment	2.2	million tonne (dry)	2.7	2.5	-0.20
	Instruments, medical, precision, optical, clocks	0.89	million tonne (dry)	2.6	2.4	-0.19

Table 5.3: Quantification of the reduction potential of the means of prevention in units monetarised environmental impacts (billion EUR).

Based on the last column in Table 5.3, the following material flows can be identified as priority flows concerning prevention: Substitution of meat with non-meat food, and reduction of the use of petrol. This identification is in line with the identified most environmental significant activities within the EU-27 economy in Table 3.8 (p 22).

It should be noted that the prevention scenario does not represent an exhaustive list of means of prevention. Therefore, the reduction potentials in Table 5.3 should be seen as examples of reduction potentials. Further, it should be noted that the reductions specified in Table 5.2 (last column) are based on estimates described in deliverable D5-3 ‘Report with description of three what-if scenarios of waste treatment policies and their interplay with the macro-economic scenarios’. It is likely, that prevention means could achieve more significant reductions than specified in Table 5.2 – especially in light of post Kyoto interventions.

6 Priority material flows and policy recommendations

Based on the scenario results in deliverable D6-2 and the contribution analysis presented in the current report, priority materials and policy recommendations are given in this section.

6.1 Priority materials for treatment, recycling and prevention

Three "what-if-scenarios on waste treatment" regarding treatment (increasing waste incineration), recycling (increasing recycling), and prevention (minimising losses throughout the product chain) has been analysed. In most cases, the three analysed scenarios on waste treatment do not exclude each other, and therefore, this study does not provide the basis for recommending one strategy over the other. The FORWAST project can be used to identify the overall contributing activities to waste generation and environmental impacts in the EU-27, and to identify the causes (upstream in the product life cycle) of environmental impact of demanding different products and services. Also, within each of the three strategies on waste treatment, the FORWAST project can be used to identify priority material flows.

In general all analysed means of improvements in the three waste treatment scenarios contributes to reductions in environmental impacts. However, there are a few exceptions, e.g. increased composting of food waste causes higher environmental impacts than the current practise, and landfilling of plastic waste is preferable over incineration. The latter is related to a relatively low energy recovery rate in the incineration of waste activity. Therefore, the figures are related to uncertainties. Also recycling of construction waste shows to related to higher environmental impacts than landfill.

The priority materials listed in the following are identified based on a combination of the total quantity of material and the environmental impact per unit of treatment/recycling/prevention.

Within **treatment** technologies (mechanical biological technologies, incineration and landfill), the largest potentials for improvements can be found within:

- Biogasification of food waste
- Incineration of food waste (biogasification is related to higher potentials)
- Biogasification of manure

Within **recycling**, the largest potentials for improvements can be found within:

- Recycling of plastic waste
- Recycling of iron waste
- Recycling of glass waste
- Recycling of aluminium waste

Within the analysed prevention means, the largest improvement potentials can be found for the following materials:

- Reduction of fuel uses by increased energy efficiencies in motor vehicles
- Displacement of meat by other food items
- Reduce the use of metals by eco-efficiency/optimising design etc.

The different policy options, instruments and technologies are further described in deliverable D5-3 ‘Report with description of three what-if scenarios of waste treatment policies and their interplay with the macro-economic scenarios’.

6.2 The role of macro-economic development - waste generation and environmental impacts

The scenario results in deliverable D6-2 show that the macro-economic development has a significant impact on the waste generation as well as environmental impacts. Thus, there is a strong relation between economic growth and waste generation, and between economic growth and environmental impacts.

Three scenarios of macro-economic development are analysed; baseline growth, high growth, and low growth. In the baseline scenario, the total waste generation is 70% higher in 2035 than in 2003. In the high and low growth scenarios the waste generation is 84% and 60% higher than in year 2003 respectively.

The growth in waste generation and environmental impact from year 2003 to 2035 due to economical growth cannot be compensated by the assessed means of reductions in the three “what-if-scenarios on waste treatment” regarding treatment, recycling, and prevention. Since the three “what-if-scenarios on waste treatment” do not represent an exhaustive list of means of improvements and since changes in scenario parameters (e.g. recycling rate that will be achieved in year 2035) are estimated rather than investigated (taking into account economical, physical and social constraints for achieving means of improvement), it cannot be concluded that the increasing tendency in waste generation and environmental impact cannot be turned into a decreasing tendency.

The strong relation between economic growth on the one hand and environmental impacts and waste generation on the other emphasise that a further decoupling between economic growth and externalities is needed if political goals on net reductions in environmental impacts should be fulfilled.

