TECHNICAL REPORT SERIES

Environmental Impact of Products (EIPRO)

Analysis of the life cycle environmental impacts related to the final consumption of the EU-25

EUR 22284 EN

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

European Science and Technology Observatory

ipts
Institute for Prospective Technological Studies

The mission of the IPTS is to provide customer-driven support to the EU policy-making process by researching science-based responses to policy challenges that have both a socio-economic as well as a scientific/technological dimension.

IPTS Networks

Since its creation in 1994, access to high quality expertise has been at the core of the IPTS's development strategy. Only through its networks can an institute the size of the IPTS hope to provide high-quality advice at the European level over the whole range of policy fields in which the Institute operates. As a result, the IPTS has established a number of networks, most notably ESTO, which enable it to access such expertise.

The ESTO Network (the European Science and Technology Observatory)

ESTO is a valuable mechanism for complementing and expanding the Institute's internal capabilities. ESTO has a core membership of around 20 institutions, all with experience in the field of scientific and technological foresight, forecasting or assessment at the national level. The role of ESTO has been to engage in monitoring and analysing scientific and technological developments and their relation and interaction with society.

Institute for Prospective Technological Studies

European Science and Technology Observatory

Environmental Impact of Products (EIPRO)

Analysis of the life cycle environmental impacts related to the final consumption of the EU-25

Main report

IPTS/ESTO project

By:

Arnold Tukker (project manager) – *TNO, the Netherlands*

Gjalt Huppes, Jeroen Guinée, Reinout Heijungs, Arjan de Koning, Lauran van Oers, and Sangwon Suh
CML, Leiden University, the Netherlands

Theo Geerken, Mirja Van Holderbeke, and Bart Jansen – *VITO, Belgium*

Per Nielsen – *Danish Technical University (DTU), Denmark*

Project co-ordinators at the IPTS:

Peter Eder and Luis Delgado

May 2006

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

EUR 22284 EN

European Commission

Joint Research Centre (DG JRC)

Institute for Prospective Technological Studies

http://www.jrc.es

Technical Report EUR 22284 EN

Catalogue number:

ISBN-10:

Printed in Spain

Table of Contents

Preface

In June 2003 the European Commission adopted a Communication on an integrated product policy (IPP) aiming to reduce the environmental impacts of products, where possible by using a market-driven approach that combines competitiveness with social concerns. In its Communication, the Commission announced plans to identify those products with the greatest potential for improvement.

As a first step the DG JRC/IPTS launched the EIPRO project (Environmental Impacts of Products), the outcome of which is presented in this report. The objective of this project was to identify those products that have the greatest environmental impact throughout their life cycle, from cradle to grave, as measured separately by different categories of environmental impact, in physical terms. Of course this does not yet mean that they are priorities for action.

The Commission should be able to use the results as an input to assessing improvement potential, i.e. to determine whether - and how - the life cycle effects of those products with the greatest impacts can be reduced and what the socio-economic costs and benefits are. Once it has done that, the Commission will stimulate action on those products that show the greatest potential for improvement at least socio-economic cost.

The EIPRO project has taken stock of research based evidence on the environmental impacts of all products consumed in Europe. It has looked at the question from different perspectives, bringing together evidence from relevant major studies and analyses covering a very broad spectrum of methodological approaches, models and data sources. In order to make such analysis with all the technical detail transparent and at the same time provide also those readers who have less time available with all the essential information, the report of the EIPRO project has been organised as follows.

1. This main volume:

The main volume contains a short summary in non-technical language of the project's objectives, process and analytical approach, results and conclusions. The summary has been written by Commission staff on the basis of the full project documentation.

The summary is followed by the main body of the technical research report, which was written by the ESTO project team and edited by JRC-IPTS.

2: Separate annex volume:

The annex volume is available in electronic format on the JRC/IPTS website (http://www.jrc.es/home/pages/publications.cfm) and contains further details on sources of information, methodology, data and results.

Summary of project set-up, methodology and results

i. Introduction

In June 2003 the European Commission adopted a Communication on Integrated Product Policy (IPP).[1] The idea behind this policy is to reduce the environmental impacts of products and services throughout their life cycles, where possible by using a market-driven approach that takes due account of competitiveness and social concerns. In its Communication, the Commission announced plans to identify those products with the greatest potential for improvement. However, when the Communication was published, there existed no analytically-based consensus on which products and services have the greatest impact, and hence no consensus on those which have the greatest potential for improvement.

ii. Objective

The objective of this project was to identify those products that have the greatest environmental impact throughout their life cycle, from cradle to grave. The Commission should now be able to use the results to assess improvement potential, i.e. to determine whether – and how – the life cycle effects of those products with the greatest impacts can be reduced. Once it has done that, the Commission will seek to address some of the products that show the greatest potential for improvement at least socio-economic cost.

This study and report address only the first stage of the process, i.e. identifying those products that have the greatest environmental impact. In the light of what is said above, this does not mean that they are necessarily priorities for action.

iii. Research team and process

The project was led by the Institute for Prospective Technological Studies (IPTS, Seville) of the Commission's DG Joint Research Centre, and its European Science and Technology Observatory (ESTO) network. The Dutch TNO-CML Centre for Chain Analysis acted as project manager, in cooperation with the Flemish Institute for Technological Research (VITO) in Belgium and the Danish Technical University (DTU).

The project started in January 2004 and consisted of five main tasks:

1. definition of goal and scope
2. evaluation of existing research as a basis for developing the methodology
3. development and refinement of the methodology
4. application of the methodology and final reporting
5. stakeholder consultations.

The results of the different tasks were discussed at special workshops, followed by meetings with stakeholders. The draft final report was published on the Commission's website in May 2005 with an invitation for comments. The final results of the study were presented to the Member States and other stakeholders in November 2005.

iv. Methodology

Definitions of product aggregates

To assess the environmental impact of products, the final consumption of the EU had to be divided

1 European Commission Communication on Integrated Product Policy COM(2003) 302 final, adopted 18.6.2003.

into product categories. This may be done in different ways and at different levels of aggregation. The levels, from high to low, can be described as:

1) **Functional areas of consumption**: up to a dozen elements, e.g. 'transport', 'clothing', 'healthcare' and 'recreation'
2) **Consumption domains:** up to several dozens of elements, e.g. 'transport' contributing to 'healthcare' and 'recreation'
3) **Product groupings:** up to several hundreds of elements, e.g. sub-division of 'Consumption domain' (2) into 'car transport', 'rail transport', 'air transport', etc.
4) **Homogeneous product groups**, e.g. medium range diesel cars
5) **Individual** products, e.g. a specific diesel car.

It was decided that the study would not go into more details than the third level of aggregation.

Scope

The scope of the project was:

- Focus on identifying products on the basis of their life cycle impacts. Identify products on the basis of the overall volume of the product used. Take account of the impact per euro.
- Focus primarily on the life cycle impacts of products (both goods and services) in terms of final consumption in the 25 Member States of the EU (both household and government expenditure). Include all processes related to resources extraction, production, use and waste management (both inside and outside the EU-25), so as to account for total final consumption in the EU-25. Use a model based on inventory/emission data for the EU-15, assuming that the differences in technologies in the new Member States will be less relevant. The life cycle impacts of production in the EU-25 for export are not included.
- Describe the current situation taking a reference year around 2000. The study did not include analyses of developments over time and in the future.
- Include capital goods, and where possible, pay attention to specific materials such as packaging and other intermediate products.
- Where relevant, use a variety of impact assessment methods. The analysis should not exclude any environmental impact category beforehand; and should be cautious when ranking on impacts of toxicity (scientific knowledge on this is limited).

A two-step approach

The methodological approach for this study was to take the results of existing studies and combine them with new research. This way, full advantage could be taken of existing research and knowledge of impacts, and the understanding could be developed further in key areas to close knowledge gaps.

The first step of the project was to review the literature on existing studies that compare the environmental impacts of products from a life cycle perspective. The project team chose seven studies for a full evaluation.

The second step was to develop a model – the CEDA EU-25 Products and Environment model – with systematic and detailed analysis based on an input-output model.

v. Analysis of existing studies

Methodology

A list of the studies most relevant for the research task was reviewed in order to establish the state-of-the-art in the area and to find the most suitable methodological approach for this project. Studies were divided into two categories according to their analytical approach:

1) **The 'bottom-up'** approach begins with an individual product and conducts a life cycle assessment (LCA).
2) **The 'top-down'** approach begins with input-output tables (I/O) produced by statistical agencies, and describes production and consumption in an economy.

Seven studies were chosen for a full evaluation, whose reports were published between 2002 and 2005.[2]

The review showed that the seven studies used a broad spectrum of approaches, methods and data sources. The diversity lay in the systems of classifying products and their level of detail, the environmental impact assessment methods, the data sources and methods for making life cycle inventories, the extent to which the environmental impacts of infrastructure and capital goods were taken into account, etc.

The initial conclusion from the review of existing studies was that substantial and useful research had been undertaken already, and despite different methodological approaches and limitations, this research could provide quite robust results at the level of functional areas of consumption and, to some extent, also at aggregation levels that distinguish up to about 50 consumption domains or product groupings. However, the studies provided far less useful information for more disaggregated product groupings, and their geographical scopes were not at all identical. The review also showed that existing knowledge did not give a full picture of consumption in the EU-25.

Analyses

The seven studies were analysed by examining and comparing their results systematically and at the most detailed level possible. The highest resolution at which the results of the studies could be compared was at a product aggregation level of about 50 product groupings. For this, it was necessary to aggregate some of the original categories in these studies to a higher level.

Analysis and comparison was possible only for those environmental aspects covered by most of the studies, and where there were widely accepted and well-established methods and data. The environmental impact categories used in most of the studies were:

- global warming
- acidification
- photochemical ozone formation
- eutrophication

For some other impact categories there were greater methodological or data uncertainties, or else those categories featured less frequently, so they have been taken into account with some caution. These include ozone layer depletion, human toxicity and ecotoxicity, land use, and depletion of non-renewable resources.

Because of differences in methodology, definitions and system boundaries, the best approach was – for a specific impact category – to compare the percentage contribution of a given product grouping to the total impact of all products considered in that particular study. For each impact category, product groupings were ranked according to their contribution in decreasing order, to determine which set of product groupings made up together the 40%, the 60% and the 80% of the total impact. It was then determined how many times the same product groupings showed up for the different impact categories. For instance,

2 The seven studies evaluated were:
- Dall *et al.* (2002): Danske husholdningers miljøbelastning. Danish EPA. Copenhagen.
- Nemry *et al.* (2002): Identifying key products for the federal product & environment policy – Final report. ASBL/VITO. Namur/Mol, Belgium.
- Kok *et al.* (2003): Household metabolism in European countries and cities. Centre for Energy and Environmental Studies. University of Groningen, the Netherlands.
- Labouze *et al.* (2003): Study on external environmental effects related to the lifecycle of products and services – Final Report Version 2. BIO Intelligence Service/O2. Paris.
- Nijdam and Wilting (2003): Environmental load due to private consumption. Milieudruk consumptie in beeld. Bilthoven, the Netherlands.
- Moll *et al.* (2004): Environmental implications of resource use – insights from input-output analyses. European Topic Centre on Waste and Material flows. Copenhagen.
- Weidema *et al.* (2005). Prioritisation within the integrated product policy. Environmental Project Nr. 980. Danish Ministry of the Environment, Copenhagen.

a specific product grouping might be part of the set of product groupings making together 40% of the total acidification, and for some other impact categories, but not for land use. This gave an indication of the importance of a product grouping for all impact categories.

Results

Allowing for the variation in the methodologies and scopes of the seven studies, the following cautious conclusions can be drawn.

- For most impact categories, in the set of product groupings making together 60% of the total impact, the top contributing product grouping represents about 20 per cent or more of the total environmental impact, and the product grouping with the lowest impact still represent 5 to 10 per cent.
- In each study the number of high impact product groupings, i.e. those representing 40 per cent of all impacts considered, tends to be only 4 to 12 depending on the study.
- In the set of product groupings making together 60% and 80% of the total impact, the number of product groupings tends to increase by a factor of 2 to 3. Outside this set covering 80% of the impact, there are still a large number of product groupings (30 to 60% of product groupings, depending on the study).
- There are certain product groupings that show up in the top rankings, although in varying order, across all the studies that cover them systematically. They are related to:

  cars

  food

  heating

  house building
- However, the results of the different studies show no conformity for the 'mid-range' of product groupings.

vi. New environmental input-output analysis model for the EU-25

Methodology

The research team carried out a systematic analysis of the environmental impacts of products for the EU-25 in sufficient detail to distinguish several hundreds of product groupings. The analysis is based on the CEDA EU-25 Products and Environment model, the new input-output (IO) model developed in this study. The model covers the environmental impacts of all products consumed in the EU-25 (produced in EU-25 and imported), including the life cycle stages of extraction, transport, production, use and waste management.

The basic structure of the model consists of matrices that quantify the relationships of the production and consumption systems in Europe in terms of purchase and sale of products, as well as resource use and emissions. The system boundaries are set to cover all cradle-to-grave life cycle chains related to the products involved and cover both final private consumption and final government consumption, in terms of expenditure on the products involved. To give a high level of detail, the model uses a pragmatic combination of different data sources, extrapolations and assumptions.

The IO tables describe the relations between the different sectors in an economy. They quantify in monetary terms how the output (goods or services) produced by one sector goes to another sector where it serves as input. An IO model assumes that each sector uses the outputs of the other sectors in fixed proportions in order to produce its own unique and distinct output. Based on this assumption, a matrix is defined such that each column shows in terms of monetary value the inputs from all the different sectors required to produce one monetary unit of a sector's output.

For each sector involved, the matrix can be extended environmentally by assuming that the amount of environmental intervention generated by a sector is proportional to the amount of

output of the sector, and that the nature of the environmental interventions and the ratios between them are fixed. In its most basic form, an environmental IO analysis can be performed using one vector and two matrices. The calculations result in an interventions matrix, which shows factors like resource extraction and emissions for each product.

- The 'final consumption vector' allocates the total consumption expenditure of a region or country to final consumption products. This final consumption, in terms of purchases of goods and services, determines all production activities and their related environmental impacts.
- The 'technology matrix' shows how the production activities of the different sectors interrelate in monetary terms.
- The 'environment matrix' shows input in terms of direct resource use (e.g. of ores) for each sector (product chain) and output in terms of direct emissions, i.e. the environmental interventions.

Although the principle of an environmental IO analysis is simple, getting the data right is challenging. Also, an IO analysis is based on the records of financial transactions between productive sectors and to final consumers, which do not generally cover the use and disposal phases of products. For a cradle-to-grave analysis, specific solutions need to be adopted to cover the use, waste management and recycling stages.

The model adapts the latest model developed with United States sectoral data (CEDA 3.0) to Europe. The resulting CEDA EU-25 Products and Environment model covers all resource use and emissions in the production, use and disposal phases of all products consumed in the EU-25. The analysis does not consider the impacts of products exported outside the EU.

In essence, the model takes the EU's total emissions and resource use in relation to expenditure on products as a basis, and distributes them between product groupings, assuming similarities in production processes in the US and Europe for most products. Hence, the model calculates some 1200 environmental interventions for a total of 478 product groupings, of which some 280 are for final consumption. In order to interpret these outcomes, an impact analysis stage was added, as is common in environmental life cycle assessment of products, distinguishing a set of impact categories so as to define operations like resource extraction and emissions in terms of environmental impact like resource depletion and global warming.

The analysis used the following eight environmental impact categories:

- abiotic depletion
- acidification
- ecotoxicity
- global warming
- eutrophication
- human toxicity
- ozone layer depletion
- photochemical oxidation

The full analysis quantifies the total impacts of product groupings over the product life cycles (i) per product consumed and (ii) per euro spent. The results are calculated as a percentage of the EU-25 total for each impact category.

Reliability of the model

The study shows that the top-down IO approach is effective in assessing the environmental impacts of products from a macro perspective. It shows the whole picture, but also gives a high level of detail, so it would seem worthwhile to develop this approach further. The model could be further refined by including government expenditure more accurately, and by making the business-to-business market visible. There are still considerable gaps in data and analytical methods; and these can be overcome only by long-term research and more work on method development. There is a particular need for (i) harmonised high

quality databases with life cycle inventory and impact data, and (ii) detailed national accounting matrices, including environmental accounts, harmonised at the European level. It would then be possible to use input-output models to describe the production and consumption system and its interactions with the environment in a fully coherent manner.

Moreover, with the methodology used, it was not possible to show certain products that may well be relevant. There are two fundamental reasons for this (unintended) invisibility:

- The product as such is not 'visible', as might be the case if a product is not defined as a separate item when determining the final product aggregations, e.g. packaging (which is grouped together with the product), or products mainly used in business to business (impacts from products exchanged between business sectors are covered only indirectly).
- The emissions and resource use and/or subsequent impact assessment are 'invisible'. The problem categories tend to involve: human and ecotoxic impacts, impacts at the waste stage, impacts from underreported activities (passenger air travel), very localised impacts, impacts on biodiversity, biotic resources use, and land use.

General results

An analysis of the environmental impacts of the full set of products using the model shows that for all impact categories there is a substantial difference between product groupings, taking into account their full life cycles and the volumes purchased each year. Comparing the extremes, the impacts per product grouping differ by five orders of magnitude. This means that the impact of the product grouping with the highest environmental impact according to this methodology is 100,000 times higher than the weakest. This is partly because of the classification system and the aggregation applied (if a product grouping is split in two halves, its scores will be halved). Disregarding the extremes (the top and bottom 20%), the difference in impact between product groupings is nearly two orders of magnitude (i.e. 100 times higher or lower). The results also show that, most of the time, there is a correlation between the different categories of environmental impact for a specific product grouping. This means in effect that a product grouping with a high impact on global warming will tend to have a similar impact on acidification or human toxicity for example.

The model suggests that consistently over all environmental impact categories some 20 per cent of product groupings account for some 80 per cent of impact (some 60 product groupings out of 283).

Detailed results

More detailed rankings have also been produced. The most detailed analysis based on CEDA EU-25 distinguishes 283 consumed product groupings. This analysis supports the main conclusions made above and gives a deeper understanding of the life cycle impacts of individual product groupings. However, the detailed results must be interpreted with caution because they are based on single studies and models only, instead of being supported by a number of converging studies. All of the models used for the analyses, do in fact include a number of assumptions and approximations. This is unavoidable as the statistical information and databases available today do not provide all the necessary information directly.

The analysis has been made for eight environmental impact categories. The results are similar in each case: Only a few product groupings cover together more than 50% of each of the potential impacts. Drawing together the product groupings responsible for half of each different environmental impact into a single list leads to a selection of not more than 22 product groupings. In alphabetical order and using the product grouping aggregations of the present study this list includes:

- car repairs and servicing
- cheese
- clothing
- domestic heating equipment, including use but excluding electric heating
- drugs
- electric light bulbs and tubes, including use
- household laundry equipment, including use
- household refrigerators and freezers, including use
- household use of pesticides and agricultural chemicals
- meat
- milk
- motor vehicles, including use
- new buildings and conversions
- new one-family houses
- other edible fats and oils
- other household appliances, including use
- other leisure and recreation services
- poultry
- sausages and other prepared meat products
- services of beauty and hairdressing salons
- services of restaurants and bars
- telephone, telex and communications services

If product groupings are ranked in descending order according to environmental impact per euro spent, the number of product groupings necessary to cover more than half of the impacts is much higher than if ranking by absolute impact. Using the example of global warming potential, 32 of the ranked product groupings make up just over half of the impact. However, only one-quarter of all consumer spending is on these product groupings. This demonstrates that the relatively high impact of these product groupings comes at a relatively low share of market volume. It would take further analyses to find out whether there are environmental costs not internalised in the price.

vii. Final results for each functional area of consumption

Environmental impact

Taken in combination, the results of the studies reviewed and the new CEDA EU-25 model exercise are strikingly robust at the level of functional areas of consumption, irrespective of the impact categories considered. In the studies that included them systematically, food and drink, transport and housing are consistently the most important areas – across both different studies and the different impact categories compared (global warming, acidification, photochemical ozone formation, and eutrophication). Together they account for 70 to 80 per cent of the whole life cycle impact of products. The following overview presents the detailed results of the main product groupings for each functional area of consumption according to the COICOP classification (Level 1 of product aggregation with 12 areas, CP01-CP12)[3].

Food and drink, tobacco and narcotics (CP01 and CP02)

This area of consumption is responsible for 20-30% of the various environmental impacts of total consumption, and in the case of eutrophication for even more than 50%. Within this area of consumption, meat and meat products (including meat, poultry, sausages or similar) have the greatest environmental impact. The estimated contribution of this product grouping to global warming is in the range of 4 to 12% of all products (CP01-12). The results reflect the impact of the full production chain, including the different phases of agricultural production.

3 COICOP: Classification of Individual Consumption According to Purpose (standard classification within the framework of the United Nations System of National Accounts).

The second important product grouping are dairy products. After these two main groupings, there is a variety of others, such as plant-based food products, soft drinks and alcoholic drinks, with lower levels of environmental impacts for most impact categories considered.

It needs to be mentioned again that these results are based on the most commonly used impact indicators only. There are less usual impact categories where rankings can differ significantly. In this consumption area, fish and fish products may be mentioned as an example, which would become more visible if impacts on 'fish resources' were included as an additional impact category.

Clothing (CP03)

There is some divergence between studies as to the absolute importance of clothing, although in all studies it ranks lower than the three most important types of consumption in all impact categories. Clothes clearly dominate this consumption area across all environmental impact categories, followed by shoes and accessories.

Housing, furniture, equipment and utility use (CP04 and CP05)

This is a very dominant area of consumption as regards environmental impact, making up 20 to 35% of the total for most impact categories. Household heating is consistently one of the most important contributors for each impact category in all studies. Its absolute contribution differs between studies, but energy use for heating, hot water and electrical appliances is by far the biggest contributor to global warming, acidification, and photochemical oxidation. Residential structures also score highly in most impact categories (3 to 4% of all products).

After domestic heating and residential structures come other energy-consuming products. The systematic comparison for these product groupings is, however, complicated by the fact that different studies define their product categories in very different ways, for instance concerning how electricity purchase and use is related to the appliances.

Wooden products are likely to have a high score on impact in terms of protecting biodiversity or natural resources, but few of the studies used this indicator so it does not show up in this review.

Healthcare (CP06)

Healthcare, in all studies, is responsible for just a minor fraction of the impacts in the different categories. There may, however, be some under-estimation for healthcare expenditures not incurred by households directly, and final conclusions on this would require additional investigations.

Transport (CP07)

Transport is one of the three areas of consumption with the greatest environmental impact. Typically, in most studies, it contributes some 15 per cent to global warming potential and acidification of all products, but less to eutrophication and more to photochemical oxidation. Under the heading of transport, all studies consistently indicate cars as the main contributor, and indeed private cars (and other private motor vehicles) account for about four fifth of the transport related impacts of consumption.

In the studies reviewed, the definition of air transport is a problem. For example, air transport as a part of package holidays or of business trips may not be visible. Also intercontinental air transport may not be properly included in consumer expenditure statistics as it is not clearly defined in which geographical area the money is spent. Therefore, the results must be treated with care.

Communication (CP08)

This area of consumption is of low relevance in absolute terms to all impact categories.

Recreation (CP09)

The overall importance of the environmental impacts of this area of consumption depends on the extent to which the different models and studies have considered here the related transport (e.g. associated to package holidays), which has the potentially biggest contribution to the impacts of this consumption area. If travel is not included, then the environmental impact of this area of consumption is much lower.

Education (CP10)

In absolute terms, this consumption area has minor relevance in all impact categories. Expenditure on education is mostly via governmental funding, and is not well covered in most of the studies reviewed and in the calculations made. Potential impacts are from transport and heating.

Restaurants, hotels (CP11)

Only the CEDA EU-25 shows restaurants and hotels to be an important contributor to global warming, acidification and eutrophication, but the result needs further validation. The fact that business-to-business expenditure is not included in virtually all the studies reviewed (i.e. they do not include business travel) can distort the relevance of this expenditure area.

Miscellaneous (CP12)

There are differences between studies that probably reflect the differences in product classifications. Typically, this 'leftover' area of consumption contributes some 2 to 5% to the environmental impacts of all products. Some results point to service providers, e.g. hairdressers, insurance agents, and government services.

Impact per euro spent

The ranking of the total environmental impact of products in terms of impact per euro spent has also been developed in the study. It appears that food products and processes, and energy for heating and electrical appliances have the highest impact per euro. Further information is available in the full report. Since only a few studies and the CEDA EU-25 clearly show impact per euro spent caution needs to be exercised in drawing conclusions. Nevertheless, it gives an interesting and innovative way to present the results, and its support potential for policymakers has to be further explored.

viii. Conclusions

This project has identified those products with the greatest environmental impact. The results are based on a life cycle analysis of the products consumed in the European Union and paid for by private households and the public sector. The current state of research identifies products in the following three areas as having the greatest impact:

- food and drink
- private transport
- housing

There is no clear ranking, as products in the three areas identified are of approximately equal importance. Together they are responsible for 70 to 80% of the environmental impact of consumption, and account for some 60% of consumption expenditure.

More detailed conclusions can be given for the main functional areas of consumption:

- **Food and drink** cause 20 to 30% of the various environmental impacts of private consumption, and this increases to more than 50% for eutrophication. This includes the full food production and distribution chain 'from farm to fork'. Within this consumption area, meat and meat products are the most important, followed by dairy products. Food and drink were covered by only some of the studies so the results for that area should be treated with more caution. However, the

general conclusions can be taken with a reasonably high level of confidence.