6.3 The role of the FORWAST model in enhancing waste statistics in the future

The comparison of FORWAST model results on waste generation and Danish waste statistics shows significant differences for most waste flows. The main reasons for the differences are identified as non-recorded waste in waste statistics, differences in waste definitions (the FORWAST model uses a broader definition), and uncertainties in estimates of product life times in the FORWAST model (further needs for calibration). In addition some uncertainties are also present in the model inputs on resource inputs, product flows, and emission outputs. However, the statistical data (resource statistics, production statistics, national emissions accounts) on these items are generally more complete and of significant better quality than waste statistics.

The fundamental mass balance principle used in the FORWAST project enables calculating the waste flows using the above mentioned good data, and to compare with waste statistics. The FORWAST project has demonstrated that the data inputs to the model exists and are accessible, and that the model is practically applicable to national economies. Referring to the above mentioned comparison of the FORWAST results and Danish waste statistics, the following issues should be addressed in future uses of the FORWAST model:

- Better data/emphasis on calibration of product life times to determine when inputs of products to economy comes out as waste. This should include an identification of the determining factors on product life times.
- More interplay with national waste statistics to improve data quality of the applied waste treatment mix
- Better national data on total production distinguishing between virgin and recycled production are needed. This will also improve data quality of the applied waste treatment mix as referred to above
- Better national statistical data on the use of products by different activities. Statistical data are generally good on production, export and import. But for uses of products by different activities in economy, data availability and quality are generally poor. The use of products is therefore to some extent determined based on monetary use (obtained from use table). This implies potentially significant uncertainties.

The FORWAST model shows advantages for bulk materials (non-toxic waste flows), but for hazardous wastes, the approach is less useful. The level of aggregation, i.e. the number of different product and waste types included in the model defines a limit for which waste flows are described. E.g. chemical products in the FORWAST model mainly belong to the product category ‘Chemicals nec.’. This means that waste originating from the use of chemicals comes out as model results in terms of quantities of ‘waste of chemicals nec.’. A considerable share of this waste fraction may belong to hazardous waste, but the category also contains large amounts of non-hazardous materials. Thus, the current model results does not provide valuable results on hazardous waste. Related to this, the current version of the model does not include toxic substances (product flows, waste flows and emissions). If the model should provide a useful description of hazardous wastes including toxic substances, it would require enormous quantity data which are currently not directly accessible.

6.4 Outlook, the role of the FORWAST model in future integrated accounting systems

The FORWAST model demonstrates an integration of economic accounts (supply-use tables), emissions accounts (NAMEA and national inventory submissions under the UNFCCC), and various sector specific production (and use) accounts (agriculture, forestry, fishery, metals and mineral extraction, energy). Currently, the methodologies used for these accounts are not standardised, i.e. there are no common standard specifying which activities, trade partners, products, substances to be included, no standards specify the units of measurement (energy, mass, water content etc.). Further, the accounts are not using a common accounting framework, e.g. supply use framework, and mass balance/energy balance framework.

In future work on harmonising accounts, experiences from the FORWAST model can be used. FORWAST demonstrates an example of a fully harmonised way of integrating all the above mentioned accounts. The key characteristics of the accounting framework in the FORWAST model can briefly be described as:

- Supply use framework
- Balanced economy and physical transactions for products and activities
- Physical transactions are measured in dry weight
- Physical inputs to the economy are resources
- Physical outputs from the economy are emissions and stocks of waste in landfills (and unauthorised placement of waste)
- Waste treatment/recycling activities supplies the service to treat or recycle waste (measured in mass unit), and most waste treatment activities supply by-products: recycled material or recovered energy
- The same convention of material inputs (resources), intra economy transactions (products, stock changes and waste), and material outputs (emissions and stocks of waste) is used for all transactions, which enables mass balance: inputs to any activity (resources, products, waste) = outputs (products, stock additions, waste, emissions)
- Intermediate flows of oxygen in combustion processes (resource input of oxygen and output of oxygen in CO_2) are not included in the mass balance

It is recommended to use the principles developed through the FORWAST model for establishing and refining future integrated accounting systems. The accounting system used in the FORWAST model also provides the option to directly establish hybrid unit input-output tables including physical transactions of waste flows. In this respect the FORWAST model is the first of its kind. The latter provides a powerful life cycled based tool for hotspot identification and for prioritising environmental and waste policy interventions.

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Appendix 1: 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.