- The contribution of **passenger transport** to the total environmental impacts of private consumption ranges from 15 to 35%, depending on the category. Based on the data used for this study, the greatest impact is from cars, despite major improvements in the environmental performance in recent years, especially on air emissions. The impact of private air travel is increasing but for methodological and data reasons, it has not been possible to adequately quantify its impact on the environment.
- The products under the heading of **housing** include buildings, furniture, domestic appliances, and energy for purposes such as room and water heating. Together they make up 20 to 35% of the impacts of all products for most impact categories. Energy use is the single most important factor, mainly for room and water heating, followed by structural work (new construction, maintenance, repair, and demolition). The next important products are energy-using domestic appliances, e.g. refrigerators and washing machines.
- All **other areas** of private consumption together (i.e. excluding food and drink, transport and housing) account for no more than 20 to 30% of most environmental impacts. There are uncertainties about the percentage contributions of the remaining products, but most of the evidence suggests that **clothing** ranks highest, accounting for between 2 and 10% of total environmental impact.

The project results are intended to help develop future product policies in a generic way. It should be stressed that the picture presented in the report gives a static view of the environmental impacts of products and services, and does not take into consideration possible future changes, e.g. due to market dynamics, or public policies that may be in place already for some of the products investigated. Most of the data used is from the end of the 1990s, with 2000 as the reference year. New policy initiatives cannot therefore be initiated on the results of this project alone. More information will be required before any new policy initiatives can be developed.

At a subsequent stage, there will have to be consideration of whether and how the life cycle impacts of those products that most affect the environment can be reduced. After that, the Commission will seek to stimulate action for those products that have the greatest potential for environmental improvement at the lowest socio-economic cost.

1 Introduction

1.1 Background: Integrated Product Policy

In June 2003, the European Commission adopted a Communication on Integrated Product Policy (IPP)[4] aiming to improve the environmental performance of products and services throughout their life cycles. The life cycle of a product is often long and complicated. It covers all the areas from the extraction of natural resources, through their design, manufacture, assembly, marketing, distribution, sale and use to their eventual disposal as waste. At the same time it also involves many different stakeholders such as designers, industry, marketing people, retailers and consumers. IPP attempts to stimulate each part of these individual phases to improve their environmental performance.

Existing environmental product-related policies have tended to focus on large point-sources of pollution, such as industrial emissions and waste management issues, rather than the products themselves and how they contribute to environmental degradation at other points in their life cycles. Measures have also tended to look at the chosen phases in isolation. IPP represents a new approach and puts emphasis on three dimensions:

- IPP advocates 'life cycle thinking', which means that when pollution-reduction measures are identified, consideration is given to the whole of a product's life cycle, from cradle to grave. In this way, appropriate action can be taken at the problem stages in the life cycle. This approach also avoids just shifting the environmental impacts from one phase of the life cycle to another. Instead it reduces the overall environmental impact where improvements are usually made through a continuous process rather than setting a precise threshold to be attained.
- IPP is flexible as to the type of policy measure to be used, working with the market where possible. Many different policy measures influence the environmental impacts of products such as taxes, product standards and labelling, and voluntary agreements. However, with so many different products it makes no sense to prefer any one type of policy-instrument. The only prerequisite is that the measure used should be the most effective.
- IPP requires full stakeholder involvement. Throughout their long and complex lives, the environmental impacts of products are affected by the actions of many different stakeholders, such as designers, industry, marketing people, retailers and consumers. Reducing these impacts requires all stakeholders to take action in their sphere of influence: for example, manufacturers on the design and marketing of products, and consumers through product choices, use and disposal habits.

Besides general measures to encourage a wide up-take of life cycle thinking among all relevant stakeholders, the Commission has announced measures to address particular products. This was announced in the IPP Communication (2003) and includes the commitment to address products which have the greatest potential for environmental improvement, and to identify and stimulate action for them. In assessing this improvement potential, the likely socio-economic effects of any such change will be taken into account. However, according to the Communication, there is no analytically-based consensus yet on which

4 COM(2003) 302 final.

products have the greatest environmental impact, nor therefore on those which have the greatest potential for environmental improvement. The Commission has therefore initiated this project in order to develop and apply a methodology for identifying these products at European level.

This report covers the first step towards this goal, namely to undertake research to identify the products that have the greatest life cycle environmental impacts.

In subsequent steps, but not part of the project covered by this report, the Commission will then assess improvement potentials, i.e. determine whether - and how - the life cycle effects of those products with the greatest impacts can be reduced. Once it has done that, the Commission will seek to address some of the products that show the greatest potential for improvement at least socio-economic cost.

As has already been said, this report addresses only the first stage of the process, i.e. identifying those products that have the greatest environmental impact. In the light of what is said above, this does not mean that they are necessarily priorities for action.

1.2 Project set-up

The research to identify the products that have the greatest life cycle environmental impacts has been carried out in a study project organised by the Institute for Prospective Technological Studies (IPTS) of the European Commission's Joint Research Centre. The project has been carried out through the European Science and Technology Observatory (ESTO). ESTO is a network of organisations which has been operating under the leadership and funding of the IPTS since 1997. The following ESTO members participated in the project and wrote this report:

- the TNO-CML Centre for Chain Analysis, the Netherlands, operating agent and project manager)[5],
- VITO, Belgium, and
- the Technical University of Denmark.

The study consisted of five main tasks:

1. Goal and scope definition;
2. Evaluation of existing research and consequences for methodology development;
3. Methodology development and refinement;
4. Application of the methodology and final reporting; and
5. Participation in stakeholder consultations.

This is the final report of the study. The work started in January 2004. The results of Task 1, 2 and 3, and from part of task 4, have been discussed in expert workshops held on 6 May and 2 September 2004. Furthermore, two short stakeholder meetings were organised on 15 September the same year. The final draft report was published on the European Commission's IPP website in May 2005 with an invitation for making comments, and extensively discussed in an expert stakeholder workshop organised by the Commission on 13 July 2005. All meetings took place in Brussels. Participant lists can be found in Annex 3. The comments made on the different occasions were carefully considered and taken into account in the analysis.

This report consists of the following main parts:

- Chapter 2 specifies the goal and scope of the study;
- Chapter 3 reviews the state of the research in the area and what it implies for the approach and methodology of this study;

5 This Centre is a collaboration of TNO Built Environment and Geosciences and the Centre of Environmental Sciences of Leiden University.

- Chapter 4 forms the first main pillar of the study: it makes a cross-cutting analysis and comparison of the relevant studies that already exist into the environmental impacts of products;
- Chapter 5 forms the second main pillar of the study: it gives a detailed analysis of the environmental impacts of products in the EU-25, with the newly developed CEDA EU-25 environmentally extended input-output model;
- Chapter 6 interprets the results of Chapters 4 and 5, and gives final conclusions.

Papers with the results of almost all underlying studies used in this project, and all key chapters of this report have been published or have been accepted for publication in reputable, peer-reviewed scientific journals such as the Journal of Industrial Ecology (see Box 1.1)[6]. With two to three reviewers per paper, this implies that almost two dozen experts have been involved in the validation process of the results that are also presented in this report.

Box 1.1: Publications based on studies and work reflected by this report

The studies discussed in Chapter 4 of this report have also been published as:

- Nemry et al. (2002): Jansen, B. and K. Thollier (2006). Bottom-up LCA Methodology for the Evaluation of Environmental Impacts of Product Consumption in Belgium. Accepted for publication, Journal of Industrial Ecology, Spring 2006
- Labouze et al. (2003): Labouze, E., V. Monier and Y. LeGuern (2006). Environmental effects related to the life-cycle of products and services consumed in EU-15. Accepted for publication, Journal of Industrial Ecology, Spring 2006
- Kok et al. (2003): Moll, H.C., K.J. Noorman, R. Kok, R. Engstrom, H. Throne-Holst and C. Clark. (2005), Pursuing more Sustainable Consumption by Analysing Household Consumption in European Countries and Cities. Journal of Industrial Ecology, Winter/Spring 2005
- Moll et al. (2004) Moll, S. and J. Acosta (2006). Environmental Implications of Resource Use – NAMEA based environmental Input-Output analyses for Germany. Accepted for publication, Journal of Industrial Ecology, Spring 2006
- Nijdam and Wilting (2005): Nijdam, D., H.C. Wilting, M. J. Goedkoop en J. Madsen (2005): Environmental Load from Dutch Private Consumption: How Much Damage Takes Place Abroad? Journal of Industrial Ecology, Winter/Spring 2005
- Weidema et al. (2005): Weidema, B.P., A.M. Nielsen, K. Christiansen, G. Norris, P. Notten, S. Suh, and J. Madsen (2006): Prioritisation within the integrated product policy. Accepted for publication, Journal of Industrial Ecology, Spring 2006

The results of Chapter 5 of this report have also been published as:

- Huppes, G., A. de Koning, S. Suh, R. Heijungs, L. van Oers, P. Nielsen, J.B. Guinée (2006). Environmental Impacts Of Consumption In The European Union Using Detailed Input-Output Analysis. Accepted for publication, Journal of Industrial Ecology, Spring 2006

The comparative analyses in Chapter 4 and Chapter 6 have been published as:

- Tukker, A. and B. Jansen (2006). Environmental impacts of products: a detailed review of studies. Accepted for publication, Journal of Industrial Ecology, Spring 2006
- Tukker, A., P. Eder and S. Suh (2006). Environmental impacts of products: Policy implications and Outlook. Accepted for publication, Journal of Industrial Ecology, Spring 2006

6 Many of the papers based on, or related to, the EIPRO work will be published in a special issue on integrated product policy of the Journal of Industrial Ecology, Spring 2006

2 Goal and scope

2.1 Objectives of the project

The objective of the project is to identify the products that have the greatest environmental impact from a life cycle perspective. This identification will be made by developing a methodology, which will be discussed with stakeholders with the aim of achieving a broad level of consensus, and by applying this methodology on products at the European level. This should allow the European Commission to select products that qualify for an assessment of their improvement potential and, depending on the outcome of such an assessment, for being addressed within the European IPP. This means that this study per se does not identify priority products for policy action.

The following boundary conditions apply:

- The study should cover EU-25;
- The work should be based as much as possible on existing research;
- The draft results should be delivered ideally within a year.

These objectives and boundary conditions were defined as the project brief before the actual start of the project. The first task after the project start was to translate them into more concrete choices about goal and scope. This is described in the subsequent section.

2.2 Specification of the goal and scope

The objectives of the project were translated into a specific goal and scope description of the project at a detailed level. The choices are presented below. They were agreed upon between the ESTO project team and the IPTS:

1. The project should focus on identifying the products on the basis of their (current) life cycle environmental impacts. They will be identified on the basis of the environmental impacts of the whole volume of the product used. The impact per euro value will also be taken into account.
2. The study should primarily focus on the life cycle impacts of products (including both goods and services) serving the *final* consumption in the EU-25 (both household and government consumption)[7]. This implies all processes related to the resource extraction, production, use and waste management (both in and outside the EU-25) needed to deliver the functionality of the total final consumption in the EU-25 are accounted for. The life cycle impacts of production in the EU-25 for export are not included[8].
3. Ideally, the study aims at describing the current situation. Taking into account the data situation, this means it should refer to a recent reference year around 2000. Analyses of developments over time and in the future are not included.
4. To assess the environmental impact of products, the final consumption of the EU had to be divided into product categories. This may be done in different ways and at

7 Final consumption expenditure consists of expenditure incurred by residential institutional units on goods or services that are used for the direct satisfaction of the individual needs or wants or the collective needs of members of the community. In the system of national accounts, only households, government and NPISH (non profit institutions serving households, of little importance in the total) have final consumption. The use of products by business or industry is not considered final consumption.

8 This implies that all products that are used within the life cycle or supply chain of (i.e. used to produce) final consumption products are included, even if not visible explicitly. For instance, business travel by plane is included as one of the life cycle impacts related to the production of a specific (final consumption) product, but only the travel by plane paid for by final consumers and government is visible as 'air travel'.

different levels of aggregation. The levels, from high to low, can be described as:

I. **Functional areas of consumption**: up to a dozen elements, e.g. 'transport', 'clothing', 'healthcare' and 'recreation'

II. **Consumption domains:** sub-areas of consumption with up to several dozens of elements, e.g. 'transport' contributing to 'healthcare' and 'recreation'

III. **Product groupings:** up to several hundreds of elements, e.g. sub-division of 'consumption domain' (2) into 'car transport', 'rail transport', 'air transport', etc.

IV. **Homogeneous product groups**, e.g. medium range diesel cars

V. **Individual** products, e.g. a specific diesel car.

It was decided that the study would not go into more details than the third level of aggregation.

5. The study should include capital goods, and where possible will pay attention to specific materials such as packaging and other intermediate products, despite the fact that they are not the primary cross-section in this study.

6. Inventory/emission data of accession countries would be modelled on the basis of EU-15. (It is assumed that differences in production technologies between old and new Member States are becoming less and less relevant.)

7. Where relevant, the study should cover a variety of impact assessment methods.

8. No impact categories should be excluded beforehand. The study must be very prudent with ranking on the basis of toxicity impacts, since scientific knowledge about this issue is limited.

The goal and scope choices make it clear that the method applied needs to be based on a system approach and elements of life cycle impact assessment. It should:

- allow identifying the products with a great environmental impact;
- be transparent;
- include assessing the degree of robustness of the results.

3 Existing studies: lessons for the approach to EIPRO

3.1 Introduction

As a second task in the project, the most relevant existing studies analysing the environmental impact of products for environmental policy making were reviewed with the aim of establishing the state of the art in the area and to find the most suitable methodological approach for carrying out the project. A summary of the review is given in Section 3.2. Section 3.3 lays out the essentials of the two principle methodological approaches that the research in the area has followed, i.e. the bottom-up approach and the top-down approach. Finally the conclusions and consequences for method development in this project are presented in chapter 3.4.

3.2 A first review of existing research

3.2.1 Selection

Annex 2 gives a long list of studies and tools that were considered for evaluation. At the start of this study (early 2004), these were the most relevant studies in this field that the authors, on the basis of a literature search and a consultation of their networks, could identify. Now, one year later, the team of authors has not yet come across other studies that should have been included in the long list at that time[9]. From the long list, the project team chose seven priority studies for a full evaluation. The selection criteria included that the studies should:

- be comprehensive (i.e. in principle covering the final consumption of 'society' as a whole);
- focus on classifying products and aggregations thereof according to their life cycle environmental impacts;
- focus on an EU country or on the EU as a whole;
- cover a reasonable set of environmental problems;
- be relatively new.

Furthermore, it was taken into account that in principle no more than one study from the same 'school' (i.e. the same or more or less similar author teams) needed to be included. In general, the most recent study was selected.

The following studies were selected (references no. 1 – 7 in Table 3.2.1). In addition, the existing external reviews (references no. 8 – 10) were taken into account.

3.2.2 Evaluation of the studies

Each of the chosen studies was evaluated by one member of the project team, followed by a crosscheck by another member. The main elements in the evaluation were:

- Main characteristics (date, overall approach, etc.);
- Methodology (goal, scope and system boundaries, aggregation level, data inventory, impact assessment);
- Main results / conclusions / product classifications;

9 After the start of EIPRO, other interesting work has become available. Part of it will be included in a special issue of the Journal of Industrial Ecology of Spring 2006, which will be based largely on EIPRO. It concerns a study on Norway (Peters and Hertwich, 2005), a study on Finland (Mäenpää, 2005), a study on decoupling indicators (van der Voet et al., 2004), and several studies into the 'ecological footprint' related to final consumption in cities or regions in the UK (see e.g. Collins et al., 2005 and Wiedmann et al., forthcoming). Overall, there are no fundamental differences in the outcomes of these studies from the work reviewed here.

Table 3.2.1: Studies selected (no. 1 – 7) and related external reviews (no. 8 – 10)

Number	Reference	Main institute involved
1	Dall et al. (2002). Danske husholdningers miljøbelastning. Miljøstyrelsen. Arbejdsrapport 13. København_	COWI/ØkoAnalyse/DHI
2	Nemry et al. (2002). Identifying key products for the federal product & environment policy – Final report. Institut Wallon de Développement Économique et Social et d'Aménagement du Territoire ASBL/Vlaamse Instelling voor Technologisch Onderzoek. Namur/Mol	IW/Vito
3	Kok et al. (2003). Household metabolism in European countries and cities. Comparing and evaluating the results of the cities Fredrikstad (Norway), Groningen (The Netherlands), Guildford (UK), and Stockholm (Sweden). Toolsust Deliverable No. 9. Center for Energy and Environmental Studies. University of Groningen	Toolsust Consortium
4	Labouze et al. (2003). Study on external environmental effects related to the lifecycle of products and services – Final Report Version 2. BIO Intelligence Service/ O2 France. Paris	Bio Intelligence/O2
5	Nijdam and Wilting (2003). Environmental load due to private consumption. Milieudruk consumptie in beeld, RIVM rapport 7714040004. Bilthoven	RIVM
6	Moll et al. (2004). Environmental implications of resource use – insights from input-output analyses. prepared by the European Topic Centre on Waste and Material flows (ETC WMF). Copenhagen	ETC-WMF
7	Weidema et al. (2005). Prioritisation within the integrated product policy. Environmental Project Nr. 980. Danish Ministry of the Environment, Copenhagen	2.-0 LCA Consultants

Number	Additional references	Study origin
8	Experts Review, Annex 1 to final report, IW/Vito, "*Identifying key products for the federal product & environment policy*", December 2002 (4 international exports: E. Labouze, Bio Intelligence Service, France; L.-G. Lindfors, IVL Swedish Environmental Research Institute; E. Hansen, COWI A/S, Denmark; W. Eichhammer, Fraunhofer Institute for Systems and Innovation Research, Germany)	IW/Vito
9	Joint Platform 'European and International Environmental Policy', *Position Integrated Product Policy, Comments on the methodology used in the Belgian study,* September 2003 (Members of Joint Platform are industry federations FEB, UWE, UEB, VEV)	IW/Vito
10	ERM, *Review of the Belgian Product Study,* M. Collins, R. Nuij, for The Alliance for Beverage Cartons and the Environment, May 2004	IW/Vito

- Evaluation of strengths/weaknesses of the study;
- Relevance of the study for IPP in the EU (geographical relevance, product focus or not, aggregation level, and general acceptance of the method).

For a full description and evaluation of each study see Annex 4.1 of this final report. Here, we briefly review and compare the methodological approaches in the different studies. Table 3.2.2 at the end of this section gives an aggregated overview[10].

Reference study no. 1 by Dall *et al.* (2002)

Scope, economic activities and period: life cycle impacts of the consumption (of both imported and domestically produced goods) by private households in Denmark, 2000.

Aggregation type: functional aggregation that groups products into 30 consumption domains or activities[11]. The consumption domains reflect the way products are used and the allocation of products to consumption domains is hence logical. However, the level of aggregation of products is to

10 Table 3.2.2 was inspired by, and in part copied from, work done by Per H. Nielsen within the framework of the EIRES project, a parallel IPTS/ESTO project on natural resources. See Nielsen *et al.* (2004).

11 The study discerned initially some 800+ expenditure categories or detailed product groupings, which were transformed into kg of pieces of a product used in the household. This was further combined with partial information about composition of products. With the help of the EDIP database, this information was transformed into environmental interventions. Where the authors judged that this procedure gave a result that were reliable at the level of the 30 activities presented in the report, they warned that the few results given at more detailed level should be used as examples only, since the uncertainty at this level is simply too high. The report gives no comprehensive overview of impacts from an individual expenditure category (though the underlying database does). Therefore, we only used results of this study at the level of 30 activities.

some extent ambiguous and specific choices can affect results substantially (e.g. different aggregation results in different product prioritisation).

Products: Products estimated to cover 93% of the total household consumption, the remainder being public transport, charter travel and smaller consumption items for which the environmental data were not available. Building structure is not included. Other missing products are reported and include, for instance, small electrical equipment's energy consumption, house maintenance, etc. For food and beverages, the production is based on a simple and quite incomplete model.

Method: bottom-up by the LCA approach. Environmental data used from the early 1990s and it is unclear if the data are differentiated per economic region. Generally, the same limitations apply as for the other bottom-up LCA studies: data gaps in process modelling, data missing for some products/services so assumptions need to be made, leading to substantial uncertainties.

Reference study no. 2 by Nemry *et al.* (2002)

Scope, economic activities and period: consumption by private households in Belgium, 2000 (imports for domestic use and production for domestic use).

Aggregation type: functional aggregation, comprehensive list but detailed data are not reported, so lacks transparency. The same limitations apply as for the other functional aggregated studies.

Products: products not considered are: food and drinks, chemicals and preparations used by households such as detergents, paints, adhesives, medicines, etc. Services are not included (healthcare, etc.). Household packaging is considered as a separate product category. Fuel, electricity or other energy consumption is not considered separately, but are allocated and included in the final product systems.

Method: bottom-up LCA. Due to the limitations of system boundaries and data availability, the resulting total life cycle impacts are incomplete, i.e. not covering all final products and services and not covering all activities involved in production processes and transport. The data used for environmental pressures from industry represent Western European or global averages. The applied methodology brings about several uncertainties and, as noted by the authors, most of the results have a considerable margin of error and should only be treated as indicative. The "Review of the Belgian Product Study", conducted by ERM (reference study no. 10) concludes in its report that the "study is too ambitious, and that in practice too many compromises have had to be made due to the lack of data and resources to render the results of this study useful in the context of defining priorities for a Belgian product study".

Reference study no. 3 by Kok *et al.* (2003)

Scope, economic activities and period: considers the entire production chain and consumption by private households in four Northern and Western European cities in 1996 (imports for domestic use and production for domestic use).

Aggregation type: very high level of functional aggregation, no detailed data reported. Products are divided over functional consumption areas and divided also direct and indirect energy use. Due to the latter, the aggregation concept is substantially different from other considered studies.

Products: due to the input-output approach, the study covers a complete list. The study only considers final consumer expenditure. Government expenditure is excluded from this study. The consequence of this exclusion is that products or services for which the cost is spread between households, government and employers (i.e. social healthcare) are only partly accounted for, i.e. as far as expenditure made by households alone is concerned.

Method: the method applied in the used Energy Analysis Program is a mix of input-output analysis, and direct LCA-type analysis of products (goods or services) that could not be covered by input-output. The only indicator considered in

this study is energy use (direct and indirect). It is unclear if the data on environmental pressures are differentiated per economic region, as in the study by Nijdam and Wilting (2003). The applied methodology brings about several uncertainties and, as noted in the report, most of the results have a considerable margin of error and should only be treated as indicative.

Reference study no. 4 by Labouze *et al.* (2003)

Scope, economic activities and period: considers the entire life cycle of products and services consumed in the entire economy of EU-15 in 1999.

Aggregation type: two complementary functional classifications are applied to cover most of the entire economy: final products, and a transversal classification including some intermediate product categories such as packaging, textiles for industry use, commercial buildings, transport of goods, etc. Due to this complementary approach, double counting occurs but is estimated to be less than 10% for the main environmental impacts. Although the effects on results of using different 'functional' classifications become visible in this way and thus less ambiguous, the aggregation is, however, more confusing compared to that of the other studies. The product list is presented transparently and in great detail.

Products: covering most products in the economy, however due to the chosen approach, lacking some substantial products and services compared to the top-down studies (i.e. healthcare services). The applied aggregation principle, however, allows individual consideration of some relevant 'intermediate' product categories, which is not the case in the studies where final product classifications apply. For some intermediate product categories, such as 'municipal waste', their presence is somewhat confusing. It is unclear from the report how this aspect is then treated in the life cycle modelling of the other product categories.

Method: bottom-up LCA. Due to limitations of system boundaries and data availability, the resulting total life cycle impacts are incomplete, i.e. not covering all final products and services and not covering all activities involved in production processes and transport. Limitations in data availability cause some products to be less represented than others (services, food products). It is unclear if the data used for environmental pressures from industry are differentiated per economic region.

Reference study no. 5 by Nijdam and Wilting (2003)

Scope, economic activities and period: consumption by private households in the Netherlands in 1995 (imports for domestic use and production for domestic use). Direct and indirect impacts are included in the scope: indirect impacts are those generated prior to purchase by the consumer, direct impacts are those during and after purchase by the consumer (use and after use phase).

Aggregation type: functional consumption areas, a comprehensive list and extensive in detail. The functional classification is logical, but to some extent ambiguous and can affect results substantially (different aggregation results in different product prioritisation). The functional aggregation is different from that used by Nemry *et al.* (2002) and Labouze *et al.* 2003. For example, Nijdam and Wilting divided transport between 'labour', 'leisure' and 'food (shopping)' while the other studies consider it as a separate functional category.

Products: due to the input-output approach, the study covers a complete list and no products (goods and services) should have been left out of consideration. The same exception is valid as for the study by Kok *et al.* (2003) (due to the focus on household consumption, the study does not cover the products and services for which payment of cost is spread between households, employers and government in full).

Method: the top-down input-output approach does not suffer from incompleteness on products and impacts as compared to the bottom-up approach. The disadvantage of this approach is the implicit assumption of homogeneity of the industry (all products from an industry assigned the same environmental impact per monetary unit). The data used for environmental pressures from industry are differentiated per economic region (the Netherlands, OECD, non-OECD).

Reference study no. 6 by Moll *et al.* (2004)

Scope, economic activities and period: final demand in the entire German economy, including export of products (including intermediates) for use abroad, 1995-2000. The inclusion of export is substantially different from other studies. Imported products are assumed to be produced in the same way as products from the corresponding German industry.

Aggregation type: aggregation relates to industrial activities and is made according to the NACE/EPA classification. This is substantially different from the other studies, which are mostly based on self-defined functional oriented aggregation of products. Only one level of aggregation is applied, although for some impact categories and for some activities results are aggregated (depending on data availability).

Products: due to the applied input-output approach, the study covers the entire final demand, imports and production (including production for export). As export is included in the scope of activities, the study also includes intermediate products (such as basic materials, mining products etc.) for export. These intermediate products do not show up in other studies.

Method: extended input-output analysis with a special focus on identifying correlations or links between resource use and emission indicators. The scope does not include the total life cycle: environmental interventions in the use phase of the product or service are not included; also waste management related to the use and disposal of the products is not included. Mainly direct and indirect interventions in production activities are considered. Environmental data for foreign production activities are assumed to be identical to German production, which significantly adds to the uncertainty of the results. These aspects are substantially different compared to the other studies.

Reference study no. 7 by Weidema *et al.* (2005)

Scope, economic activities and period: the entire Danish economy is considered from two perspectives: 1) final consumption in Denmark (both public and private) and 2) net Danish production (for both final consumption and export). Imports have been considered using US input-output data and adjusting them at eleven specified points to fit European production. This is a reasonable proxy for imported products in the study. (Seventy per cent of Danish imported products come from other European countries.)

Aggregation type: the 107 product groupings of final consumption in the input-output tables have been rearranged (by aggregation and disaggregation as appropriate) into 98 product groupings that reflect the functions of the different products in their combined use in households. Products have been distributed on 11 need groups (based on a slightly adjusted "core *economic* needs" approach by Segal (1998)). Results are reported per product grouping as well as per need groups.

Products: due to the applied input-output approach, the study covers the entire national production and consumption.

Method: assessing the environmental impacts and environmental improvement potentials related to Danish production and consumption on the basis of national accounting matrices including environmental accounts (NAMEA). The analysis applies a market-adjusted model taking into account market constraints when fixed input-output ratios appear not to be justified.

3.3 Bottom-up and top-down approaches

The overview shows that in methodological terms the existing studies can be broadly divided into two categories:

1. **Bottom-up studies** extrapolate market-oriented LCAs to arrive at the environmental interventions associated with a certain product grouping. The bottom-up approach begins with an individual product and conducts a life cycle assessment (LCA) of it. The results for this particular product are then assumed to be representative for a wider range of products and so are extrapolated to a much larger grouping of products. Combined with other LCAs for representative products, it is possible to put together a picture of the whole economy. The main weak points of the bottom-up approach are:

- that they are based on LCAs that cut off process trees so that the coverage of environmental impacts is incomplete;
- that the assumption of representativeness of specific products for the larger grouping of products is difficult to justify in many cases;
- that the LCAs for the different products often use different databases, which limits the comparability of the results for different products;
- that a conventional LCA process analysis can be a rather time and data-intensive process, if process-specific data are available at all.

The reference studies by Dall *et al.* (2002), Nemry *et al.* (2002) and Labouze *et al.* (2003) fall into this category.

2. **Top-down studies** use environmentally extended input-output analysis (IOA) to estimate the environmental interventions associated with the purchase of a certain amount of products (goods or services). The top-down approach begins with input-output tables produced, in most cases, by statistical agencies. These tables, in the form of matrices, describe production activities in terms of the purchases of products[12] of each industrial sector from all other sectors. They cover the entire economy. If they also contain data about the emissions and resource use of each sector, this information can then be used to calculate the environmental impacts of products covering the full production chains. Input-output analysis is relatively fast to conduct, but provides rather aggregated results compared to (LCA) process analysis. The main weak points of the top-down approach are:

- that the availability of suitable input-output tables including the required environmental information is rather limited;
- that the products in available input-output tables are typically rather highly aggregated;
- that standard input-output tables require specific adaptations to appropriately include the use and waste management phases of the product life cycles.

The reference studies Kok *et al.* (2003), Nijdam and Wilting (2003), Moll *et al.* (2004), and Weidema *et al.* (2005) fall into this category.

It is also possible to combine the advantages of a process analysis (relatively accurate) and an input-output analysis (relatively fast) into an LCA. Such a hybrid approach enables the analysis of large numbers of product systems and exploration of the environmental performance of production and consumption patterns on various levels (e.g. individuals, households and income groups, cities, regions, nations). However, the hybrid approach has per se not been used in this report.

3.1 Combination of existing and new research

All of the reviewed bottom-up studies focused on household consumption only, whereas some of the top-down studies cover the whole consumption.

12 In the terminology of input-output analysis, 'product' refers to any possible level of aggregation.

Most studies have a rather low resolution, and divide final (household) consumption into not more than about 30-50 consumption domains or product groupings. Only Nijdam and Wilting (2003) and Weidema *et al.* (2005) reach a greater level of detail (80-100 product groupings). Data sources depend very much on the type of study (top-down or bottom-up, geographical focus, etc.). Most studies use state of the art methods for life cycle impact assessment to assess impacts (e.g. CML 2002, Eco-indicator '99). Exceptions are Kok et. al. (2003) and Dall *et al.* (2002), who both use primary energy consumption as the main indicator.

The review showed that the seven studies used a broad spectrum of approaches, methods and data sources. The diversity lay in the systems of classifying products and their level of detail, the environmental impact assessment methods, the data sources and methods for making life cycle inventories, the extent to which the environmental impacts of infrastructure and capital goods were taken into account, etc. The studies provide quite robust results at the level of functional areas of consumption and to some extent also at the levels of consumption domains and for product groupings at higher levels of aggregation. However, they provide far less useful information for more disaggregated product groupings and their geographical scopes are not identical to EU-25.

The preferred methodological approach for this study is therefore to combine the exploitation of results of existing research studies with complementary research. This will allow us to take full advantage of the state of research and knowledge about which products have the greatest environmental impacts, and to develop it further in key areas to close existing knowledge gaps.

First, the results of existing studies are systematically examined and compared on the most detailed level possible, taking into account that the studies have used a broad spectrum of approaches, methods and data sources. The method and results of this work will be presented in Chapter 4.

Second, a coherent new analysis is carried out that allows consolidation of the results at the higher levels of aggregation, covers the full EU-25, and refines the analysis through a higher resolution that distinguishes several hundreds of products. The method and results of this work will be presented in Chapter 5.

Table 3.2.2: Summary of the reviewed studies and tools

Reference study	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Author(s)	**Dall et al.**	**Nemry et al.**	**Kok et al**	**Labouze et al.**	**Nijdam and Wilting**	**Moll et al.**	**Weidema et al.**
Year of publication	2002	2002	2003	2003	2003	2004	**2005**
Main approach	Bottom-up	Bottom-up	Hybrid	Bottom-up	Top-down	Top-down	Top-down
System boundaries	Functional approach to final household consumption Denmark	Functional approach to final household consumption in Belgium	Functional approach to final household consumption in four cities in GB, N, NL and S	Functional approach to final household consumption in Europe	Functional approach to final household consumption in Netherlands	Functional approach to final **total** consumption in EU-15	Product , functional, and production oriented approaches to the entire Danish economy
Aggregation level							
Principle	Functional, self-defined groups	Functional, self-defined groups	Functional, self-defined groups building upon consumer expenditure statistics	Functional, self-defined groups	Functional, self-defined groups	NACE /EPA classification	Final consumption in input-output tables have been rearranged into product groupings
Detail of product groupings[13]	7 functional areas of consumption, 30 sub-areas	12 functional areas of consumption, 45 sub-areas, 120 product groupings, 290 products	31-75 sectors, 14 functional areas of consumption	13 functional areas of consumption, 34 sub-areas, ± 100 product groupings	7 functional areas of consumption, 50 sub-areas	27-57 product groupings	11 functional areas of consumption, 98 product groupings
Data							
Consumption (year)	2000	2000	1990ies	1999	1995	1995-2000	1999
Production (year)	Early 1990s	1995-2000	mid 1990ies	1990s?	1995	1995-2000	1999
Production (technology)	West European	Country of origin	West European	West European	The Netherlands	Germany	Denmark and abroad
Impact assessment	Combined	Characterisationand LCIA	Energy	LCIA, and characterisation	LCIA	LCIA	LCIA
Indicators (environment)		GWP, AC, POCP, COD, heavy metals, eutrophication, etc.		GWP, ODP, AC, POCP, TOX (4), YOLL etc.	GWP, AC, POCP, Noise, NP	GWP, AC, POCP, waste	GWP, ODP, AC, POCP, NEP and toxicity (human, eco)
Indicators (resources/ other)	Primary energy, weighted resources added together, waste	Material intensity, Energy intensity, water intensity waste	Primary energy consumption	Depletion of non renewable resources (internalisation), external costs	Land use, wood, water, fish	TMR, primary energy, land use	Nature occupation
Geographic area	Denmark	Belgium	NL, N, GB, S	EU-15	Netherlands	EU-15 based on German data	Denmark

13 Different terminologies are used in the original reports.

4. Approach 1: Analysis of existing studies

4.1 Introduction

This chapter represents the first of the two pillars of the main analysis carried out in this study, i.e. to build as far as possible on existing studies for identifying the products with the greatest environmental impacts. The studies analysed are those listed in Table 3.2.2. An overview of the key characteristics of the individual studies has been given in the previous chapter. Summaries of the studies are given in Annex 4.1.

The results of existing studies are systematically examined and compared on the most detailed level possible. It is examined to which extent the different pieces of research identify similar product categories as important, taking into account that the studies use different methodological approaches, different definitions and classifications, and cover different geographical- and time scopes.

The existing studies are analysed from two main perspectives:

1. Starting from the individual studies: Which products do the studies identify as important taking into account the different types of environmental impacts? This analysis is presented in Section 4.3.
2. Starting from individual environmental aspects or themes: Which are the products that the different studies identify as being important for a particular environmental aspect? This analysis is presented in Section 4.4.

Section 4.5 then presents the overall conclusions.

This analysis is preceded by a discussion on the method followed for comparison (Section 4.2.).

4.2 Method of analysis and comparison

4.2.1 Introduction

The studies analysed show important differences in methodologies, goal, scope and system boundaries (region, time perspective, range of products and economic activities considered) that must be taken into account. Special attention needs to be given to the definition of product categories used by the studies and how they are aggregated at the different levels, as well as to the use and comparability of different environmental indicators. These aspects are discussed in the following sections.

4.2.2 Product categories and aggregation

The highest resolution at which the results of the studies can be compared is at an aggregation level of about 50 product groupings. For this it is necessary to aggregate some of the original categories in these studies to a higher level in order to create better comparability among all studies considered. The following list describes the differences in the original definitions of product categories in the different studies as well as the adaptations that we have made to improve the comparability:

- In the study by Nijdam and Wilting (2003) building structure is covered by 'shelter – rent and mortgage'. In the study by Moll *et al.* (2004) this corresponds to category category 'construction' of the Classification of Products by Activity (CPA), which however also includes offices and industrial constructions. The equivalent category in the study by Labouze *et al.* (2003) is 'building structure (commercial and residential)'. In the study by Weidema *et al.* (2005) the category is 'dwellings in Denmark'. In the

study by Nemry *et al.* (2002), the 'building structure' subcategories were at a higher detail (exterior wall, floor, interior wall, roof, building foundation, etc.) and are aggregated for the purpose of this comparative analysis. This category only considers domestic dwellings. The other studies do not include building structure.

- In the study of Labouze *et al.* (2003) drinks, animal based and non-animal based food are distinguished (though the impacts of these items are included in a relatively limited way). In the studies by Moll *et al.* (2004) and Kok et. al. (2003), only the highest level of aggregation is available: 'food products and beverages', consequently 'feeding, indirect'. In the study by Dall *et al.* (2002) 'food production' and 'alcoholic drinks' can be distinguished and in the study by Weidema *et al.* (2005) 'meat purchase in DK, private consumption' and 'bread and cereals in DK, private consumption' can be distinguished. In the study by Nijdam and Wilting (2003), all subcategories on food and beverages are aggregated to create more conformity with these classifications: 'animal based food' (meat, fish, seafood, milk, cheese and eggs, fats and oils), 'non-Animal based food (incl. non-alcoholic beverages)', 'alcoholic beverages'. Nemry *et al.* (2002) do not cover food in their study.
- In the study by Labouze *et al.* (2003) 'building occupancy (residential)' and 'building occupancy (office)' can be distinguished. Although results are given at a lower level of aggregation (space heating, water heating, cooking, lighting and appliances), which are more compatible with the categories from the other studies, data are missing in the report for some impact categories (eutrophication, ozone depletion, resource depletion, greenhouse gases). The lowest level product categories are used for the comparison where possible.
- The results reported by Kok et. al. (2003) are aggregated at a rather high level (need areas). Results are given for a variety of household types in four countries, without averages. The main report gives energy intensities solely in figures rather than in the form of numbers in tables which cannot be read precisely. The results used for the purpose of this analysis are taken from a paper based on the study, presented in a workshop at IIASA. This paper gives quantitative data on direct and indirect energy use for Dutch households. Tentatively, the direct energy uses were allocated to need areas by Tukker for a presentation in a workshop of AIST, Japan, December 2003.
- The studies by Moll *et al.* (2004) and Weidema *et al.* (2005) generally consider different and a greater number of product categories compared to the other studies, and these include for example 'chemicals and chemical products' or 'basic metals'. These studies also include the export of (intermediate) products for use by industry abroad, and they use the European classifications of products by economic activity. In the study by Moll *et al.* (2004) electricity, fuels etc. are not allocated to final product systems, thus appear as separate categories in the listing. It is important to take these differences into account. In the present analysis, the basic materials or intermediate product categories have, in some cases, been ignored to accomplish comparison of the results of the studies. It is always explicitly mentioned when this is the case.

The next table shows the number of product groupings that remain for each study after these adaptations are made.

Table 4.2.1: Number of aggregated product groupings

Reference study	Number of product groupings
3. Kok et. al. (2003)	13
2. Nemry et al. (2002)	16
1. Dall et al. (2002)	25
4. Labouze et al. (2003)	34
6. Moll et al. (2004)	57
5. Nijdam and Wilting (2003)	65
7. Weidema et al. (2005)	98

4.2.3 Environmental indicators

The environmental aspects covered by the different studies and the ways in which they are considered show important differences. Some environmental aspects are covered by all or most of the studies, others only by a few or by individual ones. A systematic analysis and comparison is only possible for those aspects that are covered by most of the studies. Table 4.2.2 gives an overview of the resources and environmental indicators that are used in the studies for those common aspects.

For the systematic comparison of *common* aspects, the used indicators are not necessarily identical. The definition and the methodology behind some indicators are quite different, but since they describe similar environmental aspects, the consequent results can be roughly compared. For the following environmental impact categories, almost identical indicators and methods have been applied across the studies:

- Depletion of non-renewable resources,
- Acidification,
- Eutrophication,
- Photochemical ozone formation (smog), and
- Global warming (greenhouse effect).

Depending on the different types of environmental aspects, the indicators used in the different studies are more or less comparable. It is, however, important to interpret the results with care, taking differences of the indicators into account. This is true for the following indicators:

- 'Land use' [km^2 built-up area (traffic and building)] used by Moll *et al.* (2004), 'land use' [m^2-III-eq.*ha] used by Nijdam and Wilting (2003) and 'nature occupation' [m^2 year] used by Weidema *et al.* (2005). The land use indicator used by Nijdam and Wilting (2003) is aggregated to type III land use, according to the definition of The World Conservation Union, with the help of weighting factors reflecting the extent of affection of natural values (Auhagen, 1994).
- Indicators on 'resources', 'energy', 'water use', 'waste', 'heavy metals' and 'dioxins'.

Other environmental aspects cannot be considered systematically in the comparison because these indicators are uniquely used for one specific study. They include:

- 'Wood use', 'fish use', 'expenditure', 'road traffic noise', 'pesticide use', which are are uniquely considered by Nijdam and Wilting (2003) ;
- 'Human toxicity', 'years of life lost', 'aquatic ecotoxicity', 'sediment ecotoxicity', 'terrestrial ecotoxicity', 'dioxins', 'dusts', 'hazardous waste', 'metals to air/water/soil', which are uniquely considered by Labouze *et al.* (2003) and to some extent by Weidema *et al.* (2004), who apply two toxicity categories: 'human toxicity' and 'eco toxicity'.

In a few cases, the results concerning specific environmental aspects in a particular study were unclear or data quality was too low to be taken into account in the comparison, namely:

- 'Consumption of raw materials' and 'fossil energy' used by Labouze *et al.* (2003).
- 'Eutrophication', 'ozone depletion', 'POPs' and 'heavy metals to air/water' used by Nemry *et al.* (2002).

Due to the differences in methodology, definitions and system boundaries, it generally makes no sense to compare absolute quantities of indicator values from different studies. The best approach for comparison is to look at the percentage contribution of product categories to the total environmental impact of a certain type caused by all product categories considered in that particular study. This is what has been done in our analysis in Section 4.4. For the different environmental impact categories it shows which products are the most relevant for different percentiles of the total impacts. The top 20-percentile, top 40-percentile and top 60-percentile are presented there. The full tables with all data on this comparison can be found in Annex 4. The product categories adding up to 80-percentile are also given in this annex.

4.3 Results per study

4.3.1 Introduction

Here each of the studies considered undergoes a systematic analysis for identifying those product groupings that are important for several of the different environmental aspects covered by the study. For each impact category used in the study, the product groupings are ranked according to their contribution to this impact category. After this, assessment is made as to which product groupings make up the 40-percentile, the 60-percentile, and 80-percentile. A result could be, for example, that product groupings A, B and C together are responsible for (at least) 40% of, for instance, the total acidification.

And after this, assessment is made as to how many times the same product grouping shows up in the 40-percentile of the different impact categories. For instance, a product grouping may be part of the 40-percentile on acidification, and some other impact categories, but not on land use. This gives an impression on how important a product grouping is with regard to all impact categories considered.

The following sections describe how many and which indicators are considered for each study, the number of product groupings distinguished and for how many environmental indicators a product shows up in the 80-percentile, 60-percentile, and 40 percentile selections. It is important to note that in this type of analysis, the same weight of relevance is given to the different environmental aspects. The detailed data tables with the results per study can be found in Annex 4.2.

4.3.2 Reference study no. 1 Dall et al. (2002)

For this study, results can be considered at the level of 25 product groupings. Four indicators on resources, energy and waste are considered for this study. Conclusions:

- When looking at the highest contributing product groupings: 12 product categories cover 80% of all environmental aspects considered; 7 cover 60%, and only 4 cover 40%.
- When looking at the 40-percentile selection: 'food production' and 'car transportation' have the highest occurrence of 3, followed by 'furniture, lighting etc.' and 'spare time' with only 1 occurrence.
- When looking at the 60-percentile selection, the following additional product groupings show up: 'heating' with an occurrence of 3, followed by 'clothes' and 'TV, computer, etc.' with an occurrence of 1.
- 'Food production' is the highest contributor for primary energy consumption, and the second highest for resources energy.
- 'Car transportation' is the highest contributor for resources (other than energy) and the second highest contributor for resources energy and primary energy consumption.
- In the 80-percentile selection 6 product groupings have an occurrence for only 1 impact indicator each: the most important being 'spare time' which is the second highest contributor to waste (after the highest: 'furniture, lighting etc.'). 'Clothes' has a relatively high share in the waste indicator (14%, compared to the highest 'furniture…' of 27%) and 'TV, computer, etc.' has a high share in resources (other than energy).

4.3.3 Reference study no. 2 Nemry et al. (2002)

For this study, results can be considered at the level of 16 product groupings. Note that this study used a two-step approach to identify the most important product categories: first a selection of product groupings was made based on the criteria of resources intensity. Secondly, for the remaining product groupings, the other environmental indicators were calculated. Thus, the 16 groupings already represent a selection of a broader range of product categories. It has to be noted that this study did not cover food products (only the packaging thereof). This, in turn implies that food in this study cannot show up as a priority, and that the percentage contribution of other product

Table 4.2.2: Comparison of indicators used in studies

Reference study (no.)	Resources	Resource depletion	Energy	Land use	Water use	Acidification	Eutrophication	Photochemical ozone formation ('smog')	Global warming	Waste
1. Dall et al. (2002)	Resources total Resources energy Resources others		Direct + Indirect							Waste [person eq.]
2. Nemry et al. (2002)	Total material intensity Material int. metal Material int. mineral Material int. synthetic Material int. organic [kg] *(note: not raw mat., fuels for energy not included)*	Depletion mineral and fossil resources [antimony eq]	Primary energy		Use water (public supply) [litre]	[SO_2-eq]		[ethylene-eq]	[CO_2-eq]	Municipal and industrial (excl. bulk)
3. Kok et al. (2003)			Direct + Indirect							
4. Labouze et al. (2003)		Depletion mineral and fossil resources [antimony eq]	Primary energy			[SO_2-eq]	[PO_4-eq]	[ethylene-eq]	[CO_2-eq]	Inert waste Municipal and industrial
5. Nijdam and Wilting (2003)				Characterised, according to the extent to which 'natural value' is affected [m^2-type III land use-eq*ha]	Water use [litre]	[SO_2-eq]	[PO_4-eq]	[ethylene-eq]	[CO_2-eq]	
6. Moll et al. (2004)	TMR total TMR fossil fuels TMR metals TMR ind. minerals TMR constr. minerals TMR Biomass [tonnes]		Direct + Indirect Supply [PJ]	Inventory, not characterised [km^2 built-up area (traffic & build.)]		[SO_2-eq]		[NMVOC-eq]	[CO_2-eq]	Bulk constr. & demolition waste Other waste [tonnes]
7. Weidema et al. (2005)				Nature occupation [Potentially Affected Fraction m^2yr]		[SO_2-eq]	[NO_3 eq]	[ethylene-eq]	[CO_2-eq]	

'eq' stands for 'equivalents'

groupings to the total impacts (hence a total without the contribution of food) will be higher in comparison to other studies.

Several conclusions can be drawn:

- When looking at the highest contributing product groupings: 11 product groupings cover 80% of all environmental aspects considered; 7 cover 60%, and 7 cover 40%.
- When looking at the 40-percentile selection: 'passenger transport' has the highest occurrence: for 6 (from the total of 12) impact categories, 'building structure' and 'industrial packaging' in 3 impact categories, 'interior climate' in 2 impact categories.
- When looking at the 60-percentile selection: besides 'passenger transport', also 'building structure' has the highest occurrence: both for 6 impact categories, followed by 'industrial packaging' for 5 impact categories.
- 'Passenger transport' (occurrence 9 in 80-percentiles, 6 in 60-percentiles and 6 in 40-percentiles) is mainly of relevance to the energy, energy related and resources indicators: primary energy, greenhouse effect, metals- and synthetic intensity, acidification and smog. In these themes it is always the highest contributor.
- 'Building structure' (occurrence 8 in 80-percentiles, 6 in 60-percentiles and 3 in 40-percentiles) is mainly of relevance to resources and waste. It is the highest contributor for total material intensity, mineral intensity, resources depletion, bulk waste and has also relatively high contributions for organic and synthetic material intensity.
- 'Industrial packaging' (occurrence 7 in 80-percentiles, 5 in 60-percentiles and 3 in 40-percentiles) is mainly of relevance to resources and waste indicators: for the aspects organic- and synthetic intensity and waste, it is the highest contributor.
- 'Interior climate' or heating (occurrence 4 in 80-percentiles, 2 in 60-percentiles and 2 in 40-percentiles) is the second highest contributor for primary energy supply and greenhouse effect.
- 5 product groupings in the 80-percentile category only apply for one specific aspect: 'furniture' for total material intensity, 'hot water' and 'lighting' for primary energy, 'healthcare and detergents' for synthetic material intensity, and 'sanitary equipment' for water use. In the 60-percentile selections, these product groupings do not appear anymore, except 'sanitary equipment', which is toiletries and water use for personal care and hygiene and is the highest contributor with regard to water use.

4.3.4 Reference study no. 3 Kok et al. (2003)

This study considers the direct and indirect energy uses for several household commodities. For this study, results can be considered at the level of 13 product groupings. 2 product groupings appear in the 40-percentile selection, 3 in the 60-percentile selection and 6 in the 80-percentile selection. 'Heating' and 'transport' are the highest contributors, followed by 'feeding'. 'Leisure', 'personal care' and 'tap water – natural gas' are of less relevance.

No conclusions with regard to other impact categories can be made from this study as it focuses on direct and indirect energy use only.

4.3.5 Reference study no. 4 Labouze et al. (2003)

For this study, results can be considered at the level of 34 product grouping. 8 impact indicators are considered for this study. Conclusions:

- First, it must be noted that the impacts related to food were not fully covered in this study. The study distinguishes 3 main grouping: 'vegetables' where only wheat (for bread consumption) and potatoes are the analysed elements. Another grouping is 'food from animals' where meat and milk from cows are the analysed elements. The

last grouping is 'alcoholic beverages' where only wine is the analysed element. Although these elements represent large shares of total food and beverage consumption, the food product coverage is limited, also in terms of neglected impacts (i.e. fishery, non-alcoholic beverages, etc.). Also, packaging is not included in the scope of food products, but is considered separately.

- When looking at the highest contributing product groupings: 23 product groupings cover 80% of all environmental aspects considered; 16 cover 60%, 10 cover 40%.
- When looking at the 40-percentile selection: 'personal cars' has the highest occurrence of 5, followed by 'textile-apparel' with an occurrence of 4 and 'heating-domestic' with an occurrence of 3.
- When looking at the 60-percentile selection some more product groupings show up with a high presence: 'goods transport' (occurrence 5) and 'building structure' (occurrence 3).
- 'Personal cars' is the highest contributor for smog and greenhouse effect and relatively high for primary energy, resources depletion, acidification.
- 'Goods transport' is relevant for primary energy, resource depletion, acidification (highest contributor), smog and greenhouse effect. Only once is it the highest contributor, and for the other impacts, it always occurs in the 60-percentile selection, and twice in the 40-percentile selection.
- 'Space heating – domestic' is one of the highest contributors for: primary energy, acidification and greenhouse effect.
- 'Building structure' is not in the range of the highest contributors, but its occurrence is relatively high in the 60- and 80- percentile selections. Only for inert waste 'building structure' follows 'civil work' as highest contributor.
- 'Textile – apparel'; also here is the occurrence high, but the contribution relatively low.
- 'Vegetables' appear as high contributors for eutrophication and municipal waste. 'Animal-based food' is a high contributor for smog, but of less relevance for waste.
- Of 9 product groupings in the 80-percentile selection that only occur for one impact, 5 still remain in the 60-percentile selection and 3 in the 40-percentile selection. So even when their occurrence is relatively low, their importance for these specific impact categories is rather high: 'civil work' for inert waste, 'gardening' for the municipal waste aspect and 'domestic building occupancy' for resources depletion.