Appendix 2: Disaggregation of Eurostat 60x60 SUTs

Split No.	Default Values i.e TOTALS	Default Values (Proportional)	New Product No.	New Code	ORIGINAL Product Categories from Original_V i.e.Row Headings	New Product Categories for Result_V i.e. ROW Headings
6	14,390,422	0.279544	1	1.21	Products of agriculture, hunting an	Bovine meat and milk
	3,222,000	0.0625896	2	1.23		Pigs
	3,839,065	0.0745765	3	01.24+01.25		Poultry and animals n.e.c.
	8,003,200	0.1554677	4	01.1(disaggr.)		Grain crops
	20,148,520	0.391399	5	01.1(disaggr.)		Crops n.e.c.
	1,875,000	0.0364232	6	01(disaggr.)+01.4+01.5		Agricultural services n.e.c.
2	35,326,614	1	7	2 (disaggr.)	Products of forestry, logging and re	Forest products
	0	0	8	2 (disaggr.)		Recycling of waste wood
1		1	9	05	Fish and other fishing products; se	Fish and other fishing products; servi
1		1	10	10	Coal and lignite; peat	Coal and lignite; peat
1		1	11	11	Crude petroleum and natural gas; s	Crude petroleum and natural gas; ser
7	6,521,808	0.3212054	12	13.1	Metal ores	Iron ores from mine
	6,103	0.0003006	13	13.2(disaggr.)		Bauxite from mine
	3,007,717	0.148133	14	13.2(disaggr.)		Copper from mine
	2,061,539	0.1015328	15	13.2(disaggr.)		Metals from mine n.e.c.
	7,138,660	0.3515859	16	14.1+14.21		Sand, gravel and stone from quarry
	744,684	0.0366764	17	14.22		Clay and soil from quarry
	823,656	0.0405659	18	14.3+14.4+14.5		Minerals from mine n.e.c.
10	43,195,740	0.2675913	19	15.1+15.2	Food products and beverages	Meat and fish products
	22,973,020	0.1423145	20	15.5		Dairy products
	14,758,580	0.0914272	21	15.3		Fruits and vegetables, processed
	4,611,080	0.028565	22	15.4		Vegetable and animal oils and fats
	2,273,520	0.0140841	23	15.6		Flour
	6,196,050	0.0383836	24	15.83		Sugar
	7,785,580	0.0482305	25	15.7		Animal feeds
	35,970,300	0.2228307	26	15.8(ext.)		Food preparations n.e.c.
	19,586,340	0.1213345	27	15.9		Beverages
	4,074,101	0.0252385	28	16		Tobacco products
1		1	29	17	Textiles	Textiles
1		1	30	18	Wearing apparel; furs	Wearing apparel; furs
1		1	31	19	Leather and leather products	Leather and leather products
1		1	32	20	Wood and products of wood and c	Wood and products of wood and cork
3	45,701,313	0.3206103	33	21.11(disaggr.)	Pulp, paper and paper products	Pulp, virgin
	0	0	34	21.11(disaggr.)		Pulp, recycled
	96,843,431	0.6793897	35	21.12+21.2		Paper and paper products
1		1	36	22	Printed matter and recorded media	Printed matter and recorded media
2	1	1	37	23 (disaggr.)	Coke, refined petroleum products a	Refined petroleum products and fuels
	0	0	38	23 (disaggr.)		Recycling of waste oil
5	1,309,700	0.0076162	39	24.15(disaggr.)	Chemicals, chemical products and	Fertiliser, N
	280,815	0.001633	40	24.15(disaggr.)		Fertiliser, other than N
	35,563,740	0.2068118	41	24.16(disaggr.)+24.17(di		Plastics basic, virgin
	0	0	42	24.16(disaggr.)+24.17(di		Plastics basic, recycled
	134,807,619	0.783939	43	24(disaggr.)		Chemicals n.e.c.
1		1	44	25	Rubber and plastic products	Rubber and plastic products
8	8,708,241	0.5210384	45	26.1(disaggr.)+26.2(disa	Other non-metallic mineral product	Glass, mineral wool and ceramic goo
	0	0	46	26.1(disaggr.)+26.2(disa		Glass, mineral wool and ceramic goo
	1,260,088	0.0753946	47	26.5(disaggr.)		Cement, virgin
	0	0	48	26.5(disaggr.)		Recycling of slags and ashes
	6,526,420	0.390494	49	26.6(disaggr.)+26.7(disa		Concrete, asphalt and other mineral p
	0	0	50	26.6(disaggr.)+26.7(disa		Recycling of concrete, asphalt and ot
	218,492	0.013073	51	26.3(disaggr.)+26.4		Bricks
	0	0	52	26.3(disaggr.)+26.4		Recycling of bricks
12	66,406,060	0.5818543	53	27.1(disaggr.)	Basic metals	Iron basic, virgin
	0	0	54	27.1(disaggr.)		Recycling of iron basic
	8,538,471	0.0748146	55	27.42(disaggr.)		Aluminium basic, virgin
	0	0	56	27.42(disaggr.)		Recycling of aluminium basic
	4,262,383	0.0373473	57	27.44(disaggr.)		Copper basic, virgin