4.3.6 Reference study no. 5 Nijdam and Wilting (2003)

For this study, results can be considered at the level of 65 product groupings. 6 impact indicators are considered for this study. Conclusions:

- This study and the study by Weidema *et al.* (2005) generally have a lower level of aggregation compared to the other studies. More product groupings could mean more contributing product groupings in the subsequent 40/60/80 percentiles. However this is not the case: only 25 of the 65 product groupings remain in the 80-percentile selection, 9 in the 60- percentile selection and 5 in the 40 percentile selection.
- The 5 product groupings covering 40% of all environmental impacts considered in the study are: 'non-animal-based food' (occurrence 6), 'animal-based food' (occurrence 4), 'rent and mortgage' (occurrence 1), 'commuting, private transport' (occurrence 2) and 'heating' (occurrence 1).
- The additional product groupings covering 60% of all considered impacts are: 'clothes' (occurrence 4), 'restaurant, pub etc.' (occurrence 2), 'holidays' (occurrence 4), 'electricity' (occurrence 1).
- 'Rent and mortgage', equivalent to dwelling for households, is the highest contributor

for land use, but for the other impacts, they make a minor contribution (<5%).

- 'Non-animal-based food' and 'animal-based food' contribute strongly to the impacts of water use, land use, acidification, eutrophication and greenhouse effect. Only for land use, they do not represent the highest contributors ('rent and mortgage' is highest there).
- 'Commuting, private transport' and 'mobility for leisure' present the highest contributors for the impact smog, and a rather high contribution to acidification and greenhouse effect (but for both indicators less compared to food).
- 'Heating' has a relatively high contribution to greenhouse effect but less compared to 'mobility for leisure' and 'commuting, private transport' together, and also less compared to food.
- Also the 'clothes' category has a high occurrence when looking at the 60-percentile and 80-percentile selections, namely an occurrence of 4 and 6 respectively, but always contribute a minor quantity to the impact.
- 4 product groupings appear in the 80-percentile selection for 2 impact indicators and 7 product groupings for 1 impact indicator. However, in the 60-percentile selection, they all disappear. These are: 'shoes', 'accessories', 'energy, hot water', 'shelter – other', 'personal care – water', 'personal care – other', 'alcoholic beverages', 'smoking', 'painting and wallpaper', 'flowers and plants (in house)', 'taxes'.

4.3.7 Reference study no. 6 Moll et al. (2004)

In this study the product classification approach is quite different from the other studies. It includes for example 'basic metals', which is for the most part an 'intermediate' industrial product and mainly for input in other 'final demand' products. Moll *et al.* distinguish 57 product groupings and 12 indicators are considered: Total Material Requirement (TMR) for several material categories, primary energy supply, waste, land use, acidification, smog and greenhouse effect.

The study includes final demand in the German economy as well as products for export. These exported 'intermediate' groupings of resources and materials are not included in the other studies, which focus on final demand. Therefore, the results of this study are a bit difficult to compare to other studies in terms of percentage contributions. However, in terms of ranking, the most important product groupings can be compared, provided the 'intermediate' groupings for export are neglected. In the case of TMR metals, the grouping 'basic metals' is neglected to verify what the other priority categories are. Conclusions:

- 39 product groupings cover 80% of all environmental aspects considered; 24 cover 60%, and 12 cover 40%.
- When looking at the 40-percentile selection: 'construction' is overall the most important product grouping with high contributions to 9 impact categories. 'Motor vehicles, trailers and semi-trailers' have a contribution in 6 indicators and 'food products and beverages' and 'electricity, gas, steam and hot water supply' have high contributions in 5 impact categories. The latter can be explained by the fact that the use phase is not included in the product systems, thus showing up as a separate category. Other product groupings with high contributions, but low occurrences are: 'other transport equipment' (smog), 'coal, lignite and peat' (TMR fossil fuel), 'machinery and equipment n.e.c.' (TMR metals), 'products from agriculture, hunting and related service activities' (TMR biomass), 'basic metals' (TMR total and TMR construction minerals) and 'chemical and chemical products' (TMR fossil, acidification and primary energy supply). 'consumption by private households (domestic)' is relevant for land use and waste, the first probably interpreted as the total amount of land used for construction of household dwellings and

the second as the total amount of municipal household waste.

- When looking at the 60-percentile selection, 12 additional product groupings show up: 'public administration and defence; compulsory social security' (primary energy), 'coke, refined petroleum products and nuclear fuel' (TMR fossil fuels), 'basic metals; fabricated metal products, except machinery and equipment' (waste, excluding bulk), 'retail trade, except of motor vehicles and motorcycles; repair of personal and household goods' (acidification, greenhouse effect), 'other non-metallic mineral products' (TMR construction minerals), 'land transport services' (acidification and smog), 'health and social work' (primary energy supply), 'pulp, paper and paper products' (TMR biomass), 'air transport systems' (smog), 'metal ores and other mining and quarrying products' (TMR construction minerals).
- When looking at the 80-percentile selection, 15 additional product groupings show up, but for only one indicator.
- When neglecting the basic material groupings (mostly intermediates for export) and focusing on the final demand product groupings for use by households and industry; the highest contributors for the different impact categories are:
  - 'Motor vehicles, etc.', 'construction' and 'food products and beverages' for primary energy supply;
  - 'Construction', 'motor vehicles, etc.' for TMR total;
  - 'Motor vehicles, etc.' and 'machinery and equipment n.e.c.' for TMR metals;
  - 'Construction' for TMR minerals;
  - 'Food products and beverages' for TMR biomass;
  - 'Energy using products' and 'construction' for TMR fossil fuels;
  - 'Building land for dwellings' for land use;
  - 'Energy using products', 'motor vehicles, etc.', 'construction' and 'food products' for acidification;
  - 'Other transport equipment' for smog;
  - 'Energy using products', 'food products and beverages', 'motor vehicle, etc.' and 'construction' for greenhouse effect;
  - 'Food products and beverages' and 'construction' for waste.

4.3.8 Reference study no. 7 Weidema et al. (2005)

The Weidema *et al.* study considers 98 product groupings and six indicators: global warming, ozone depletion, acidification, nutrient enrichment, photochemical ozone formation and nature occupation. The study has a very low level of aggregation compared to the other studies. Weidema *et al.* (2005) only report the top 20 product groupings for each impact category. We hence can only assess which product groupings are in the 25% percentile; on the basis of this data, it is not feasible to indicate which groupings are in the 80/60/40 percentiles.

It has to be noted that this study is based on marginal impacts, i.e. it analyses which *change* of impacts would occur if an extra monetary unit would be spent on a product. It also takes into account certain market constraints, implying that an increase in demand does not always automatically lead to an equivalent increase in production. For example, because of the quotas on milk production, a change in the output of milk from dairies does not mean that also milk production by agriculture increases. Instead, it may be compensated by decreasing the dairy output of milk powder and butter. This is different from all other studies reviewed, which attribute impacts according to fixed input per output ratios. The consequence is that those results of the Weidema *et al.* study, for which such restrictions are

assumed, must be interpreted carefully as they do not take into account the entire production chain in a proportional way. For example, environmental impacts of agricultural production may not be included proportionally in the life cycle impacts of certain food products down the production chain.

The conclusions of this study are:

- Seventeen product groupings cover 25% of the environmental impacts considered. Thirteen product groupings cover 15% and three product groupings cover 5%.
- 'Dwellings and heating', 'car purchase and driving' and 'meat purchase' are found in the 5-percentile selection. 'Dwelling and heating' score high on three impact categories: global warming, ozone depletion and photochemical ozone formation. 'Car purchase and driving' score high on acidification and photochemical ozone formation. 'Meat purchase' scores high on nutrient enrichment and nature occupation.
- Thirteen product groupings are found in the 15-percentile selection. In addition to 'dwellings and heating', 'car purchase and driving' and 'meat purchase' discussed above, the most important product groups (in terms of the number of impact categories where the score is high) are 'tourist expenditures' and 'clothing purchase'. 'Tourist expenditures' score high in four impact categories: global warming, ozone depletion, acidification and nutrient enrichment. 'Clothing purchase' scores high in global warming and ozone depletion.
- Seventeen product groupings are found in the 25-percentile. In addition to those already mentioned above, the following product groupings turn out to be important (in terms of the number of impact categories where the score is high (three or more)): 'personal hygiene', 'general public services', 'catering', 'education and research' and 'ice cream, chocolate and sugar products'.

4.4 Comparison of results per environmental theme

4.4.1 Introduction

In this section the results of the different studies concerning the environmental impacts of products are analysed separately for each environmental theme. Here we present the main findings of the comparison for the following environmental themes: resources, energy, greenhouse gas emissions, land use, water use, eutrophication and waste. The full data tables of the comparison are presented in Annex 4.

Before entering into the details, a number of general observations can be made:

- In most cases, the top contributing product grouping represents about 20% or more of the total impact.
- In most cases, the product groupings with the lowest contribution to environmental impact in the 60-percentile still represent 5% to 10% of the total impact.
- The details of this depend on the product scope and aggregation principle applied in the studies. For example, the studies by Weidema *et al.* (2005) and Nijdam and Wilting (2003) have many more groupings compared to the other studies and consequently the individual contributions are smaller, with the top contributing product grouping ranging from 10% or more depending on the impact indicator considered.

4.4.2 Comparison of results on greenhouse effect

Highest contributors to the greenhouse effect:

- Nemry *et al.* (2002): 'passenger transport' (33%), 'interior climate' (31%), 'building structure' (11%);
- Labouze *et al.* (2003): 'personal cars' (17%), 'space heating – domestic' (16%), 'building occupancy – commercial' (12%), 'goods

transport (road, rail, water)' (10%), 'EEE – domestic appliances' (8%);

- Nijdam and Wilting (2003): 'non-animal based food' (12%), 'animal based food' (10%), 'heating' (9%), 'mobility for leisure' (8%), 'commuting, private transport' (8%);
- Moll *et al.* (2004): 'electricity, gas, steam and hot water supply' (16%) ,'food products and beverages' (9%), 'motor vehicles, trailers and semi-trailers' (8%), 'construction' (7%);
- Weidema *et al.* (2005): 'dwellings and heating' (7.7%), 'car purchase and driving' (6.0%), 'meat purchase' (3.4%), 'tourist expenditures' (3.7%).

This shows that there is coincidence on the high importance of transport and heating. There is also coincidence on the high importance of food in the studies that included this item systematically (as discussed before, its modelling was relatively limited in Labouze *et al.* (2003) and not included in Nemry *et al.* (2000).

The picture is less clear for building structure and energy using domestic appliances. In the study by Labouze *et al.* (2003), 'building structure' only contributes 3% to the total greenhouse gas emissions. A lower relative contribution can be explained partly by the fact that goods transport is not considered as a separate grouping in the other studies. Also data availability and completeness of the building structure grouping can contribute to this difference in results. The different aggregation principle for 'EEE – domestic appliances' in the other studies (more disaggregated) accounts for the fact that in the Labouze *et al.* study, it constitutes as a grouping a relevant contribution and pushes the other groupings such as 'building structure' further back.

4.4.3 Comparison of results on acidification

Highest contributors to acidification:

- Nemry *et al.* (2002): 'passenger transport' (39%), 'industrial packaging' (15%), 'building structure' (10%), 'household packaging' (8%), 'heating' (7%);
- Labouze *et al.* (2003): 'goods transport' (15%), 'heating – domestic' (11%), 'EEE – domestic appliances' (10%), 'personal cars' (10%), 'textile – apparel' (6%), 'space heating – commercial' (6%), 'building structure' (6%);
- Nijdam and Wilting (2003): 'animal based food' (18%), 'non-animal based food' (13%), 'mobility for leisure' (7%), 'commuting, private transport' (7%), 'clothes' (6%);
- Moll *et al.* (2004): 'electricity, gas, steam and hot water supply' (13%), 'motor vehicles, trailers and semi-trailers' (9%), 'construction' (8%), 'chemicals and chemical products' (6%), 'food products and beverages' (6%);
- Weidema *et al.* (2005): 'car purchase and driving' (5%), 'dwellings and heating' (4.3%), 'meat purchase' (3.4%), 'tourist expenditures' (3.3%).

Taking into account the limited modelling of food in Nemry *et al.* (2002) and Labouze *et al.* (2003), agreement exists on the following product groupings: 'personal cars', 'heating', 'building structure' and 'food'. The results are less obvious for: 'domestic appliances', 'textile' and 'packaging'.

The differences in aggregation principles for 'domestic electrical appliances' seem to explain the high results observed by Labouze *et al.* (2003). In the other studies, they are divided over different groupings, i.e. 'leisure', 'office equipment' etc., while in the Labouze *et al.* (2003) study they are all kept together in one grouping.

Food has a very high ranking in the study by Nijdam and Wilting (2003), while it makes a very low contribution in the study by Labouze *et al.* (2003) (3% for 'vegetables' and zero for 'animal-based food'). The explanation is similar to that of the other impact categories where food has a high ranking in the other studies: background data and modelling is less complete and detailed in the study by Labouze *et al.* (2003) compared to the other studies and mainly the study by Nijdam and Wilting (2003).

In Nemry *et al.* (2002), textile (clothing) does not show up in the 60-percentile share, however it still has a relatively important contribution (4,9%).

Industrial packaging and household packaging are only considered separately by Nemry *et al.* (2002) and Labouze *et al.* (2003) and there seems to be a disagreement on importance. In the study by Labouze *et al.* (2003) the different types of packaging contribute less than 4% to the total acidification impact each. On one hand, the omission of 'goods transport' in the study by Nemry *et al.* (2002) explains a relatively higher contribution for packaging in this study, and also the different aggregation principle for domestic electrical appliances (split up into functional categories). Other possible explanations are differences in modelling of the packaging categories and data availability.

4.4.4 Comparison of results on photochemical ozone formation (smog)

Highest contributors to smog formation:

- Nemry *et al.* (2002): 'passenger transport' (62%), 'heating' (20%);
- Labouze *et al.* (2003): 'personal cars' (24%), 'animal based food' (13%), 'goods transport' (13%), 'building structure' (7%) and 'cleaning agents' (7%);
- Nijdam and Wilting (2003): 'commuting, private transport' (17%), 'mobility for leisure' (17%), 'non-animal based food' (8%), 'clothes' (5%), 'holidays' (5%), 'animal based food' (4%);
- Moll *et al.* (2004): 'other transport equipment' (33%), 'motor vehicles, trailers and semi-trailers' (5%), 'construction' (5%), 'food products and beverages' (5%);
- Weidema *et al.* (2005): 'car purchase and driving' (17%), 'dwellings and heating' (7.1%).

Agreement exists on the following product groupings: 'transport', 'building structure' and 'food' (in studies with full coverage). Less obvious are the conclusions for: 'heating', 'cleaning agents', 'clothes' and 'holidays'.

In the study by Nijdam and Wilting (2003), 'non-animal based food' contributes substantially to the total impact, and more than 'animal-based food'. In the study by Labouze *et al.* (2003), which in principle also considers them separately, 'non-animal based food' (more precisely vegetables) makes zero contribution to smog and 'animal-based food' (meat and milk) makes a relatively high contribution. This can be explained by a lack of data on photo oxidant formation with regard to vegetables, the use of mixed data sources with different scopes, background methods and data. The high contribution of 'animal based food' is due to photo oxidants formation from milk production.

'Heating-domestic' makes a very high contribution in the study by Nemry *et al.* (2002) (20%) and a relatively low contribution in the studies by Labouze *et al.* (2003) (5%) and Nijdam and Wilting (2003) (3%). This is strongly related to data on fuel and natural gas use and the omission of other important product groupings in the Nemry *et al.* (2002) study that also strongly contribute to this impact category (food, goods transport and cleaning agents). In the study by Moll *et al.* (2004) 'heating' is not considered as a separate product grouping due to the applied aggregation principle, but is included in the 'electricity, gas, steam and hot water supply' grouping (contributing 4%).

4.4.5 Comparison results on eutrophication

Highest contributors:

- Labouze *et al.* (2003): 'vegetables' (64%), 'furniture' (14%) ;
- Nijdam and Wilting (2003): 'non-animal based food' (36%), 'animal based food' (29%), 'personal care – other' (6%), 'restaurant, pub, etc.' (5%);
- Weidema *et al.* (2005): 'meat purchase' (9.0%), 'tourist expenditures' (3.3%), 'car purchase and driving' (3.0%), 'dwellings and heating' (2.1%).

Agreement clearly exists on the importance of food. The relatively low score in the Weidema study is probably due to their approach based on marginal impacts, (see Section 4.3.8).

4.4.6 Comparison of results on resources

The following product grouping are the highest contributors in the studies that consider an indicator on (primary) resources use related to the full life cycle of a product grouping (percentages from table "Resources" where all material types are aggregated):

- Dall *et al.* (2002): 'car transportation' (21%), 'food production' (20%), 'heating' (11%) and 'TV, computer etc.' (10%);
- Nemry *et al.* (2002): 'building structure' (56%);
- Moll *et al.* (2004): 'construction' (11%), 'basic metals' (11%), 'motor vehicles, etc.' (10%) and 'electricity, gas, steam and hot water' (9%), 'food products' (7%).

Note that Nemry *et al.* (2002) did not trace back the input of 'primary resources' needed over the full life cycle of the product, but only the total material mass that ends up in the product composition, including the materials consumed during the use stage of the products (consumables). The indicator applied by Nemry *et al.* (2002) on material intensity does not include resources related to energy or fuels, while in the studies by Dall *et al.* (2002) and Moll *et al.* (2004) resources related to energy or fuels are included. When looking at the 'resources (non-fuel)' in Dall *et al.* (2002), the highest contributors are: 'TV, computer, etc.' (22%), followed by 'car transportation'.

Other differences are that Dall *et al.* (2002) do not include grouping on construction and building structures and the study by Nemry *et al.* (2002) does not include groupings on food and beverages production. The product groupings considered in the study by Moll *et al.* (2004) also include exported intermediate resources and basic materials, while the other studies are more focused on final products and services delivered to households. Also, fuels and other energy related products are considered separately in the Moll *et al.* (2004) study because the use stage of products is not considered. In this sense, a link could be made between energy use and heating, which is a priority grouping in the study by Dall *et al.* (2002). Packaging is considered separately only in the study by Nemry *et al.* (2002). When aggregating both industrial and household packaging, they represent a relevant share in non-energy related resources use. This cannot be really concluded from any of the other studies, except the study by Labouze *et al.* (2003), that also considers packaging, but in this case the indicator and results on raw materials consumption cannot be interpreted clearly.

It is striking that even with such differences in scopes and methods, the results point to the same main product groupings (listed above). However, it is more difficult to draw a clear conclusion on the relevance of some products that use energy: Nemry *et al.* (2002) 'office machines' vs. Dall *et al.* (2002) 'dishwashing', 'clothes washing', 'TV, computer, etc.' (due to energy, but also substantially due to non-energy resources). Note that in the study by Nemry *et al.* (2002), the paper use of office machines such as copiers and printers during the use stage is also taken into account, hence a high priority with regard to organic material intensity.

When considering the resources depletion indicator, used by Nemry *et al.* (2002) and also in the study by Labouze *et al.* (2003), similar main product groupings show up:

- Nemry *et al.* (2002): 'building structure' (64%); followed by 'passenger transport' (15%);
- Labouze *et al.* (2003): 'building occupancy, domestic' which is an aggregation of heating, lighting, energy for cooking, etc. (26%), 'personal cars' (15%) and 'building occupancy commercial' (14%), 'goods transport' (11%), 'EEE – domestic appliances' (9%).

Transport of goods is only considered separately in the study by Labouze *et al.* (2002) and since passenger transport is highly relevant,

a similar high relevance with regard to resources can be assumed (both energy and non-energy).

Note also, that when comparing the material intensity indicator (no characterisation, kg-based) with the resources depletion indicator (characterised by factors of non renewable resources scarcity), the relative importance of 'building construction' compared to the other categories reduces substantially. This is mainly because construction materials comprise many renewable materials (not included in abiotic depletion indicator) and also because of the high mineral content (high mass, but less relevant for scarcity). This is also true for packaging. On the other hand the relevance of passenger cars increases.

4.4.7 Comparison of results on land use

Highest contributors to land use:

- Nijdam and Wilting (2003): 'total feeding excluding food preparation and restaurants' (36%), 'total shelter' (33%), 'clothes, shoes and accessories' (6%);
- Moll *et al.* (2004): 'land use by households (53%)', 'food products and beverages' (8%), 'mining natural resources' (6%), 'construction' (4%), 'land transport services' (3%);
- Weidema *et al.* (2005): 'meat purchase' (10%), 'dwellings in Denmark' (6.4%), 'tourist expenditures' (3.0%), 'catering' (2.3%), 'bread and cereals' (1.9%), 'car purchase and driving' (1.7%).

Possible explanation of disconformities:

- Difference in methodology and indicators: Nijdam and Wilting (2003) use a characterised indicator with regard to the 'natural value' affected by specific land uses. Moll *et al.* (2004) provides an inventory of km^2 built-up area for traffic and buildings.
- Mining activities as such are not considered by Nijdam and Wilting (2003).

Outstanding contributors are obviously food production and use for domestic dwellings/ construction.

In the study by Moll *et al.* (2004), land use for roads is considered, hence the contribution of land transport services. It is unclear if land use for passenger cars (transport for leisure and commuting transport) is considered by Nijdam and Wilting (2003). Also, Nijdam and Wilting (2003) did not consider transport of goods. There are no clear conclusions on land use for 'Clothes, textile and accessories', because of contradictions in the results.

4.4.8 Comparison of results on water use

Highest contributors to water use:

- Nijdam and Wilting (2003): 'non-animal related food' (33%), 'animal related food' (10%), 'clothes' (5%), 'restaurant, pub, etc.' (5%), 'holidays' (4%)
- Nemry *et al.* (2002): 'sanitary equipment' (93%)

The high share of sanitary equipment observed in the study by Nemry *et al.* (2002) can be easily explained because only tap water is considered in this study, while Nijdam and Wilting (2003) considers total water use. In this sense and when comparing Nemry *et al.* (2002) 'sanitary equipment' and Nijdam and Wilting (2003) 'personal care – water', the difference in relative importance seems high.

4.4.9 Comparison of results on energy

The following product groupings are the highest contributors in the studies that consider an indicator on primary energy supply:

- Dall *et al.* (2002): 'food production' (24%), 'car transportation' (18%), 'heating' (15%);
- Nemry *et al.* (2002): 'passenger transport' (34%), 'interior climate' (~heating and air conditioning) (32%);

- Kok et. al. (2003): 'heating and domestic appliances' (30%, can be slit up: 26%, 4% respectively), 'transport, direct + indirect' (18%), 'feeding, indirect' (13%);
- Labouze *et al.* (2002): 'space heating – domestic' (17%), 'personal cars' (12%), 'EEE – domestic appliances' (10%), 'goods transport' (10%), 'space heating – commercial' (7%);
- Moll *et al.* (2004): 'chemicals and chemical products' (12%), 'electricity, gas, steam and hot water supply' (10%), 'motor vehicles, trailers, etc.' (9%), 'construction' (7%) and 'food and beverages' (6%).

The main contributors are obviously 'heating', 'transport' and 'food production'. The order of importance cannot be concluded from this comparison, because it is inconsistent in the different studies.

The relative importance of 'lighting', 'domestic household appliances', and 'office appliances' is less obvious. The importance of 'food' is assessed differently in different studies: in the study by Nijdam and Wilting (2003), it is given a rather high importance, in the Moll *et al.* (2004) study it is positioned somewhere in the middle and in the study by Labouze *et al.* (2003) it seems to be much less relevant. When looking at the background data and modelling for the food category, the study by Nijdam and Wilting (2003) seems to be more complete and detailed compared to the study by Labouze *et al.* (2003). The wide range and extent of many product groupings in the study by Moll *et al.* (2004) and also because it includes the exportation of products (giving more relevance to the produced products in an economy compared to the amounts consumed) can contribute to these differences.

4.4.10 Comparison of results on waste generation

Highest contributors (results = municipal and industrial waste, excluding construction and bulk waste):

- Dall *et al.* (2002): 'furniture, lighting' (27%), 'spare time' (19%), 'clothes' (14%), 'food production' (12%), 'car transportation' (6%);
- Nemry *et al.* (2002): 'industrial packaging' (31%), 'household packaging' (20%), 'office machinery' (19%), 'passenger transport' (18%);
- Labouze *et al.* (2003) (excluding the service category 'municipal waste' from the product list and ranking): 'gardening' (18%), 'vegetables' (18%), 'packaging – household' (15%), 'paper products' (13%), 'packaging – industrial' (11%), 'animal based food' (9%);
- Moll *et al.* (2004), excluding bulk waste: 'consumption of private households (domestic)' (20%), 'food products and beverages' (9%), 'construction' (7%), 'electricity, gas, steam and hot water supply; collection, purification and distribution of water' (7%), 'basic metals; fabricated metal products, except machinery and equipment' (6%).

Results for waste differ considerably. The method and definition of waste used for the varying studies probably has the most influence on disconformities: the Moll *et al.* (2004) study classifies several categories of industrial waste (excluding bulk) but summarises all household waste under one aggregated category; the Nemry *et al.* (2002) study considers both household and industrial waste but only solid waste, thus no sewage sludge, etc. A similar method is used in the study by Labouze *et al.* (2003). The definition of waste used by Dall *et al.* (2002) is not clear.

In the study by Labouze *et al.* (2003) 'Municipal waste management' is also considered a separate product/service. When not omitting this from the ranking, it contributes about 50% to the total 'municipal and industrial waste' indicator. It is rather unclear as to why this is considered as a separate product grouping and how waste is then treated in the life cycle modeling of the other product groupings.

Disregarding these differences, some product groupings appear in several studies as important: 'industrial and household packaging', 'food' and 'cars'. There is no clarity with regard to 'furniture', 'office machines', 'spare time' (unclear definition) and 'clothes'.

When considering inert waste, in the studies by Moll *et al.* (2004) and Labouze *et al.* (2003), it is clear that building structure is of high relevance. Labouze *et al.* (2003) also considers 'civil work' and concludes that its relevance is even higher compared to building structures.

4.5 Conclusions – analysis of existing studies

The considered studies vary considerably with respect to methods and scopes. The main differences are:

System boundaries and functional unit[14]

- Region: the studies have been carried out for different countries.
- Coverage of institutional sectors: most studies consider domestic final demand by consumers, some include (partially) demand by industry and government.
- Economic activities: usually the studies cover domestic production and consumption, plus production outside the region for imports. Only the studies by Moll *et al.* (2004) and Weidema *et al.* (2005) also consider export, which is the reason why the product list also includes 'intermediates' (for input to other final product systems) such as 'basic metals', 'chemicals' etc.
- Coverage of products: the scope of products covered differs between the studies. For example, not all studies consider 'building structures', 'food production', 'goods transport' or 'civil work'.

Product groupings

- Principle of aggregation: most are function-oriented self-defined product groupings, so differences exist. The study by Moll *et al.* (2004) uses the NACE /EPA classification, based on industry activities.
- Furthermore, the study by Moll *et al.* (2004) is not fully function-oriented. It considers direct and indirect inputs to the system up to final demand. In this study expenditure categories such as 'electricity, gas, steam, hot water supply, etc.' are not allocated to the final functional activities (e.g. cooking/ food, personal hygiene) and hence show up as 'product categories' in themselves.
- Other studies that define some 'intermediate' product categories (mostly considered due to their political relevance) are Labouze *et al.* (2003) and Nemry *et al.* (2002), which consider, for example, 'packaging' separately. In the other studies, packaging is not visible as such, but included in the product groupings where the packaging is used to pack goods (e.g. food).

Data inventory

- The top-down studies generally cover all environmental interventions (emissions and resource use) during the total life cycle more fully, although the reliability of the results at a detailed level is lower (impact per euro of economic activity) compared to the bottom-up studies that allow the modelling of individual product systems in more detail, but a strong limitation here is data availability. This is reflected by the relatively

14 Apart from the points mentioned, the main approach for a data inventory (bottom-up via LCAs or top-down via environmental input-output tables) implicitly influences the system boundaries. Environmental input-output tables in principle cover the full consumption-production system, whereas LCAs necessarily are cut off since not all small inputs into the life cycle can be inventoried in practice. At the same time, impacts related to the use and waste phase of products need to be specifically modeled in environmental input-output analysis and this is cannot always be done at a very high level of detail.

limited modelling of food in the studies by Nemry *et al.* (2002) and Labouze *et al.* (2003).

- In the study by Nijdam and Wilting (2003), the data used for environmental pressures from industry are differentiated per economic region (the Netherlands, OECD, non-OECD). The Weidema *et al.* (2005) study has used the CEDA 3.0 database to model environmental interventions for products and services imported to Denmark. The other studies do not distinguish between different regions.
- The Weidema *et al.* (2005) study has used a different method to allocate impacts to product groupings as have all other studies ('consequential' or the marginal impacts per extra euro/kronor spent; versus 'attributional' or the average impact per euro/kronor spent). It followed this approach to such extremes, that for products for which the volume of production is restricted, it was assumed that marginal expenditure does not lead to extra production and hence impact. This, in turn implies that certain products (e.g. dairy and meat) have low scores compared to other studies. The results for certain products may therefore underestimate their relevance for the environment.

Impact assessment

- Impact indicators: the results for a number of environmental impacts compare well because definitions of indicators are mostly uniform and calculation principles are standardised to a large extent. Results for resources are more difficult to compare because no common indicators are applied and calculation principles vary from study to study.

In summary, acknowledging that methodologies and scopes vary among the considered studies, the following cautious conclusions can thus be drawn:

1. In most cases, the top contributing product grouping represents about 20% or more of the total impact.
2. In most cases, the product groupings with the lowest impact in the 60-percentile still represent 5 to 10% of the total impact.
3. This depends, however, on the product scope and aggregation principle applied in the studies. For example, the studies by Weidema *et al.* (2005) and Nijdam and Wilting (2003) have many more product groupings compared with the other studies and consequently the individual contributions are smaller, with the top contributing product grouping ranging from 10% or more depending on the impact indicator considered.

When looking at each study and the highest impact product groupings that represent 40% of all impacts considered in that study, the number of groupings is rather limited to a few top rankers (4 to 12 groupings, depending on study). When

Table 4.5.1: Number of product groupings representing 40%/60%/80% of all impacts considered in the studies[15]

Study	Total product groupings	40-percentile	60-percentile	80-percentile	Product groupings outside 80-percentile (%)
1. Dall et al. (2002)	25	4	7	12	52%
2. Nemry et al. (2002)	16	7	7	11	31%
4. Labouze et al. (2003)	34	10	16	23	32%
5. Nijdam and Wilting (2003)	65	6	12	25	62%
6. Moll et al. (2004)	57	12	24	39	32%

15 The Kok *et al.* (2003) study just scored on one impact category (energy use) and is not included here. The Weidema *et al.* (2005) study only allows the assessment of product groupings in the 25-percentile. Therefore, only 17 out of the 98 grouping used are reflected here.

looking at the 60-percentile and 80-percentile, the number of groupings representing these shares grows by a factor two to three. The lowest impact contributors outside the 80-percentile still constitute a large number of products (30 to 60% of product groupings, depending on the study). This is shown in the following table.

There are certain product groupings that show up in the top rankings, although in varying order, across all the studies that cover them systematically. They are related to[16]:

- cars
- food
- heating
- house building.

Among the studies, general agreement exists on these highest contributors, however differences exist about their mutual ranking.

No agreement has been found on the 'midrange' product groupings following these top rankers; here, the results from the different studies show no conformity. The following product groupings show up as relatively high contributors in some studies, however this is not confirmed by the other studies that also treat these categories:

- Packaging: When considered as a separate product grouping, it is relevant with regard to resources use (kg-based, not characterised) and waste. However, when the characterised indicator on resources scarcity is applied (Labouze *et al.* (2003)), packaging does not stand out. When packaging is considered an integral part of final product systems, the impacts are scattered accordingly over these final product groupings (i.e. packaging for food and beverages).
- Household (electrical) appliances: The importance strongly depends on how these products are aggregated. Some studies keep them all together; others subdivide them according to function (cooking, lighting, leisure, etc.). Some studies show them including the impact of electricity used; others show the purchase of electricity separately.
- Office (electrical) appliances: This is not a domestic product grouping but could be of relevance for IPP. Mainly the paper use related to these appliances seems relevant (resources and waste). Only Nemry *et al.* (2002) considers this product grouping, so its importance cannot be confirmed by the other studies.
- Furniture: This probably has to do with the very different definitions of this product grouping. For example, Nemry *et al.* (2002) just seems to include furniture as such, whereas Dall *et al.* (2002) uses the product grouping 'furniture, lighting, etc.' and hence includes many impacts related to electricity use.
- Clothing and textile: Here, differences have, in part, to do with the question as to whether clothes washing has been included with this product grouping or not.
- Spare time, restaurants, hotels, holidays: We see here significant differences, mainly related to the question if transport for holidays is included or not.
- Water supply for dwellings: The main impact here is related to heating water (for bathing, (dish)washing, etc.) if the impacts related to the use of gas or electricity are included and not considered a separate product grouping.

The following groupings came up as relevant product groupings mainly from the studies by Labouze *et al.* (2003) and Nemry *et al.* (2002):

- packaging (household and industrial)
- office appliances (copiers, computers and peripherals, etc.)

16 That food does not show up as important to all impact categories in the studies of Nemry *et al.* (2002), Labouze *et al.* (2003), or Weidema *et al.* (2005), is no sign of disagreement among these studies: these studies simply did not (or not fully) analyse the impacts of food production, as discussed extensively in Sections 4.3 and 4.4.

- non-residential building occupancy (heating, lighting in office buildings, etc.)
- non-residential construction (i.e. office buildings, civil work)

The results of this comparative analysis are summarised in Table 4.5.2. An indication is given of the classes in the COICOP (Classification of Individual Consumption According to Purpose)[17] categorisation with which the product groupings can be compared. For those product groupings for which conformity exists on a high relevance an indication is given (++ for highest contributor or + for generally high contribution). In some cases, there is less conformity, these are marked (+(-)). Also, an indication is given of the studies that agree with the importance of these product groupings.

Concerning the implications of these results, the following needs to be taken into account: All studies reviewed consider final consumption by households, whereas in some cases final demand by public expenditure is included. Hence this does not make the products used in the production system explicitly visible (i.e. for business to business activities). For instance, cars are used by final consumers, but also for business purposes. Furthermore, most studies reviewed applied a strong functional approach. This implies that some product groupings that have historically been targeted by policy are not made explicitly visible in the studies (e.g. packaging becomes part of the final product groupings 'food', 'electrical appliances', etc.)

17 The classification of individual consumption by purpose (COICOP) is a classification used to classify both individual consumption expenditure and actual individual consumption. It is a standard classification with the framework of the United Nations System of National Accounts.

Table 4.5.2: Main product groupings and environmental impacts

COICOP category		Energy	Land	Resource	Water	Eutrophication	Greenhouse gas	Smog	Acid.	Waste
1 and 2.1	Food and beverages	++[4,5,6]	++[3,5]	++[4,5] (energy related, biomass) +[4,5] (non- energy related)	++[3]	++[1,3]	+(+)[3,5]	+[1,3,5]	++[3,5]	+(+)[1,4,5]
3	Clothing and footwear		+(-)[3]		+[3]	+(-)[3]	+(-)[3]	+(-)[1,3]	+[1,3]	+(-)[4]
4.1 to 4.3	Construction – Residential dwellings	+(-)[2,5]	++[3,5]	++[2,5] (energy and non-energy, mineral, biomass, synthetic) +[2,5] (metal)			+[2,5]	+[1,5]	+(+)[1,2,5]	++[1,2] (inert, bulk)
4.4	Water supply and misc. services related to dwellings				+(+)[2,3] (toilet and sanitary use)					
4.5	Electricity, gas and other fuels									
Aspect of 4.5	- *Heating / Hot water*	++[1,2,4,5,6]		+(+)[1,4,5] (energy related)			++[1,2,3,5]	+(-)[2,3]	+(+)[1,2,5]	
Aspect of 4.5	- *Lighting*	+(-)[1,2,4] (important domestic and commercial)		+(-)[4] (energy and non-energy)						
5.1.1	Furniture			+(-)[4,5] (non- energy related, metals)		+(-)[1]				+(-)[4]
5.3	Household appliances	+(-) [1,5]		+(-)[1,5]			+(-)[1]	+(-)[5]	+(+)[1,5]	
Aspect of 4.5 & 5.3	- *Food storage, preparation, dishwashing*			+(-)[4] (non-energy)				+(-)[3]		
Aspect of 4.5 & 5.3	- *Maintenance clothes and textiles*	+(-)[4]		+(-)[4] (energy and non-energy)						
Aspect of 4.5 & 5.3	- *House maintenance*									
Aspect of 4.5 & 5.3	- *Audio, TV, computer, etc.*			+(-)[4] (non-energy)						
No COICOP category (intermediate product)	Office appliances (incl. paper use)	+(-)[5] (energy use in offices, public administration etc…)		+(-)[2] (organic, depends on product definition)						+(+)[1,2] (paper products)
7.1. and 7.2.	Personal vehicles	++[1,2,4,5,6]		++[1,2,4,5] (energy and non-energy, metal, synthetic)			++[1,2,3,5]	++[1,2,3,5]	++[1,2,3,5]	+(-)[2]
11	Restaurants and hotels		+(-)[3]		+(-)[3]	+(-)[3] ('holidays' and 'restaurant, pub')		+(-)[3] ('holidays')	+(-)[3] ('holidays' and 'restaurant, pub')	
No COICOP category (intermediate product)	Household packaging			+(-)[2] (synthetic) -[1,2] (depletion)					+(-)[1,2]	++[1,2]

++ : agreement on high relevance
+ : agreement on relevance, but not with the highest contributors
+(-) : disagreement or relevance not clear from this analysis
Indication of the studies that agree on the importance of the product category: (1) Labouze et al. (2003), (2) Nemry et al. (2002), (3) Nijdam and Wilting (2003), (4) Dall et al. (2002), (5) Moll et al. (2004), (6) Kok et al. (2003)

5. Approach 2: Analysis with CEDA EU-25

5.1 Introduction

The methodological approach chosen for this study (see Chapter 3) is to combine the use of existing research with a new analysis. This chapter presents the new analysis, which carries out a system-wide analysis of the environmental impacts of products for the EU-25 with a resolution that allows the distinction of several hundreds of product groupings.

As Chapter 3 has shown, there are in principle two approaches to such an analysis: bottom-up or top-down. The 'bottom-up' approach begins with an individual product and a Life cycle Assessment (LCA) is carried out. The results for this particular product are then assumed to be representative for a wider range of products and so are extrapolated to a much larger grouping of products. Combined with other LCAs for representative products, it is possible to put a picture of the whole economy together. On the contrary, the 'top-down' approach begins with 'input-output' tables produced, in most cases, by statistical agencies. These tables, in the form of matrices, describe production activities in terms of the product purchases of each industrial sector from each of the other sectors. The input-output tables that are available have different degrees of aggregation (between some 30 and 500 products or sectors). If they also contain data about the emissions and resource use of each sector, this information can then be used to calculate the environmental impacts of products covering the full production chains.

After considering carefully the pros and cons of both methodological approaches it was decided to follow the top-down approach for the new analysis. The advantage of the top-down approach is that it offers a consistent framework of allocating the environmental impacts caused by a region to the products that cause them. There is no need, as in the case of bottom-up approaches, to make cut-offs for which processes (and as a consequence, which environmental impacts) to include; they are all fully taken into account in a systematic way. This approach also avoids having to extrapolate the environmental impacts of very specific products to whole product groupings, which bears a high risk of not being representative in the case of the bottom-up approach and, at the same time, is extremely laborious.

The main challenges of following the top-down approach is that the required highly disaggregated input-output tables with environmental information are not readily available for the EU-25 and considerable efforts are required to construct them. Extra efforts are also required to take into account in these tables the environmental effects of the use phase of products as well as the management of wastes emerging after the use of products in households.

In this chapter, an operational model is elaborated in detail, and applied, that follows the top-down approach and allows analysing the environmental effects of the consumption of products. The functional unit and related system boundaries of the analysis are defined as follows:

- The functional unit is the *total* domestic final demand for each of the products[18] consumed in the EU-25, together covering the total consumption of EU-25. Therefore, the model covers both final private household consumption and final government consumption, both in terms of their expenditure on the products involved.

18 Products cover both goods and services.

- The system boundaries are set to cover all *cradle-to-grave life cycle chains* related to products involved (i.e. consumed in Europe). The model hence aims to cover impacts related to the production of imported goods, production of goods in Europe, and the use and waste management of products – all for products consumed in EU-25. Production in Europe for exports is not within the scope of this study.

The analysis will not explicitly address the environmental scores of intermediate outputs. This would be outside the goal and scope of this study, which has limited the analysis to the environmental effects of the final consumption of products. Going beyond this scope would also lead to a number of serious technical problems. First, the nature of the products sold in the production chain is usually very different from those sold to private households. 'Abrasive products' sold to household really constitute something totally different from abrasive products sold to the metals coating industry. The same is true for non-woven fabrics, etc. Secondly, these environmental scores of intermediate sales would not be cradle-to-grave scores but cradle-to-gate scores only, however, the goal of this study is to cover the full life cycle. For instance, a newspaper from intermediate sales would not have waste management connected to it including the recycling of paper, as does the newspaper sold to private consumers.

The various sections included in this chapter will discuss:

- The overall outline of the input-output analysis and the model used (Section 5.2.)
- The details of the model and data used (Section 5.3; with specific data sources in the Annexes to chapter 5)
- Results (Section 5.4.)
- Interpretation (Section 5.5.), and
- Conclusions (Section 5.6.)

5.2 Input-output analysis: principles and model outline

5.2.1 The principle of an environmental input-output analysis

In the original work by W. Leontief the input-output tables describe how industries are inter-related though producing and consuming intermediate industry outputs as represented by monetary transaction flows between industries. The input-output models assume that each industry consumes outputs from various other industries in fixed ratios in order to produce its own unique and distinct output. Under this assumption, an m×m matrix $\mathbf{A}$ is defined where each column of $\mathbf{A}$ shows domestic intermediate industry outputs in monetary values required to produce one unit of monetary output of another product flow, here as required for final consumption. This basic matrix is also referred to as the make-use table. If $\mathbf{x}$ denotes the total industry output, then $\mathbf{x}$ is equal to the sum of the industry output consumed by intermediate industries, by final consumers, (and by exports which is left out for convenience here, as the focus is on domestic consumption), i.e.:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y}$$

where $\mathbf{y}$ denotes the total final consumption of industry outputs. Then, the total domestic industry output $\mathbf{x}$ required to satisfy final consumption is calculated by:

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

where $\mathbf{I}$ denotes the m×m identity matrix. This part of the analysis gives the economic structure of production and consumption.

The next step is that a matrix is specified representing environmental interventions for each industry involved, as an environmental extension. Environmental extensions of input-output analysis

can easily be made by assuming that the amount of environmental intervention generated by an industry is proportional to the amount of output of the industry, and that the identity of the environmental interventions and the ratio between them are fixed. Let us define a q×m matrix B, which shows the amount of pollutants emitted and natural resources consumed to produce one monetary unit of each industry's output. Then the total direct and indirect pollutant emissions and natural resources consumed by domestic industries to deliver a certain amount of industry output is calculated by:

$$M = B(I - A)^{-1}k$$

where M is the total domestic direct and indirect environmental intervention vector, and k is any vector that shows net industry output of the system, which will be supplied to outside of the production system, here to final domestic consumption. So, in its most basic form, environmental input-output analysis can be performed making use of two matrices and one vector:

- The final consumption vector, k. This vector basically distributes the total available income in a region/country over products used for final consumption. This final demand, as purchases of goods and services, drives all production activities and their related environmental effects. The number of products that can be distinguished can be, at the most, the amount of industry sectors distinguished in the technology matrix (see below)[19].
- The technology matrix A. This matrix gives the interrelations of production activities in monetary terms. The economic production system is divided into a number of m sectors, and the matrix shows per sector the monetary value of the products delivered to each other sector, and purchased from each other sector. Most countries gather such data, though often at a very aggregate level of industry groups.
- The environment matrix B. For each sector, the direct resource use, as inputs from nature like ores, and the direct emissions, as outputs to nature like CO_2 emissions, can be inventoried. These results are again in a matrix (of m sectors by q types of environmental interventions). The matrix gives the environmental interventions per monetary unit of production of each sector, here per euro of turnover.

Though this all suggests that the principle of an environmental input-output analysis is simple, getting the data right is the main problem. Also, an input-output analysis is based on records accounting for financial transactions between productive sectors and to final consumption, and the use and disposal phases are generally not accounted for. For cradle-to-grave analysis, as required in consumption analysis, the use stage and the post-consumer disposal management (waste management and recycling) need to be covered by adopting specific solutions. This led to the development of the CEDA EU-25 Products and Environment model.

5.2.2 The CEDA EU-25 model: an overview

This model was developed to overcome both database and methodological problems. To start with the data problem, for Europe no detailed input-output tables are available; however, input-output models with a more detailed sectoral resolution are available for other (similar by level of development) economies, such as Japan and the USA. The CEDA EU-25 model builds on the latest available model developed with US sector data, CEDA 3.0, with a resolution of 480 times 480 sectors. First, this model was Europeanised by forcing the European production structure on it, which was available at a more aggregate (35

19 Since not all industry sectors deliver goods and services for final consumption, the number of final products purchased for final consumption is lower than the number of industry sectors.

times 35) level from the latest OECD input-output tables available at the beginning of this project. The method used is the RAS method, which is described in detail in Annex 5.1.1.

Another problem is that input-output models in general do not cover the use and waste management stages[20]. Hence, from a variety of sources such as Oeko-invent and other regular LCA databases, some of the most important processes in the use- and waste management stage (of which two processes were already available in the CEDA 3.0 model) have been added, resulting in a basic use- and disposal management matrix. Together with the matrix with the remaining 478 production sectors, the full life cycle of each product is covered. On top of this, the total EU-25 emissions as reported in van Oers *et al.* (2001) were forced upon this model[21], so that in the end the final consumption in the EU-25 is related to the true final emissions in the EU-25.

As a whole, the resulting CEDA EU-25 Products and Environment model covers as a whole resource use and emissions in the production, use and disposal phase of the life cycle of all products[22] consumed in the EU-25. The next sections discuss the model and data sources in more detail.

5.2.3 The CEDA EU-25 model: outline of the data inventory

Building the model requires filling in the interrelations of activities within and between each phase. Thus, the volume of activities required for the consumption of each product is specified. Next, for each phase of the life cycle, the environmental interventions of the activities are specified. Before going into the details of all model elements and data sources in Section 5.4, an overview of the structure is outlined below.

The basic structure is constituted of three fields of activities and their interrelation. The central focus is on **consumption of products described in $\mathbf{A}_{22}$**, the central part of Figure 5.2.1 below. For this consumption, on the one hand, production activities are required, represented by the *production technology matrix* $\mathbf{A}_{11}$. On the other hand, after use, products require disposal activities, represented in the *use of wastes between disposal activities matrix* $\mathbf{A}_{33}$. These disposal activities have been taken out of the full technology matrix $\mathbf{A}_{11}$. The link with consumption of products is given by the *use of disposal services by consumption of products matrix* $\mathbf{A}_{32}$. As these disposal activities have been lifted out of the overall production matrix, the relations between these two are also to be established, in the *use of waste disposal services by production matrix* $\mathbf{A}_{31}$ and the *use of products by disposal matrix* $\mathbf{A}_{13}$. The link between production and the consumption of products is in the *consumption expenditure vector* $\mathbf{k}_2$. Each of these will be treated in more detail in the next section, see the review of matrices and vectors for CEDA EU-25 given in Table 5.2.1, after Figure 5.2.1.

All direct environmental interventions are generated by *activities*, with a matrix for production, a matrix for consumption of products and one for disposal activities, see Figure 5.2.2 below. The first is the *environmental interventions by production matrix,* $\mathbf{B}_1$. The second is the *environmental interventions by consumption activities matrix* $\mathbf{B}_2$. The third is the *environmental interventions by disposal activities matrix* $\mathbf{B}_3$.

20 Or only in a very rudimentary form; e.g. CEDA 3.0 distinguishes just two types of solid waste management processes, and covers sewage treatment combined with drinking water production. It is described later how these are transformed into nine disposal sectors.

21 As explained in the next sections, the original US emissions were basically used to distribute the total EU emissions to different sectors in the model.