Split No.	Default Values i.e TOTALS	Default Values (Proportional)	New Product No.	New Code	ORIGINAL Product Categories from Original_V i.e.Row Headings	New Product Categories for Result_V i.e. ROW Headings
	0	0	58	27.44(disaggr.)		Recycling of copper basic
	5,228,127	0.0458092	59	27.4(disaggr.)		Metals basic, n.e.c., virgin
	0	0	60	27.4(disaggr.)		Recycling of metals basic, n.e.c.
	20,373,407	0.1785131	61	27.2(disaggr.)+27.3(disa		Iron, after first processing
	5,228,957	0.0458165	62	27.2(disaggr.)+27.3(disa		Aluminium, after first processing
	2,697,462	0.0236353	63	27.2(disaggr.)+27.3(disa		Copper, after first processing
	1,393,461	0.0122096	64	27.2(disaggr.)+27.3(disa		Metals n.e.c., after first processing
1		1	65	28	Fabricated metal products, except	Fabricated metal products, except m
1		1	66	29	Machinery and equipment n.e.c.	Machinery and equipment n.e.c.
1		1	67	30	Office machinery and computers	Office machinery and computers
2	0.58	0.5829049	68	31	Electrical machinery and apparatu	Electrical machinery n.e.c.
	0.42	0.4170951	69	32		Radio, television and communication
0					Radio, television and communicati	Radio, television and communication
1		1	70	33	Medical, precision and optical inst	Medical, precision and optical instrur
1		1	71	34	Motor vehicles, trailers and semi-tr	Motor vehicles, trailers and semi-trail
1		1	72	35	Other transport equipment	Other transport equipment
1		1	73	36	Furniture; other manufactured gooc	Furniture; other manufactured goods
1		1	74	37	Secondary raw materials	Secondary raw materials
2	139,802,200	0.9505431	75	40 (disaggregated)	Electrical energy, gas, steam and	Electricity, steam and hot water
	7,273,935	0.0494569	76	40 (disaggregated)		Gas
1		1	77	41	Collected and purified water, distrit	Collected and purified water, distribut
3	0.31	0.3144896	78	45 (disaggregated)	Construction work	Buildings, residential
	0.38	0.3796825	79	45 (disaggregated)		Buildings, non-residential
	0.31	0.3058278	80	45 (disaggregated)		Infrastructure, excluding buildings
3	0.16	0.1614668	81	50	Trade, maintenance and repair ser	Trade and repair of motor vehicles; se
	0.43	0.4299727	82	51		Wholesale trade
	0.41	0.4085605	83	52		Retail trade and repair services
0					Wholesale trade and commission	Wholesale trade and commission tra
0					Retail trade services, except of m	Retail trade services, except of motc
1		1	84	55	Hotel and restaurant services	Hotel and restaurant services
1		1	85	60	Land transport; transport via pipelir	Land transport; transport via pipeline
1		1	86	61	Water transport services	Water transport services
1		1	87	62	Air transport services	Air transport services
1		1	88	63	Supporting and auxiliary transport	Supporting and auxiliary transport se
1		1	89	64	Post and telecommunication servic	Post and telecommunication services
1		1	90	65	Financial intermediation services, (	Financial intermediation services, exc
1		1	91	66	Insurance and pension funding ser	Insurance and pension funding servic
1		1	92	67	Services auxiliary to financial interi	Services auxiliary to financial interme
1		1	93	70	Real estate services	Real estate services
1		1	94	71	Renting services of machinery and	Renting services of machinery and ec
1		1	95	72	Computer and related services	Computer and related services
2	0.08	0.0799209	96	73	Research and development service	Research and development
	0.92	0.9200791	97	74		Business services n.e.c.
1		1	98	75	Public administration and defence	Public administration and defence se
1		1	99	80	Education services	Education services
1		1	100	85	Health and social work services	Health and social work services
8	1	1	101	90 (disaggregated)	Sewage and refuse disposal servic	Incineration of waste
	0	0	102	90 (disaggregated)		Manure treatment
	0	0	103	90 (disaggregated)		Biogasification of waste
	0	0	104	90 (disaggregated)		Composting of food waste
	0	0	105	90 (disaggregated)		Waste water treatment
	0	0	106	90 (disaggregated)		Landfill of waste
	0	0	107	90 (disaggregated)		Land application of waste
	0	0	108	90 (disaggregated)		Unexpected waste
1		1	109	91	Membership organisation services	Membership organisation services n.(
1		1	110	92	Recreational, cultural and sporting	Recreational, cultural and sporting se
1		1	111	93	Other services	Other services