22 As usual in input-output terminology, the term 'product' here applies to any level of aggregation.

Figure 5.2.1: Economic activities and their interrelations

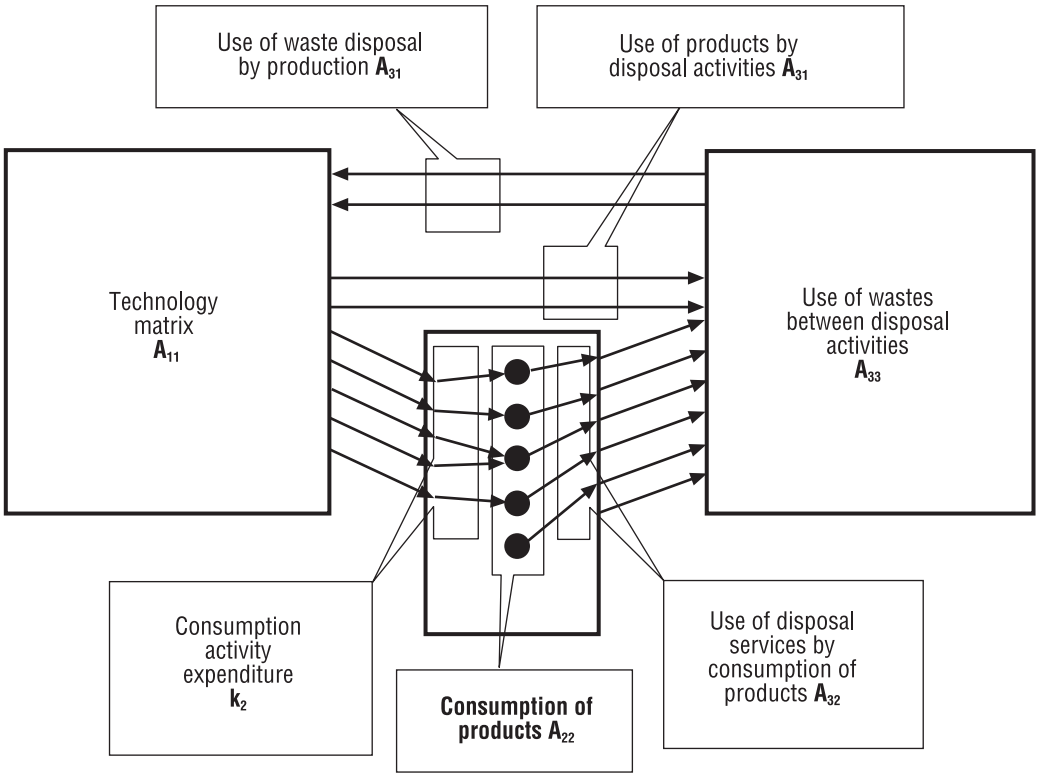
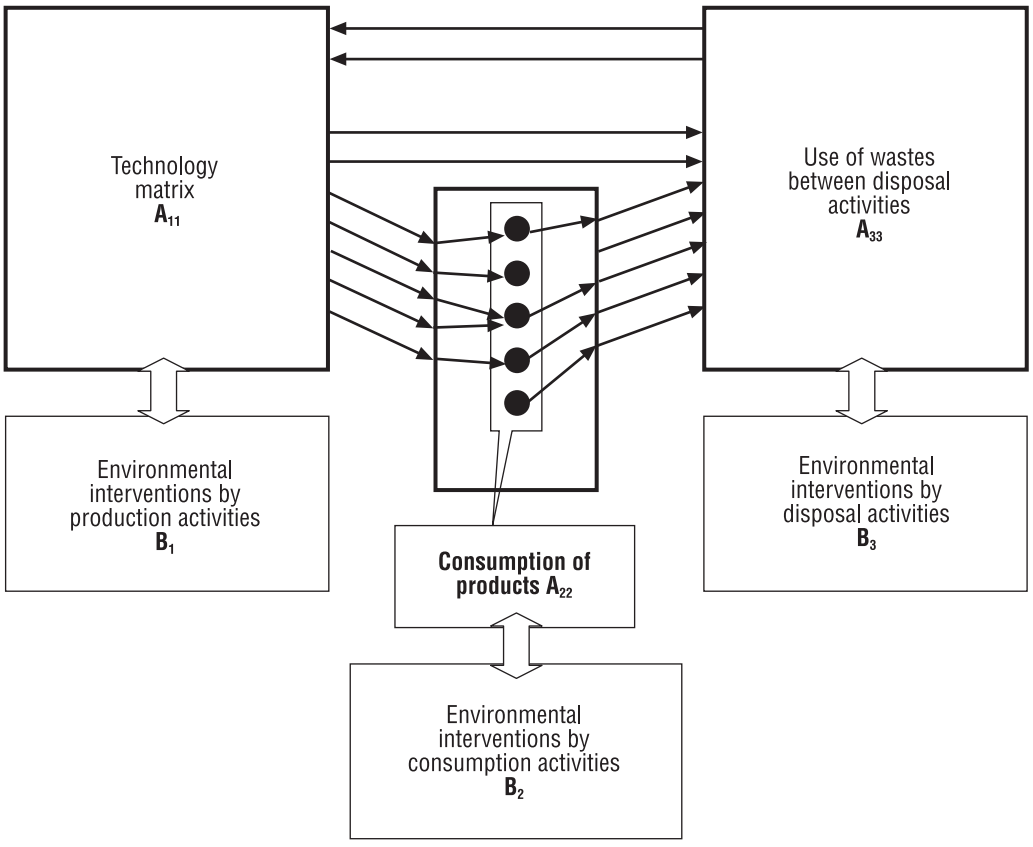


Figure 5.2.2: Economic activities and their environmental interventions



Written out in full, the general mathematical structure is as follows, see equation:

$$m = \begin{pmatrix} B_1 & B_2 & B_3 \end{pmatrix} \left(I - \begin{pmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{pmatrix} \right)^{-1} \begin{pmatrix} k_1 \\ k_2 \\ k_3 \end{pmatrix}$$

The full A matrix (with nine sub-matrices) has 965 rows x 965 columns, and the B matrix (with three sub-matrices) has 965 rows x 1355 columns (the number of environmental interventions). The full k vector has 965 rows. Some of the matrices and vectors are empty (e.g. A_{23} and k_3) or are only sparsely filled (e.g. B_2). Table 5.2.1 shows a survey of all elements of this equation, and also indicates the sections of this report where each will be treated in more detail.

First, the three technology matrices, A_{11}, A_{22} and A_{33} are defined. Next, their interrelations are specified, in principle involving six linking A_{ij} matrices. However, two of them have been left out of the analysis, as empty matrices. They are the sales from households to production sectors A_{21}, as with selling a private car to a garage, and the sales from households to waste disposal sectors A_{23}, as with selling the lead metal of a private house's roof to a scrap handler. Such transactions occur very seldom and no data are available. Also, some conceptual elements would then have to be worked out. Next, the three B matrices on environmental interventions are described and finally the consumer expenditure vector $\mathbf{k}_2$ and the resulting vector **m** of environmental interventions for each product consumed are shown.

Table 5.2.1: Review of matrices and vectors for CEDA EU-25, with size and dimensions specified

Symbol◊	Size (rows*columns)	Unit	Meaning	In Section
A_{11}	478*478	€/€	technology matrix for production sectors	5.3.2
$A_{21} = 0$	478*478	–	sales from households to production sectors (set to zero)	not relevant
A_{31}	5*478	€/€	sales from disposal services sectors to production sectors	5.3.8
A_{12}	478*478	€/€	sales from production sectors to final consumption	5.3.5
$A_{22} = 0$	478*478	€/€	technology matrix for final consumption activities (zero matrix)	5.3.3
A_{32}	1*478	€/€	sales from disposal services sectors to final consumption	5.3.6
A_{13}	478*5	€/€	sales from production sectors to disposal services sectors	5.3.7
$A_{23} = 0$	478*4	–	sales from households to disposal services sectors (set to zero)	not relevant
A_{33}	9*9	€/€	technology matrix for disposal services sectors (nine sectors)	5.3.4
B_1	1344*478	kg†/€	environmental interventions by production sectors	5.3.9
B_2	1344*478	kg†/€	environmental interventions by consumption activities	5.3.10
B_3	1344*9	kg†/€	environmental interventions by disposal sectors	5.3.11
$k_1 = 0$	478(*1)	€	consumption spending on industrial activities	not relevant
k_2	478(*1)‡	€	spending on consumptive activities (consumption activity** expenditure)	5.3.12
$k_3 = 0$	9(*1)	€	consumption spending on disposal activities	not relevant
k_0	478(*1)¶	€	consumption expenditure on products, precursor of k_2)	5.3.12
m	1344(*1)	kg†	environmental interventions in the life cycle for each consumption activity	5.3.13

◊ *Capitals denote matrices; lower case letters denotes vectors.*
† *Or Bq, m2 and further measures for environmental interventions.*
** *In the activity a number of products are used in combination, like cars and petrol, for 'car driving'.*
‡ *Effective size: 282 (see Section 5.3.12)*
¶ *Effective size: 288 (see Section 5.3.12)*

For the expenditure vector, two options exist. One is to use the actual purchases of individual products, $\mathbf{k_0}$, the other is the combined expenditure on items consumed together, like petrol and cars required for 'car driving'. The latter option is most flexible in relation to consumption analysis, and has been applied for the most relevant products (i.e. with major direct emissions in the use phase and where electricity use is at stake. This is the reason why k_2 has fewer items than its precursor k_0. To avoid renaming problems, each consumption-activity expenditure is linked to its main product. In the car example, there is a 'car expenditure' and a 'car driving expenditure' which also includes expenditure on petrol, repairs, etc. This combination of products in one activity corresponds to the set-up of the A_{22} matrix and the B_2 matrix. All results are only given as related to the combined functioning of the car and the petrol, and a limited number of similar combinations.

The six non-zero A matrices, the three B matrices, and the one consumption expenditure vector, all filled with data, together combine to make the first part of the CEDA EU-25 Products and Environment model, covering what in LCA is called the inventory analysis. It states the environmental interventions in the life cycle of all products consumed, as vector **m**.

5.2.4 The CEDA EU-25 model: outline of the impact assessment and interpretation

The inventory results relate to major environmental problems, involving over one thousand environmental interventions per product. Hence, for interpretation of these outcomes (see the sub-tables in Annex 5.3.1, including scores for total EU-25 consumption), the impact analysis step has been added as is common in the environmental life cycle assessment of products (LCA). This considers a ***set of environmental impact categories***, transforming environmental interventions, as resource extractions and emissions, into more aggregated environmental impacts, like resource depletion and global warming. In this study, the impact assessment step is taken from one authoritative source, Guinée *et al.* (2002). It was decided not to include environmental impacts categories for which methodologies are not yet well-established, such as loss of biodiversity. Related indicators like land use and material requirement (see, e.g. the discussions in Sections 4.4.5 and 4.4.6) might be used in the future to cover remaining gaps. The following impact categories were considered in the assessment:

1. abiotic depletion
2. global warming
3. ozone layer depletion
4. human toxicity
5. ecotoxicity[23]
6. photochemical oxidation
7. acidification
8. eutrophication

With the full model thus defined, the environmental impacts over the life cycle of the consumption of products can be quantified, both as a total per product consumed and per euro spent. The resulting scores on impact categories are presented in *normalised* form, i.e. as a percentage of the European (EU-25) total score on that theme; see Annex 5.1.2 for details on impact assessment. The interpretation fully relies on these normalised scores on these individual impact categories. Sometimes, it appeared that for some forms of presentation, the calculation of a single weighted score over the various impact categories would have added value. Merely for such 'auxiliary' or 'secondary' use, a weighted one-point score was calculated per product. For this, weighting factors were used developed in a stakeholder panel

23 For impact categories, scores have been calculated making use of the Guinée *et al.* (2002) manual mentioned above. Guinée et al (2002), however, give three independent procedures for calculating terrestrial, aquatic and marine ecotoxicity. The ecotoxicity score used here is an average of these three types of ecotoxicity scores.

procedure in a project for the Dutch Government and the Dutch oil and gas production branch, see Annex 5.1.2 as well.

5.3 Detailed discussion of the CEDA EU-25 Products and Environment model

5.3.1 Introduction

The main modelling set-up for the inventory computation has been given in Section 5.2.3 above. The matrices and vectors involved are worked out in detail here. In order to get started with a good overview of the steps taken, the main data sources used have been summarised with the adaptations included. The following data problems had to be dealt with in this project:

- Given its far superior resolution above anything available in Europe, CEDA 3.0 was used as the basic input-output table in this project. This caused three problems:
  - The technology matrix takes the US industry structure as a point of departure.
  - The environmental matrix (emissions per euro/dollar turnover per sector) uses US emission factors.
  - The classification of industry sectors is the one from the US Bureau of Economic Analysis (BEA), whereas in Europe the final (consumer) expenditures are reported in a different structure (the so-called COICOP structure, at level 3).
- Neither the use nor the waste phases are included in sufficient detail in input-output models.
- Europe imports goods. The processes for import have to be modelled.
- For Europe, statistics on final demand are only available in great detail for consumer expenditures in the EU-15. This study aims to cover total final expenditure (hence including government expenditure) in the EU-25.

To deal with these problems, the following main steps were taken.

1. For Europe, technology matrices are available at a higher aggregation level than the CEDA 3.0 480 times 480 sector model. One of these matrices, an OECD 35 times 35 matrix, has been used in a mathematical procedure that 'forces' the CEDA 3.0 to comply with this 35 times 35 matrix, resulting in a 'Europeanised' CEDA 3.0 technology matrix, see Annex 5.1.1. With both Europe and the US being advanced economies, one can assume that industry structures are rather similar, and that any differences which could occur at the lower levels of detail are not of high relevance[24]. See Section 5.3.2 for further, minor adaptations.
2. After this procedure, the use phase and the waste phase, including emissions in the use and waste phase, were modelled specifically for Europe. This was carried out for only the most relevant products (e.g. cars, heating systems, etc., but not for issues such as VOC emission from paint use and soot emissions from candles). For further information, see Sections 5.3.3 and 5.3.4.
3. The imports (and exports) are a substantial fraction of the European economy, at 26.9% of GDP (see http://www.eurunion.org/legislat/agd2000/agd2000.htm). Imported goods are modelled as if they were made in Europe. The source of distortion is smaller however than indicated by this figure. Firstly, the US is the major trade partner of EU-25, with a share of 23.3% in total international

24 Of course demand for certain products can differ considerably (e.g. in the US expenditure on train travel is relatively low), but that is not the issue here – CEDA EU-25 uses European demand data. What is argued here is that the technologies and the production chains to make the same product (e.g. clothes) will be rather similar in the US and Europe.

trade of EU-25 with, by necessity, very similar emissions to CEDA EU-25. Furthermore, countries like Switzerland and Japan have similar economies adding another 13.8%.

4. In order to ensure that – when the CEDA EU-25 model is run with the EU-25 final demand as input – total European emissions result, these totals are calculated and 'forced' upon the CEDA model in the following way:

   a. European LCA normalisation data (total emissions for EU-15) by van Oers *et al.* (2001, see also Huijbregts *et al.* 2001) were scaled up to EU-25 on the basis of PPP (Purchasing Power Parity, the same as was also used in scaling up final consumption from EU-15 to EU-25). In principle, these data *include* emissions and resource use production in Europe for export, but *exclude* emissions and resource use related to imports. The assumption is that imports and exports outweigh each other in their resource use and emissions.

   b. The emissions and resource extractions as present in CEDA3.0 have been matched with those in van Oers. Hence, the CEDA EU-25 model can be assumed to give a good estimate of total emissions and resource use (mostly fossil energy) related to final consumption in the EU-25. A list of all emissions and resource use covered is in Annex 5.3.1[25].

   c. For each matching substance, the ratio of total EU-25 emissions to total US emissions was used for converting the US emission factors to European ones. Where there were no matching European data, the median of the conversion factors (1.06) has been applied. The result is the Europeanised CEDA EU-25 model.

5. With no detailed government expenditure tables available for Europe (EU-15 or EU-25), the consumer expenditures found in COICOP terms for EU-15 were scaled up on the basis of the total known government expenditure on products (also covering both goods and services)[26]. A further scaling up on the basis of national incomes, using PPP[27], resulted in a total final demand for EU-25 (see section 5.3.14).

6. In order to link our European expenditure data, available in COICOP format, with the BEA expenditure categories, a transformation table was developed. Since no official transformation tables are available, this procedure had to be worked out ad hoc. In essence, the following strategy was followed (see Section 5.3.14):

   a. Categories with more or less corresponding names were linked one to one.

   b. When BEA was more aggregated (very seldom), several COICOP categories were combined to one BEA category, by simple addition.

   c. When COICOP was more aggregated, the expenditure within such a COICOP category was distributed over the corresponding BEA categories using the relative expenditures in BEA in the US.

7. As COICOP data are in consumer prices and all input-output data in producer prices, the expenditure data from the previous step were converted into producer prices, based on the BEA conversion tables, as no EU conversion tables are available. In principle, a similar

25 Ideally, from these total emissions, the emissions modelled specifically for the use phase (see step 2) would be subtracted, but due to current software this was not possible now.

26 Total share in GDP of government purchases of goods and services in the EU is around 20% and quite stable over time. See Schuknecht and Tanzi (2003).

27 Exchange rates are used for all technology relations and PPP for all volume estimations involving New Member States, as exchange rates would underestimate their consumption volumes.

conversion structure is to be expected, except in cases where large differences in excise exist. The main difference is in petrol and diesel taxes for passenger car use, where price levels in the EU are 2.5 times higher than in the US. This factor has been used for further conversion. The full result is the k_1 purchases from industry vector, which forms the basis for defining the consumer activity vector k_2. See Annex 5.2.9.2 for a more detailed description and sources.

To conclude, the model built takes European total emissions and resource use related to truly European expenditures as a basis – and essentially distributes these interventions over each expenditure category. Deviations from these totals are hence impossible; and given the various steps to Europeanise CEDA 3.0, the similarities in production processes in the US and Europe for similar products, it is rather unlikely that in this overall procedure substantial mistakes could be made.

The rest of Chapter 3.5 is divided into sections according to matrixes and vectors:

- The three different technology matrices are presented in Sections 5.3.2 – 5.3.4;
- The four matrices linking production-consumption-disposal activities are presented in Sections 5.3.5 – 5.3.8;
- The three matrixes on environmental interventions by activities are presented in Sections 5.3.9 – 5.3.11;
- The last two sections present the final demand vector (Section 5.3.12) and the environmental intervention vector (Section 5.3.13).

The next sections discuss in more detail the elaboration of each part of the model. As a background, Figure 5.3.1 gives an overview of data sources used in this modelling process.

5.3.2 Technology matrix 1: the production technology matrix (A_{11})

The technology matrix specifies all intermediate activities involved in the production of final output. As indicated, for imported goods the normal default assumption was used that all imported products are produced using the same technology as that used in the EU.

The basic data used are the adapted CEDA 3.0 database on the basis of the RAS procedure described in Annex 5.1.1 (basically forcing the US technology matrix to 'comply' with the 35 x 35 matrix for EU-25 derived from OECD data[28]. From this, the two available waste management processes have been split off in order to build a separate, more complete waste management matrix, $\mathbf{A_{33}}$. The remaining matrix $\mathbf{A_{11}}$ with 478 sectors now only covers production processes. In this matrix further specific adaptations in energy and agriculture have been included, which are described in detail in Annex 5.2, under $\mathbf{A_{11}}$ and involve:

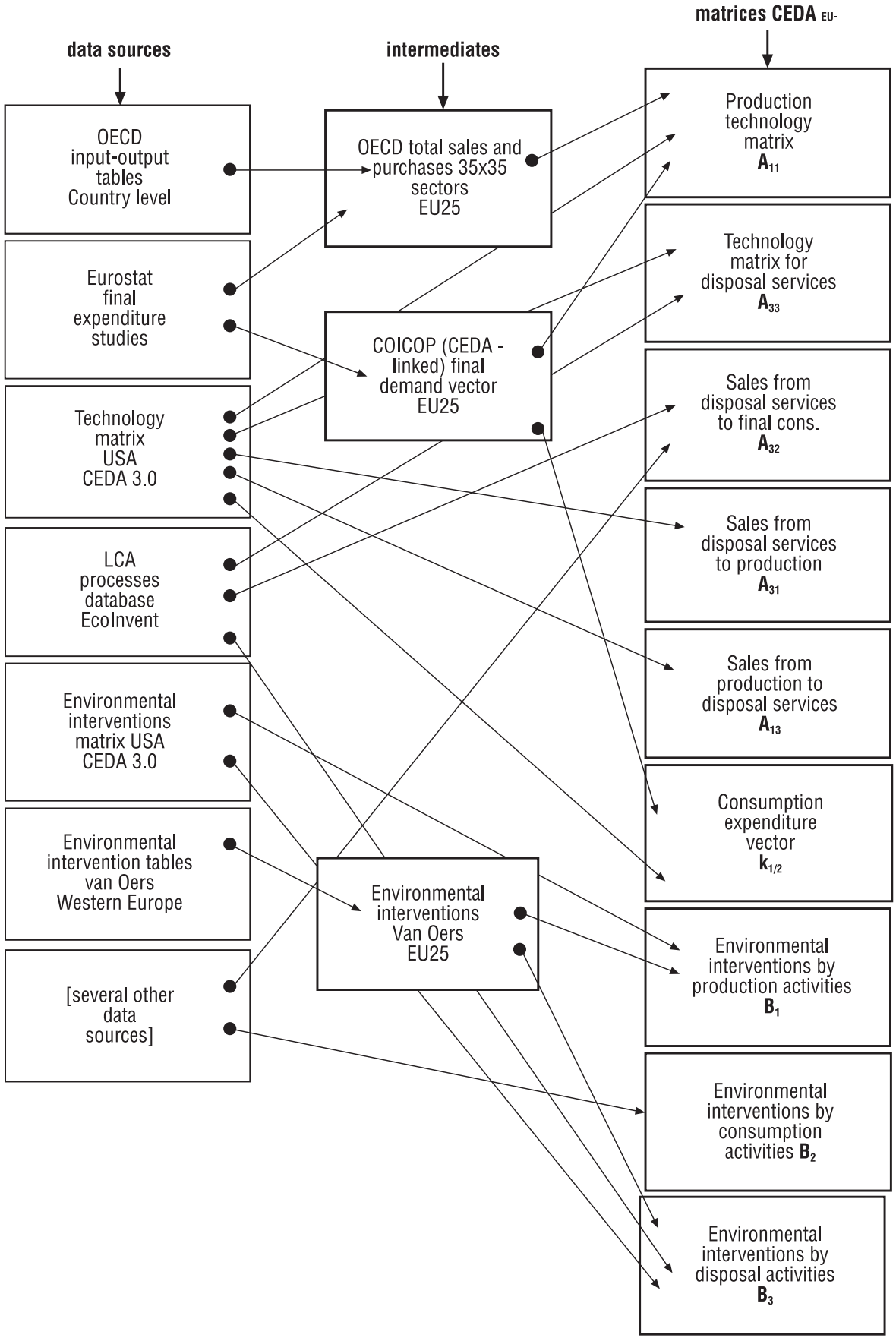
- OECD statistics on energy use for US and EU-15.
- FAO data on fertiliser and pesticide use in US and EU-15.

5.3.3 Technology matrix 2: the technology matrix for final consumption activities (A_{22})

There are some sales of consumers to consumers directly, with relevance for the economic life time of products. Such activities, however, are disregarded here. This matrix is a diagonal of all '1's. No data were required. How goods purchased for consumption combine into consumption activities is specified in A_{12} below.

28 http://www.oecd.org/document/6/0,2340,en_2825_495684_2672966_1_1_1_1,00.html
These data refer to 1990 and are the latest available (!) authoritative and mutually coherent input-output tables for main parts of the EU, available at the start of the study. In the mean time the OECD has published more recent input-output tables.

Figure 5.3.1: Main data sources and their destinations



5.3.4 Technology matrix 3: the technology matrix for disposal activities (A_{33})

The two main disposal management sectors in the CEDA technology matrix are *680302 Sanitary services, steam supply, and irrigation systems*, which covers collection, landfill and incineration; and *810001 Scrap*, which covers some main recycling activities. A third, *680301 Water supply and sewerage systems,* is a combination of production activities and disposal activities. Since in many countries payments for these activities are combined, it would have taken considerable effort to disentangle these activities into their production and waste management constituent parts. As washing requires water, indirectly the waste management activities of cleaning the water from the sewer thus are linked. The starting point are two disposal sectors. However, the aggregate nature of these sectors makes them less apt for linking to the specific products going into recycling and waste handling. We distinguish four main recycling flows from consumer products: paper, metals, glass, and plastics. In order to link the value of the recyclable product and the recycle product created, the scrap sector is therefore broken down into four recycling processes, one for each of these four main flows. The recyclable flows are delivered to each of them by the general waste management sector. To keep the link to specific products this sector has also been broken down, into five sub-sectors, one for general waste to incineration and landfill (not differentiated) and four for each of the main recyclable wastes flows. These collecting and sorting sectors sell their recyclable products to the recycling sectors.

This approach to waste management is a flexible approach and is open to further, more detailed development.

The input-output coefficients now used are derived from the technology matrix as available in the intermediate part of the input-output table in CEDA 3.0. The total amount of recyclable flows of glass, paper, metal and plastics has been attributed to the products containing them. Per group the contribution has been made on the basis of the share of products in sales. This seems a reasonable approximation. After collection and sorting, these flows are sold to the recycling sectors, to process them into secondary products, or for glass production, prepare them as cullet for further use. The purchase prices of recyclable materials have been gathered from British and US sources. The value added and the selling prices resulting have been based on a rough estimate of the fraction of value added in sales per recycling industry, see Annex 5.2.6.

For greater resolution of recycling activities for specific products, a number of such disposal management activities are distinguished. The first step for all sectors is collection/separation. The further flows between these disposal activities concern the recyclable flows. Final waste management, mainly by incineration and landfill, is in the original waste management process from CEDA, including collection and separation. All data and sources are described in detail in Annex 5.2.

5.3.5 Matrix 1 linking production-consumption: Sales from production sectors to final consumption (A_{12})

In this matrix the products that combine in consumption activities are specified, as ratios of spending on the contributing 'pure' products. Simply said, this matrix allows making combinations such as the purchase of water, electricity and washing machines into the consumption activity 'washing'.

For most products, there is no need to produce such combinations. For instance, newspapers and pottery are bought, used and then discarded, without any specific link to other products. For other products there is a more inherent relation, as in the petrol, which is required for driving a car, or the electricity used by household appliances. One might even go one step further than just these very direct relations and combine products, which functionally are connected in consumption, like driving a car for the shopping of food, or for leisure. This study remains as much as possible at the level of individual products, and such further functional relations have not been taken into account. All

car fuels, electricity and gas, and most water, are linked to the products using these: car driving, heating including hot water and cooking, and washing of clothing (for a further aggregation into product groups see Section 5.4.3 below). Direct household emissions for car driving and heating with gas and oil, and for a few more products consumed, are not specified here but in B_2.

Combining different products purchased into *consumption activities* of a product is a technically simple operation but requires some additional information.

For the CEDA EU-25 consumption activity category *590301 Car driving* there are five products needed in addition to the car itself:

- *590301 Motor vehicles and passenger car bodies*
- *310101 Petroleum refining*
- *310102 Lubricating oils and greases*
- *320100 Tires and inner tubes*
- *500100 Carburettors, pistons, rings, and valves*
- *590302 Motor vehicle parts and accessories*

Electricity is not taken as an independent product here but as used for power and some heating in household appliances. So, total electricity supply to households by:

- *680100 Electric services (utilities)*

has been distributed over the appliances using electricity in private households:

- *470401 Power-driven handtools*
- *510102 Calculating and accounting machines*
- *510103 Electronic computers*
- *510104 Computer peripheral equipment*
- *510400 Office machines, n.e.c. (n.e.c. meaning: "all other")*
- *540100 Cooking equipment*
- *540200 Household refrigerators and freezers*
- *540300 Household laundry equipment*
- *540400 Electric housewares and fans*[29]
- *540500 Household vacuum cleaners*
- *540700 Household appliances, n.e.c.*
- *550100 Electric lamp bulbs and tubes*
- *560100 Household audio and video equipment*
- *560300 Telephone and telegraph apparatus*
- *580600 Magnetic and optical recording media*

Data on shares of appliances were taken from an English study, see the corresponding Annex 5.2.5 for details.

Similarly, for apparatus using gas, the purchases are from:

- *680202 Natural gas distribution*

and have been distributed to all gas using apparatus in households as specified in CEDA EU-25.

These include:

- *400300 Heating equipment, except electric and warm air furnaces*
- *540100 Household cooking equipment*

The heating equipment includes hot water for washing and bathing. Gas has been distributed according to its share in heating and cooking, using German data for 2002. Oil for heating purposes has been added. Corresponding emission data are in matrix B_2.

29 Which include electric room heaters

5.3.6 Matrix 2 linking production-consumption: Sales from disposal services sectors to final consumption (A_{32})

The categories to be considered in this part are the waste disposal services for solid wastes generated after the use of products by households. Sewer emissions are not specified in relation to waste flows; these are linked to water use only. As we stick to the level of individual products purchased, the use of disposal services is very much linked to the nature of the products. Detergents purchased end their life in the sewer (not specifically covered here but only through water use), while washing machines go to scrap; and services like hair dressing have no disposal flows from the use phase. Cars are scrapped (air emissions during the use of cars are not considered here but in the environmental interventions of by consumption matrix B_2). Tobacco is smoked, as yet without a disposal step. Food is not linked to its disposal phase, so its packaging waste is not yet covered. Fuels are emitted, only in combination with the products using them, so fuels do not require disposal services. Non-woven fabrics end up in mixed waste, distributed over landfill and incineration. Metallic and plastic household appliances go to scrap, etc.

In some cases an allocation procedure would be needed in principle, as when a house is being demolished and goes to demolition waste services. In the house, several products acquired will be demolished with the house. Lifts in houses require their own disposal service, in order to be scrapped. Such detail cannot be covered because neither the COICOP nor the BEA/CEDA categories on housing are detailed enough in this respect.

In the simplified waste model, all material products discarded first go into collection and sorting. The amount of this service is proportional to its price. For four main recyclable flows, this step is placed in a special sector, in order to link them to specific recycling activities: metals, plastics, paper and glass recycling sectors. These sectors have been derived from the one scrap process present in BEA/CEDA.

The data on technologies refer to the sector covering waste management in CEDA3.0:

- *680302 Sanitary services, steam supply, and irrigation systems*

and the sector covering recycling:

- *810001 Scrap handling.*

This means that the US shares in incineration and landfill have been used for general wastes from households. However, the volumes refer to European totals as established by Eurostat. The costs of household waste processing have been taken from detailed Dutch studies. The volumes of recyclable materials have been taken from the same Eurostat publication. They have been distributed over relevant products partially based on that source and partly based on common sense. For example, products not requiring deposal, like services, electricity, and gasoline, have been excluded. The full list of recyclable waste flows is available at CML. The prices of collected and sorted recyclable materials have been taken from British and US sources, and the prices of secondary materials produced by recycling sectors have been estimated based on market prices. For detailed references, see Annex 5.2.6.

5.3.7 Matrix 3 linking production-consumption: Sales from production sectors to disposal services sectors (A_{13})

Disposal activities use products produced by industries such as energy, capital goods, and sometimes wastes as raw materials to produce heat. This part been taken out of the full (RAS transformed) technology matrix, with all links as present there, for the two disposal sectors distinguished. As the two disposal services sectors have been disaggregated into nine sectors, these linking flows have been split up as well, using the same input-output ratios.

The data are readily available in CEDA 3.0. The volume of the linking flows results from the quantification of the model and has no independent meaning in this analysis.

5.3.8 Matrix 4 linking production-consumption: Sales from disposal services sectors to production sectors matrix (A31)

Production sectors require services from disposal activities. The source and treatment is exactly the same as for A_{13} (in Section 5.3.7) above.

Data are directly available from CEDA 3.0. The volume of the linking flow results from the quantification of the model and has no independent meaning in this analysis.

5.3.9 Environmental intervention by production sectors matrix (B_1)

The environment matrix gives the direct environmental interventions of all sectors (as production activities). It is based partly on European statistics for emission totals and partly on US data for the detailed structure of emissions, originally linked to the 480 x 480 US table, giving the distribution over sectors. The emissions are given per unit of sales of the sector involved, in euro.

Environmental interventions consist of emissions and resource use. The main source for European emissions is van Oers (2001), who covered Western Europe (EU-15 with Norway and Switzerland) rescaled on the basis of national incomes of 2003 to the level of EU-25[30], as 'van Oers EU-25'. The total emissions resulting cover both production and consumption. In a first step, the primordial CEDA EU-25 model produces inventory data, based on EU-25 public and private expenditure. These totals reflect US emission coefficients, apart from a number of direct emissions from consumption. The totals resulting have been rescaled, for each environmental intervention, forcing it to be exactly equal to its number in 'van Oers EU-25'. For environmental interventions lacking in the van Oers study, the rescaling is based on the median rescaling factor. The same correction factors are used for the production and the disposal management activities, B_1 and B_3 respectively.

This approach has been used for all environmental interventions, including resource extraction. As EU-25 resource extraction is relatively small, this leads to an underestimation of primary abiotic resource use. However, as the energy use has been Europeanised in the A_{11} production matrix, the numbers for energy are correct. As these are totally dominating the abiotic depletion score, the deviation on the other (underlying) abiotic resources involved is acceptable. As data on non-energy resource use are not adequate, they have been left out of the Table 5.3.1.a presented in Annex 5.

5.3.10 Environmental intervention by consumption activities matrix (B_2)

Direct emissions from households have been specified for five consumption activities which have their important direct emissions in the use stage: car driving; heating, cooking; washing; and use of pesticides. The emissions are given per unit of expenditure on the consumption activity involved, in euro.

Limitations in the directly available data and time imply that for other products, such as spray cans, paint, cigarettes, candles, to name but a few, the direct emissions have not yet been specified. Also, direct emissions from human and pet excretion resulting from food consumption are left out.

Many activities customarily attributed to the use phase do not have direct emissions. Use of electricity has no direct emissions from private households as electricity is produced by firms. Also emissions from the use of detergents do, in general, not take place from households but mainly from waste water treatment plants where they are delivered. Such further links have not been specified.

30 Source for national incomes: OECD 1995, for information on how this source has been used and reference see Annex 5.2.1.

The products being combined in consumption activities have been specified in A_{12}. Waste water treatment is included linked to water use, and not to specific wastes being processed in the waste water treatment system.

Data on car driving; heating, cooking; washing, and use of pesticides are described in detail in Annex 5.2.8, under $\mathbf{B}_2$. This includes a discussion on emission factors for calculating air emissions by cars.

5.3.11 Environmental intervention by disposal activities matrix (B_3)

Disposal activities treat wastes but also produce environment interventions. More specifically, effluent emissions from waste water treatment facilities, air emissions from incineration plants, and leaching emissions from landfills are specified in one combined sector. Waste water treatment emissions are part of B_1.

CEDA 3.0 covers major emissions from waste water treatment and from incineration and landfill activities, but aggregated in

- *680301 Water supply and sewerage systems (including waste water treatment)*
- *680302 Sanitary services, steam supply, and irrigation systems (including incineration and landfill)*
- *810001 Scrap*

Water supply as a product and waste water treatment sector has not been split up but left in the production technology matrix. So, waste water treatment is included in the system linked to water use, and not to specific wastes being processed in the waste water management system.

For the five collection and sorting sectors, the CEDA emission factors from '680302 sanitary services' have been used. For the four recycling sectors, the emission factors of '810001 scrap' have been used, which are US data forced into the European emission volume, as described in Section 5.3.9.

5.3.12 Final demand: Consumption activity expenditure vector (k_2)

First, the outlays by consumers and government on consumption activities are specified here. As discussed before, due to the lack of available data, government demand was calculated as an extrapolation of demand per private consumption category. This may underestimate certain expenditures largely made via government channels, such as on healthcare. This demand is what sets the system, and the model, moving. The European consumption expenditure data in terms of COICOP level 3 have been transformed into CEDA terms, as described above. The result is the consumption expenditure on products vector $\mathbf{k}_0$. A number of products have been combined into consumption activities. These involve products with major emissions in the use phase, especially as due to combustion processes and use of pesticides, with emissions in $\mathbf{B}_2$, and products involving electricity use by consumers, not involving direct emissions from households. The full survey is given in three tables in Annex 5.2.5.

The $\mathbf{A}_{12}$ matrix reflects the relation between the consumption expenditure on products vector $\mathbf{k}_0$ and the consumption activity vector $\mathbf{k}_2$. The formal dimension of $\mathbf{k}_0$ is 478. However, there are many product categories for which there is no final consumption, e.g. copper ore and pulp mills. The effective size of $\mathbf{k}_0$ is 288, and for $\mathbf{k}_2$ it is 282.

The conversion table between COICOP level 3 and BEA/CEDA is given in Annex 5.2.9, Table 5.2.9.6, stating the shares of products in BEA in the more aggregate COICOP categories. The vectors $\mathbf{k}_1$ and $\mathbf{k}_2$ are given in Table 5.2.9.9 in Annex 5.2.

5.3.13 Results, as environmental interventions vector (m)

All matrices and the consumption activity expenditure vector combine in one computational structure, see the formula in Section 5.2.3. The result gives the environmental interventions for each product, and hence the combination for all

products is a matrix again. As an interventions matrix, this result is too large to put on paper – it roughly consists of some 1200 environmental interventions for 478 products in total, of which some 280 products are for final consumption. After the impact assessment step, however, this list becomes much more manageable. This step aggregates the 1200 interventions into just eight impact categories (such as global warming, ozone depletion, etc.)[31]. This matrix of 478 products and scores on eight impact categories can be found in Annexes 5.3.2 and 5.3.3.

There is no independent data input at this level. All data used in this study combine into these final results.

5.3.14 Conversion tables for product and activity classifications

In the studies used several not fully linked classification systems were applied.

The EU consumption data mainly use the UN COICOP classification at level 1, 2 and 3, and one study at level 4; the OECD has input-output tables on European countries using 35 sectors; CEDA 3.0 uses the BEA classification for 480 sectors. Also, the purchases of products by households and consumption of products by households have slightly differing definitions. Petrol and cars are purchased, but after that cars are driven. All these classifications are converted into each other, for several purposes.

The BEA sector classifications as used in CEDA EU-25, see Annex 5.2, correspond roughly with the COICOP decimal levels 1, 2 and especially 3, see Table 5.2.9.6 in Annex 5.2.9, requiring a transformation table. With this link established, CEDA results can be translated back by transformation to level 3, and additionally to level 1, which mostly corresponds to the main consumption areas as used in many consumption studies. In linking CEDA products to COICOP products we first link the COICOP classification level 3, e.g.

- *660100 Telephone, telegraph communications, and communications services n.e.c.*
- *660200 Cable and other pay television services*

fit into COICOP level 3:

- *08.3.0 Telephone and telefax services (S)*

This level 3 happens to be equal to level 2 as no further differentiation is made here in COICOP , so that is also equal to:

- *08.3 Telephone and telefax services (S).*

When adding other items at this level, like

- *08.1.0 Postal services (S)*
- *08.2.0 Telephone and telefax equipment (D)*

the sum total at level 1 results for level 1 consumption area

- *08 Communications.*

Using these transformation tables, results from CEDA EU-25 may be transformed back into results for COICOP consumption areas, using the same basic format as in the analysis for detailed products. Only the conversion from COICOP level 3 to CEDA has been made and the conversion backwards to COICOP level 1. Where several CEDA products fall into one COICOP category, the share of these products in US final demand has been used to indicate their share in that COICOP category. Due to the lack of adequate category descriptions, this transformation is a weak point. Also the current categories have diverging and vague principles behind them and even with full descriptions linking these different systems, the principles will not become fully clear.

31 Annex 5.4.1 shows which intervention contributes to which impact category.

The names of two product groupings were changed: The first is [A393] Non-durable household goods, which was originally named 'brooms and brushes' (BEA Category 640800). In CEDA this varied grouping of products goes under the name 'brooms and brushes', with a one to one correspondence with COICOP 0561 'non-durable household goods'. To avoid misinterpretation in this case we chose to change the name. Secondly, in the BEA term 'US Postal services' we skipped the "US", otherwise, the BEA/CEDA product names have been retained as they were. The full conversion matrix CEDA – COICOP is given in Annex 5.2.9.

5.4 Results of the CEDA EU-25 Products and Environment model

5.4.1 Introduction

The presentation of the results has to deal with an immense number of data produced. There are results for several hundreds of product groupings, distinguishing eight different environmental impact categories for each. In the main report, we therefore present the detailed results for a selection of product groupings only: for each of the impact categories, the 35 highest scoring product groupings and the 10 lowest scoring product groupings (out of a total of 282 products). The full collection of results is given in the annexes.

The first set of detailed results quantifies the size of the different environmental impacts that corresponds to the volumes of products bought per year. For each impact category, the environmental impact of a product grouping is calculated as the share in the total impact caused by all products consumed in the EU-25 (private and public final demand together). In LCA terminology, this is the normalised score at European level, see van Oers *et al.* (2001).

The second set of detailed results gives the normalised values of environmental impacts per euro spent on the consumption of each product grouping (impact intensity), again for the groups of the highest 35 and the lowest scoring 10 product groupings.

Finally, aggregated results are presented in which the product groupings and their impacts have been further grouped together according to the main consumption areas.

In addition to the data tables, there are graphs to illustrate the distribution of the environmental impacts over the individual product groupings, and to show how the impacts can be explained as a combination of the size of the expenditure on a product and the per euro impacts.

It is important to be aware that the different types of results always include the full environmental impacts caused by a product during all the different phases of its life cycle, including the environmental impacts throughout the full production chains of products, during the use of products and after the use of the products (waste management or recycling).

It should also be remembered that it has been assumed in the model that the structure of public consumption (the distribution of expenditure over the different products) is the same as for private consumption (about three quarters of consumption expenditure is private in Europe and one quarter is public.)

5.4.2 Environmental impacts of products: full consumption

Table 5.4.1 quantifies the size of the different environmental impacts caused by the products consumed in the EU-25 per year as well as the yearly expenditure on the products. This table consists of eight sub-tables for:

- abiotic depletion;
- global warming;
- ozone layer depletion;
- human toxicity;
- ecotoxicity,
- photochemical oxidation;
- acidification; and
- eutrophication.

For each environmental impact category, the 35 highest scoring product groupings and the 10 lowest scoring product groupings are included. (The complete results are available in Annex 5.3.2.) Both the numbers for each product grouping and cumulative values are given (totalling from the top for the top 35 and totalling from the bottom for the bottom 10).

Note that the tables present calculation results of a model that includes a number of assumptions and approximations, the implications of which are discussed in Section 5.5. The data also do not reflect possible improvements in the environmental performance of products in the most recent years and that further improvements may arise in the future. (For example, air emissions of new cars per kilometre have been improving considerably.) The pure results should not be used in an isolated way to draw final conclusions about the impact of products. For conclusions about the impacts of products we refer to Chapter 6, which makes a cross-cutting analysis between these results and those of other studies presented in Chapter 4 including the qualitative aspects of the models involved.

Note also that the results on human toxicity and ecotoxicity have to be interpreted with particular caution. Despite significant improvements in the last five years, the impact assessment modelling in these areas is still considered as less reliable than in the other areas. They also require emission data for at least a few hundred potentially toxic substances. The inventory of these many different emissions is usually related to higher uncertainties than the inventory corresponding to the other impact categories, which can be assessed on the basis of a very limited number (some 20 in total) of substances. Furthermore, it should be kept in mind that life cycle impact assessment methodologies basically calculate generic, time and location independent *impact potentials* rather than real impacts that are a function of a specific exposure of a specific population or ecosystem during a specific time period at a specific location. For instance, the health effects of direct exposure of VOC emissions from paint during painting are hence not well included, and neither are the direct health effects from inhaling cigarette smoke[32].

Distribution of the environmental impacts

Figure 5.4.1 illustrates the distribution of environmental impacts and expenditure over the whole set of products going to final consumption. It is based on the cumulative values and shows that roughly an 80/20 rule applies to the case of global warming. Fewer than 20% of the product groupings together make up more than 80% of the environmental impact. And as few as 11 product groupings together cover more than 50% of the impact. For expenditure, this trend is less pronounced. Similar curves would be obtained for the other environmental impact categories. Table 5.4.2 shows the minimum number of product groupings that cover more than 50% of the impacts for the different impact categories.

Figure 5.4.2 illustrates the different environmental impacts of the full set of products in one graph. For this purpose the product groupings have been ordered based on the aggregated score of their environmental impact.

Firstly, the figure shows again that there is substantial inequality between the product groupings for all impact categories. Comparing the extremes, the scores per product grouping differ in five orders of magnitude (the y-axis is logarithmic!). This is partly determined by the classification system of the products and the aggregation applied (if a grouping is split in two halves, its scores will halve as well). Also well before the extremes, 20% from the bottom to 20%

32 Apart from this generic methodological issue of using life cycle impact assessment, a specific point in the CEDA EU-25 model is the following: Emissions from the use phase had to be modeled specifically, and this was only done for a number of major emission sources (such as car driving, fuel use for heating, etc.). The emissions from less voluminous product uses, such as paint use and cigarette smoking, were not modeled for the use stage.

Table 5.4.1: Environmental impacts related to the final consumption of products and corresponding consumption expenditures

Sub-table 5.4.1a: Abiotic depletion	Impact	Cumulative impact	Consumption expenditure	Cumulative consumption expenditure
Top 35	*Each expressed as fraction of EU-25 total*			
[A257] (Heating with) heating equipment, except electric and warm air furnaces	0.1870	0.19	0.0232	0.02
[A354] (Driving with) motor vehicles and passenger car bodies	0.1540	0.34	0.0876	0.11
[A446] Eating and drinking places	0.0617	0.40	0.0823	0.19
[A52] Meat packing plants	0.0301	0.43	0.0198	0.21
[A31] New residential 1 unit structures, nonfarm	0.0267	0.46	0.0592	0.27
[A54] Poultry slaughtering and processing	0.0253	0.48	0.0163	0.29
[A59] Fluid milk	0.0172	0.50	0.0109	0.30
[A333] (Washing with) household laundry equipment	0.0164	0.52	0.0127	0.31
[A33] New additions & alterations, nonfarm, construction	0.0149	0.53	0.0295	0.34
[A56] Natural, processed, and imitation cheese (10th)	0.0147	0.55	0.0087	0.35
[A53] Sausages and other prepared meat products	0.0142	0.56	0.0083	0.36
[A115] Apparel made from purchased materials	0.0142	0.58	0.0227	0.38
[A332] (Use of) household refrigerators and freezers	0.0117	0.59	0.0086	0.39
[A448] Automotive repair shops and services	0.0115	0.60	0.0206	0.41
[A431] Beauty and barber shops	0.0111	0.61	0.0141	0.42
[A331] (Use of) household cooking equipment	0.0107	0.62	0.0055	0.43
[A399] Local and suburban transit and interurban highway passenger transportation	0.0107	0.63	0.0067	0.44
[A407] Telephone, telegraph communications, and communications services n.e.c.	0.0106	0.64	0.0358	0.47
[A419] Insurance carriers	0.0094	0.65	0.0473	0.52
[A93] Edible fats and oils, n.e.c.	0.0088	0.66	0.0065	0.53
[A337] (Use of) electric lamp bulbs and tubes	0.0080	0.67	0.0055	0.53
[A86] Bottled and canned soft drinks	0.0079	0.68	0.0073	0.54
[A336] (Use of) household appliances, n.e.c.	0.0078	0.68	0.0088	0.55
[A457] Other amusement and recreation services	0.0078	0.69	0.0216	0.57
[A340] (Use of) household audio and video equipment	0.0076	0.70	0.0069	0.58
[A42] Maintenance and repair of farm and nonfarm residential structures	0.0075	0.71	0.0141	0.59
[A75] Bread, cake, and related products	0.0075	0.71	0.0109	0.60
[A413] Water supply and sewerage systems	0.0073	0.72	0.0083	0.61
[A187] Drugs	0.0071	0.73	0.0097	0.62
[A98] Cigarettes	0.0068	0.74	0.0138	0.63
[A475] Postal service	0.0066	0.74	0.0025	0.64
[A403] Air transportation	0.0065	0.75	0.0037	0.64
[A92] Roasted coffee	0.0062	0.76	0.0044	0.64
[A66] Frozen fruits, fruit juices, and vegetables	0.0061	0.76	0.0048	0.65
[A176] (Use of) pesticides and agricultural chemicals, n.e.c. (35th)	0.0057	0.77	0.0048	0.65
Bottom 10				
[A141] Wood television and radio cabinets (10th)	5.00E-06	0.00	6.35E-06	0.00
[A267] Crowns and closures	3.84E-06	0.00	3.61E-06	0.00
[A30] Chemical and fertilizer minerals	3.37E-06	0.00	8.38E-06	0.00
[A263] Prefabricated metal buildings and components	3.12E-06	0.00	3.28E-06	0.00
[A339] Wiring devices	2.55E-06	0.00	4.17E-06	0.00
[A390] Marking devices	2.38E-06	0.00	3.54E-06	0.00
[A226] Concrete products, except block and brick	1.38E-06	0.00	1.67E-06	0.00
[A14] Miscellaneous crops	8.03E-07	0.00	8.52E-07	0.00
[A239] Steel wiredrawing and steel nails and spikes	7.38E-07	0.00	4.58E-07	0.00
[A205] Boot and shoe cut stock and findings	6.51E-07	0.00	6.51E-07	0.00

Table 5.4.1: Environmental impacts related to the final consumption of products and corresponding consumption expenditures (cont.)

Sub-table 5.4.1b: Global warming	Impact	Cumulative impact	Consumption expenditure	Cumulative consumption expenditure
Top 35	*Each expressed as fraction of EU-25 total*			
[A354] (Driving with) motor vehicles and passenger car bodies	0.1500	0.15	0.0876	0.09
[A446] Eating and drinking places	0.0808	0.23	0.0823	0.17
[A52] Meat packing plants	0.0554	0.29	0.0198	0.19
[A257] (Heating with) heating equipment, except electric and warm air furnaces	0.0473	0.33	0.0232	0.21
[A54] Poultry slaughtering and processing	0.0393	0.37	0.0163	0.23
[A31] New residential 1 unit structures, nonfarm	0.0319	0.40	0.0592	0.29
[A53] Sausages and other prepared meat products	0.0252	0.43	0.0083	0.30
[A59] Fluid milk	0.0238	0.45	0.0109	0.31
[A333] (Washing with) household laundry equipment	0.0237	0.48	0.0127	0.32
[A56] Natural, processed, and imitation cheese (10th)	0.0211	0.50	0.0087	0.33
[A33] New additions & alterations, nonfarm, construction	0.0182	0.52	0.0295	0.36
[A332] (Use of) household refrigerators and freezers	0.0177	0.53	0.0086	0.37
[A115] Apparel made from purchased materials	0.0164	0.55	0.0227	0.39
[A407] Telephone, telegraph communications, and communications services n.e.c.	0.0134	0.56	0.0358	0.43
[A93] Edible fats and oils, n.e.c.	0.0129	0.58	0.0065	0.43
[A337] (Use of) electric lamp bulbs and tubes	0.0123	0.59	0.0055	0.44
[A448] Automotive repair shops and services	0.0122	0.60	0.0206	0.46
[A431] Beauty and barber shops	0.0116	0.61	0.0141	0.47
[A340] (Use of) household audio and video equipment	0.0115	0.62	0.0069	0.48
[A419] Insurance carriers	0.0113	0.64	0.0473	0.53
[A331] (Use of) household cooking equipment	0.0100	0.65	0.0055	0.53
[A336] (Use of) household appliances, n.e.c.	0.0095	0.66	0.0088	0.54
[A457] Other amusement and recreation services	0.0091	0.66	0.0216	0.56
[A86] Bottled and canned soft drinks	0.0091	0.67	0.0073	0.57
[A75] Bread, cake, and related products	0.0089	0.68	0.0109	0.58
[A187] Drugs	0.0075	0.69	0.0097	0.59
[A66] Frozen fruits, fruit juices, and vegetables	0.0075	0.70	0.0048	0.59
[A98] Cigarettes	0.0074	0.70	0.0138	0.61
[A12] Vegetables	0.0071	0.71	0.0071	0.62
[A92] Roasted coffee	0.0071	0.72	0.0044	0.62
[A42] Maintenance and repair of farm and nonfarm residential structures	0.0069	0.73	0.0141	0.63
[A413] Water supply and sewerage systems	0.0067	0.73	0.0083	0.64
[A34] New residential garden and high-rise apartments construction	0.0066	0.74	0.0112	0.65
[A475] Postal service	0.0058	0.75	0.0025	0.66
[A65] Prepared fresh or frozen fish and seafoods (35th)	0.0057	0.75	0.0037	0.66
Bottom 10				
[A195] Products of petroleum and coal, n.e.c. (10th)	5.48E-06	0.00	5.39E-06	0.00
[A267] Crowns and closures	4.71E-06	0.00	3.61E-06	0.00
[A141] Wood television and radio cabinets	4.66E-06	0.00	6.35E-06	0.00
[A263] Prefabricated metal buildings and components	4.13E-06	0.00	3.28E-06	0.00
[A339] Wiring devices	2.94E-06	0.00	4.17E-06	0.00
[A390] Marking devices	2.45E-06	0.00	3.54E-06	0.00
[A226] Concrete products, except block and brick	2.31E-06	0.00	1.67E-06	0.00
[A14] Miscellaneous crops	1.07E-06	0.00	8.52E-07	0.00
[A205] Boot and shoe cut stock and findings	9.30E-07	0.00	6.51E-07	0.00
[A239] Steel wiredrawing and steel nails and spikes	9.18E-07	0.00	4.58E-07	0.00

Table 5.4.1: Environmental impacts related to the final consumption of products and corresponding consumption expenditures (cont.)

Sub-table 5.4.1c: Ozone layer depletion	Impact	Cumulative impact	Consumption expenditure	Cumulative consumption expenditure
Top 35	*Each expressed as fraction of EU-25 total*			
[A354] (Driving with) motor vehicles and passenger car bodies	0.1030	0.10	0.0876	0.09
[A446] Eating and drinking places	0.0788	0.18	0.0823	0.17
[A431] Beauty and barber shops	0.0391	0.22	0.0141	0.18
[A31] New residential 1 unit structures, nonfarm	0.0363	0.26	0.0592	0.24
[A52] Meat packing plants	0.0332	0.29	0.0198	0.26
[A176] (Household use of) pesticides and agricultural chemicals, n.e.c.	0.0316	0.32	0.0048	0.27
[A54] Poultry slaughtering and processing	0.0311	0.35	0.0163	0.28
[A115] Apparel made from purchased materials	0.0227	0.38	0.0227	0.31
[A187] Drugs	0.0226	0.40	0.0097	0.32
[A33] New additions & alterations, nonfarm, construction (10th)	0.0199	0.42	0.0295	0.35
[A457] Other amusement and recreation services	0.0197	0.44	0.0216	0.37
[A407] Telephone, telegraph communications, and communications services n.e.c.	0.0192	0.46	0.0358	0.40
[A59] Fluid milk	0.0187	0.48	0.0109	0.41
[A53] Sausages and other prepared meat products	0.0166	0.49	0.0083	0.42
[A336] (Use of) household appliances, n.e.c.	0.0164	0.51	0.0088	0.43
[A56] Natural, processed, and imitation cheese	0.0157	0.52	0.0087	0.44
[A393] Non-durable household goods	0.0140	0.54	0.0072	0.45
[A448] Automotive repair shops and services	0.0140	0.55	0.0206	0.47
[A419] Insurance carriers	0.0137	0.57	0.0473	0.51
[A86] Bottled and canned soft drinks	0.0116	0.58	0.0073	0.52
[A93] Edible fats and oils, n.e.c.	0.0113	0.59	0.0065	0.53
[A257] (Heating with) heating equipment, except electric and warm air furnaces	0.0109	0.60	0.0232	0.55
[A332] (Use of) household refrigerators and freezers	0.0098	0.61	0.0086	0.56
[A333] (Washing with) household laundry equipment	0.0089	0.62	0.0127	0.57
[A201] Miscellaneous plastics products, n.e.c.	0.0082	0.63	0.0026	0.58
[A75] Bread, cake, and related products	0.0081	0.64	0.0109	0.59
[A42] Maintenance and repair of farm and nonfarm residential structures	0.0080	0.64	0.0141	0.60
[A98] Cigarettes	0.0076	0.65	0.0138	0.61
[A66] Frozen fruits, fruit juices, and vegetables	0.0075	0.66	0.0048	0.62
[A92] Roasted coffee	0.0075	0.67	0.0044	0.62
[A447] Automotive rental and leasing, without drivers	0.0071	0.67	0.0075	0.63
[A458] Doctors and dentists	0.0067	0.68	0.0201	0.65
[A424] Hotels	0.0066	0.69	0.0095	0.66
[A96] Potato chips and similar snacks	0.0063	0.69	0.0050	0.67
[A191] Toilet preparations (35th)	0.0062	0.70	0.0050	0.67
Bottom 10				
[A267] Crowns and closures (10th)	5.35E-06	0.00	3.61E-06	0.00
[A390] Marking devices	4.97E-06	0.00	3.54E-06	0.00
[A276] Steel springs, except wire	4.77E-06	0.00	5.92E-06	0.00
[A339] Wiring devices	4.19E-06	0.00	4.17E-06	0.00
[A263] Prefabricated metal buildings and components	3.48E-06	0.00	3.28E-06	0.00
[A205] Boot and shoe cut stock and findings	2.80E-06	0.00	6.51E-07	0.00
[A30] Chemical and fertilizer minerals	1.72E-06	0.00	8.38E-06	0.00
[A226] Concrete products, except block and brick	1.15E-06	0.00	1.67E-06	0.00
[A14] Miscellaneous crops	7.46E-07	0.00	8.52E-07	0.00
[A239] Steel wiredrawing and steel nails and spikes	7.02E-07	0.00	4.58E-07	0.00

Table 5.4.1: Environmental impacts related to the final consumption of products and corresponding consumption expenditures (cont.)

Sub-table 5.4.1d: Human toxicity	Impact	Cumulative impact	Consumption expenditure	Cumulative consumption expenditure
Top 35	*Each expressed as fraction of EU-25 total*			
[A354] (Driving with) motor vehicles and passenger car bodies	0.2070	0.21	0.0876	0.09
[A446] Eating and drinking places	0.0736	0.28	0.0823	0.17
[A31] New residential 1 unit structures, nonfarm	0.0409	0.32	0.0592	0.23
[A52] Meat packing plants	0.0359	0.36	0.0198	0.25
[A54] Poultry slaughtering and processing	0.0296	0.39	0.0163	0.27
[A33] New additions & alterations, nonfarm, construction	0.0230	0.41	0.0295	0.29
[A115] Apparel made from purchased materials	0.0187	0.43	0.0227	0.32
[A59] Fluid milk	0.0186	0.45	0.0109	0.33
[A53] Sausages and other prepared meat products	0.0178	0.47	0.0083	0.34
[A257] (Heating with) heating equipment, except electric and warm air furnaces (10th)	0.0177	0.48	0.0232	0.36
[A407] Telephone, telegraph communications, and communications services	0.0170	0.50	0.0358	0.40
[A56] Natural, processed, and imitation cheese	0.0164	0.52	0.0087	0.40
[A448] Automotive repair shops and services	0.0159	0.53	0.0206	0.42
[A333] (Washing with) household laundry equipment	0.0152	0.55	0.0127	0.44
[A419] Insurance carriers	0.0134	0.56	0.0473	0.48
[A431] Beauty and barber shops	0.0130	0.57	0.0141	0.50
[A336] (Use of) household appliances, n.e.c.	0.0119	0.59	0.0088	0.51
[A332] (Use of) household refrigerators and freezers	0.0116	0.60	0.0086	0.52
[A86] Bottled and canned soft drinks	0.0107	0.61	0.0073	0.52
[A93] Edible fats and oils, n.e.c.	0.0100	0.62	0.0065	0.53
[A457] Other amusement and recreation services	0.0092	0.63	0.0216	0.55
[A42] Maintenance and repair of farm and nonfarm residential structures	0.0091	0.64	0.0141	0.57
[A75] Bread, cake, and related products	0.0084	0.64	0.0109	0.58
[A34] New residential garden and high-rise apartments construction	0.0082	0.65	0.0112	0.59
[A66] Frozen fruits, fruit juices, and vegetables	0.0077	0.66	0.0048	0.59
[A98] Cigarettes	0.0076	0.67	0.0138	0.61
[A340] (Use of) household audio and video equipment	0.0074	0.68	0.0069	0.61
[A92] Roasted coffee	0.0073	0.68	0.0044	0.62
[A187] Drugs	0.0073	0.69	0.0097	0.63
[A447] Automotive rental and leasing, without drivers	0.0073	0.70	0.0075	0.63
[A331] (Use of) household cooking equipment	0.0071	0.70	0.0055	0.64
[A176] (Household use of) pesticides and agricultural chemicals, n.e.c.	0.0069	0.71	0.0048	0.65
[A337] (Use of) electric lamp bulbs and tubes	0.0068	0.72	0.0055	0.65
[A393] Non-durable household goods	0.0066	0.72	0.0072	0.66
[A84] Wines, brandy, and brandy spirits (35th)	0.0060	0.73	0.0062	0.66
Bottom 10				
[A263] Prefabricated metal buildings and components (10th)	6.41E-06	0.00	3.28E-06	0.00
[A141] Wood television and radio cabinets	5.28E-06	0.00	6.35E-06	0.00
[A339] Wiring devices	4.84E-06	0.00	4.17E-06	0.00
[A30] Chemical and fertilizer minerals	4.57E-06	0.00	8.38E-06	0.00
[A195] Products of petroleum and coal, n.e.c.	4.08E-06	0.00	5.39E-06	0.00
[A14] Miscellaneous crops	3.46E-06	0.00	8.52E-07	0.00
[A390] Marking devices	2.86E-06	0.00	3.54E-06	0.00
[A226] Concrete products, except block and brick	2.04E-06	0.00	1.67E-06	0.00
[A239] Steel wiredrawing and steel nails and spikes	1.34E-06	0.00	4.58E-07	0.00
[A205] Boot and shoe cut stock and findings	7.98E-07	0.00	6.51E-07	0.00

Table 5.4.1: Environmental impacts related to the final consumption of products and corresponding consumption expenditures (cont.)

Sub-table 5.4.1e: Ecotoxicity	Impact	Cumulative impact	Consumption expenditure	Cumulative consumption expenditure
Top 35	*Each expressed as fraction of EU-25 total*			
[A354] (Driving with) motor vehicles and passenger car bodies	0.1106	0.11	0.0876	0.09
[A446] Eating and drinking places	0.0810	0.19	0.0823	0.17
[A52] Meat packing plants	0.0488	0.24	0.0198	0.19
[A115] Apparel made from purchased materials	0.0463	0.29	0.0227	0.21
[A31] New residential 1 unit structures, nonfarm	0.0351	0.32	0.0592	0.27
[A54] Poultry slaughtering and processing	0.0315	0.35	0.0163	0.29
[A59] Fluid milk	0.0261	0.38	0.0109	0.30
[A56] Natural, processed, and imitation cheese	0.0230	0.40	0.0087	0.31
[A53] Sausages and other prepared meat products	0.0219	0.42	0.0083	0.32
[A33] New additions & alterations, nonfarm, construction (10th)	0.0192	0.44	0.0295	0.35
[A93] Edible fats and oils, n.e.c.	0.0166	0.46	0.0065	0.35
[A407] Telephone, telegraph communications, and communications services	0.0152	0.48	0.0358	0.39
[A448] Automotive repair shops and services	0.0148	0.49	0.0206	0.41
[A333] (Washing with) household laundry equipment	0.0146	0.50	0.0127	0.42
[A176] (Household use of) pesticides and agricultural chemicals, n.e.c.	0.0145	0.52	0.0048	0.43
[A336] (Use of) household appliances, n.e.c.	0.0119	0.53	0.0088	0.43
[A431] Beauty and barber shops	0.0118	0.54	0.0141	0.45
[A332] (Use of) household refrigerators and freezers	0.0115	0.55	0.0086	0.46
[A75] Bread, cake, and related products	0.0110	0.57	0.0109	0.47
[A12] Vegetables	0.0108	0.58	0.0071	0.48
[A86] Bottled and canned soft drinks	0.0104	0.59	0.0073	0.48
[A257] (Heating with) heating equipment, except electric and warm air furnaces	0.0104	0.60	0.0232	0.51
[A419] Insurance carriers	0.0095	0.61	0.0473	0.55
[A98] Cigarettes	0.0095	0.62	0.0138	0.57
[A81] Candy and other confectionery products	0.0094	0.63	0.0042	0.57
[A92] Roasted coffee	0.0092	0.63	0.0044	0.58
[A66] Frozen fruits, fruit juices, and vegetables	0.0089	0.64	0.0048	0.58
[A457] Other amusement and recreation services	0.0089	0.65	0.0216	0.60
[A117] Housefurnishings, n.e.c.	0.0084	0.66	0.0030	0.60
[A106] Carpets and rugs	0.0081	0.67	0.0033	0.61
[A393] Non-durable household goods	0.0079	0.68	0.0072	0.62
[A42] Maintenance and repair of farm and nonfarm residential structures	0.0075	0.68	0.0141	0.63
[A10] Fruits	0.0072	0.69	0.0040	0.63
[A96] Potato chips and similar snacks	0.0071	0.70	0.0050	0.64
[A340] (Use of) household audio and video equipment (35th)	0.0071	0.71	0.0069	0.64
Bottom 10				
[A445] Accounting, auditing and bookkeeping, and miscell. services (10th)	5.99E-06	0.00	1.34E-05	0.00
[A339] Wiring devices	5.65E-06	0.00	4.17E-06	0.00
[A30] Chemical and fertilizer minerals	4.38E-06	0.00	8.38E-06	0.00
[A141] Wood television and radio cabinets	4.16E-06	0.00	6.35E-06	0.00
[A390] Marking devices	2.46E-06	0.00	3.54E-06	0.00
[A195] Products of petroleum and coal, n.e.c.	2.24E-06	0.00	5.39E-06	0.00
[A226] Concrete products, except block and brick	1.70E-06	0.00	1.67E-06	0.00
[A239] Steel wiredrawing and steel nails and spikes	1.48E-06	0.00	4.58E-07	0.00
[A205] Boot and shoe cut stock and findings	8.91E-07	0.00	6.51E-07	0.00

Table 5.4.1: Environmental impacts related to the final consumption of products and corresponding consumption expenditures (cont.)

Sub-table 5.4.1f: Photochemical oxidation	Impact	Cumulative impact	Consumption expenditure	Cumulative consumption expenditure
Top 35	*Each expressed as fraction of EU-25 total*			
[A354] (Driving with) motor vehicles and passenger car bodies	0.1660	0.17	0.0876	0.09
[A446] Eating and drinking places	0.0782	0.24	0.0823	0.17
[A52] Meat packing plants	0.0388	0.28	0.0198	0.19
[A31] New residential 1 unit structures, nonfarm	0.0383	0.32	0.0592	0.25
[A257] (Heating with) heating equipment, except electric and warm air furnaces	0.0376	0.36	0.0232	0.27
[A54] Poultry slaughtering and processing	0.0342	0.39	0.0163	0.29
[A115] Apparel made from purchased materials	0.0218	0.41	0.0227	0.31
[A33] New additions & alterations, nonfarm, construction	0.0214	0.44	0.0295	0.34
[A59] Fluid milk	0.0208	0.46	0.0109	0.35
[A53] Sausages and other prepared meat products	0.0193	0.48	0.0083	0.36
[A56] Natural, processed, and imitation cheese	0.0181	0.49	0.0087	0.37
[A407] Telephone, telegraph communications, and communications services	0.0161	0.51	0.0358	0.40
[A419] Insurance carriers	0.0140	0.52	0.0473	0.45
[A448] Automotive repair shops and services	0.0140	0.54	0.0206	0.47
[A431] Beauty and barber shops	0.0136	0.55	0.0141	0.49
[A86] Bottled and canned soft drinks	0.0116	0.56	0.0073	0.49
[A93] Edible fats and oils, n.e.c.	0.0115	0.58	0.0065	0.50
[A333] (Washing with) household laundry equipment	0.0107	0.59	0.0127	0.51
[A336] (Use of) household appliances, n.e.c.	0.0107	0.60	0.0088	0.52
[A457] Other amusement and recreation services	0.0100	0.61	0.0216	0.54
[A187] Drugs	0.0091	0.62	0.0097	0.55
[A42] Maintenance and repair of farm and nonfarm residential structures	0.0089	0.62	0.0141	0.57
[A75] Bread, cake, and related products	0.0089	0.63	0.0109	0.58
[A332] (Use of) household refrigerators and freezers	0.0083	0.64	0.0086	0.59
[A176] (Household use of) pesticides and agricultural chemicals, n.e.c.	0.0082	0.65	0.0048	0.59
[A66] Frozen fruits, fruit juices, and vegetables	0.0078	0.66	0.0048	0.60
[A393] Non-durable household goods	0.0076	0.67	0.0072	0.60
[A98] Cigarettes	0.0075	0.67	0.0138	0.62
[A34] New residential garden and high-rise apartments construction	0.0070	0.68	0.0112	0.63
[A447] Automotive rental and leasing, without drivers	0.0068	0.69	0.0075	0.64
[A92] Roasted coffee	0.0068	0.69	0.0044	0.64
[A96] Potato chips and similar snacks	0.0062	0.70	0.0050	0.64
[A413] Water supply and sewerage systems	0.0062	0.71	0.0083	0.65
[A424] Hotels	0.0061	0.71	0.0095	0.66
[A331] (Use of) household cooking equipment (35th)	0.0059	0.72	0.0055	0.67
Bottom 10				
[A276] Steel springs, except wire (10th)	5.56E-06	0.00	5.92E-06	0.00
[A267] Crowns and closures	5.41E-06	0.00	3.61E-06	0.00
[A263] Prefabricated metal buildings and components	4.59E-06	0.00	3.28E-06	0.00
[A390] Marking devices	3.69E-06	0.00	3.54E-06	0.00
[A339] Wiring devices	3.50E-06	0.00	4.17E-06	0.00
[A30] Chemical and fertilizer minerals	3.05E-06	0.00	8.38E-06	0.00
[A226] Concrete products, except block and brick	1.56E-06	0.00	1.67E-06	0.00
[A205] Boot and shoe cut stock and findings	1.19E-06	0.00	6.51E-07	0.00
[A14] Miscellaneous crops	8.16E-07	0.00	8.52E-07	0.00
[A239] Steel wiredrawing and steel nails and spikes	7.93E-07	0.00	4.58E-07	0.00

Table 5.4.1: Environmental impacts related to the final consumption of products and corresponding consumption expenditures (cont.)

Sub-table 5.4.1g: Acidification	Impact	Cumulative impact	Consumption expenditure	Cumulative consumption expenditure
Top 35	*Each expressed as fraction of EU-25 total*			
[A354] (Driving with) motor vehicles and passenger car bodies	0.1030	0.10	0.0876	0.09
[A446] Eating and drinking places	0.0845	0.19	0.0823	0.17
[A52] Meat packing plants	0.0614	0.25	0.0198	0.19
[A54] Poultry slaughtering and processing	0.0446	0.29	0.0163	0.21
[A333] (Washing with) household laundry equipment	0.0400	0.33	0.0127	0.22
[A31] New residential 1 unit structures, nonfarm	0.0301	0.36	0.0592	0.28
[A332] (Use of) household refrigerators and freezers	0.0295	0.39	0.0086	0.29
[A53] Sausages and other prepared meat products	0.0280	0.42	0.0083	0.29
[A257] (Heating with) heating equipment, except electric and warm air furnaces	0.0265	0.45	0.0232	0.32
[A59] Fluid milk (10th)	0.0263	0.47	0.0109	0.33
[A56] Natural, processed, and imitation cheese	0.0234	0.50	0.0087	0.34
[A337] (Use of) electric lamp bulbs and tubes	0.0223	0.52	0.0055	0.34
[A340] (Use of) household audio and video equipment	0.0198	0.54	0.0069	0.35
[A33] New additions & alterations, nonfarm, construction	0.0182	0.56	0.0295	0.38
[A115] Apparel made from purchased materials	0.0166	0.57	0.0227	0.40
[A331] (Use of) household cooking equipment	0.0153	0.59	0.0055	0.41
[A407] Telephone, telegraph communications, and communications services	0.0138	0.60	0.0358	0.44
[A431] Beauty and barber shops	0.0127	0.62	0.0141	0.46
[A448] Automotive repair shops and services	0.0126	0.63	0.0206	0.48
[A419] Insurance carriers	0.0114	0.64	0.0473	0.53
[A336] (Use of) household appliances, n.e.c.	0.0102	0.65	0.0088	0.53
[A457] Other amusement and recreation services	0.0101	0.66	0.0216	0.56
[A93] Edible fats and oils, n.e.c.	0.0096	0.67	0.0065	0.56
[A86] Bottled and canned soft drinks	0.0095	0.68	0.0073	0.57
[A75] Bread, cake, and related products	0.0083	0.69	0.0109	0.58
[A42] Maintenance and repair of farm and nonfarm residential structures	0.0070	0.69	0.0141	0.59
[A34] New residential garden and high-rise apartments construction	0.0068	0.70	0.0112	0.61
[A187] Drugs	0.0065	0.71	0.0097	0.62
[A424] Hotels	0.0064	0.71	0.0095	0.62
[A413] Water supply and sewerage systems	0.0063	0.72	0.0083	0.63
[A66] Frozen fruits, fruit juices, and vegetables	0.0062	0.73	0.0048	0.64
[A57] Dry, condensed, and evaporated dairy products	0.0060	0.73	0.0033	0.64
[A98] Cigarettes	0.0060	0.74	0.0138	0.66
[A447] Automotive rental and leasing, without drivers	0.0055	0.74	0.0075	0.66
[A475] Postal service (35th)	0.0055	0.75	0.0025	0.66
Bottom 10				
[A141] Wood television and radio cabinets (10th)	4.68E-06	0.00	6.35E-06	0.00
[A267] Crowns and closures	4.64E-06	0.00	3.61E-06	0.00
[A263] Prefabricated metal buildings and components	3.99E-06	0.00	3.28E-06	0.00
[A30] Chemical and fertilizer minerals	3.21E-06	0.00	8.38E-06	0.00
[A339] Wiring devices	3.05E-06	0.00	4.17E-06	0.00
[A390] Marking devices	2.29E-06	0.00	3.54E-06	0.00
[A226] Concrete products, except block and brick	2.05E-06	0.00	1.67E-06	0.00
[A205] Boot and shoe cut stock and findings	9.28E-07	0.00	6.51E-07	0.00
[A239] Steel wiredrawing and steel nails and spikes	8.64E-07	0.00	4.58E-07	0.00
[A14] Miscellaneous crops	7.62E-07	0.00	8.52E-07	0.00

Table 5.4.1: Environmental impacts related to the final consumption of products and corresponding consumption expenditures (cont.)

Sub-table 5.4.1 h: Eutrophication	Impact	Cumulative impact	Consumption expenditure	Cumulative consumption expenditure
Top 35	*Each expressed as fraction of EU-25 total*			
[A446] Eating and drinking places	0.1210	0.12	0.0823	0.08
[A52] Meat packing plants	0.1100	0.23	0.0198	0.10
[A54] Poultry slaughtering and processing	0.0668	0.30	0.0163	0.12
[A59] Fluid milk	0.0491	0.35	0.0109	0.13
[A53] Sausages and other prepared meat products	0.0483	0.40	0.0083	0.14
[A354] (Driving with) motor vehicles and passenger car bodies	0.0475	0.44	0.0876	0.23
[A56] Natural, processed, and imitation cheese	0.0432	0.49	0.0087	0.23
[A115] Apparel made from purchased materials	0.0358	0.52	0.0227	0.26
[A75] Bread, cake, and related products	0.0331	0.55	0.0109	0.27
[A70] Prepared flour mixes and doughs (10th)	0.0251	0.58	0.0024	0.27
[A69] Cereal breakfast foods	0.0231	0.60	0.0037	0.27
[A93] Edible fats and oils, n.e.c.	0.0178	0.62	0.0065	0.28
[A97] Food preparations, n.e.c.	0.0144	0.64	0.0021	0.28
[A76] Cookies and crackers	0.0122	0.65	0.0042	0.29
[A31] New residential 1 unit structures, nonfarm	0.0115	0.66	0.0592	0.35
[A96] Potato chips and similar snacks	0.0115	0.67	0.0050	0.35
[A57] Dry, condensed, and evaporated dairy products	0.0109	0.68	0.0033	0.35
[A81] Candy and other confectionery products	0.0103	0.69	0.0042	0.36
[A71] Dog and cat food	0.0102	0.70	0.0022	0.36
[A257] (Heating with) heating equipment, except electric and warm air furnaces	0.0100	0.71	0.0232	0.38
[A78] Sugar	0.0095	0.72	0.0007	0.38
[A92] Roasted coffee	0.0092	0.73	0.0044	0.39
[A2] Poultry and eggs	0.0085	0.74	0.0027	0.39
[A393] Non-durable household goods	0.0084	0.75	0.0072	0.40
[A86] Bottled and canned soft drinks	0.0081	0.76	0.0073	0.41
[A10] Fruits	0.0076	0.76	0.0040	0.41
[A66] Frozen fruits, fruit juices, and vegetables	0.0073	0.77	0.0048	0.41
[A68] Flour and other grain mill products	0.0067	0.78	0.0005	0.42
[A33] New additions & alterations, nonfarm, construction	0.0067	0.78	0.0295	0.44
[A117] Housefurnishings, n.e.c.	0.0066	0.79	0.0030	0.45
[A106] Carpets and rugs	0.0065	0.80	0.0033	0.45
[A4] Miscellaneous livestock	0.0064	0.80	0.0015	0.45
[A457] Other amusement and recreation services	0.0064	0.81	0.0216	0.47
[A82] Malt beverages	0.0057	0.82	0.0040	0.48
[A333] (Washing with) household laundry equipment (35th)	0.0056	0.82	0.0127	0.49
Bottom 10				
[A141] Wood television and radio cabinets (10th)	1.85E-06	0.00	6.35E-06	0.00
[A267] Crowns and closures	1.61E-06	0.00	3.61E-06	0.00
[A195] Products of petroleum and coal, n.e.c.	1.52E-06	0.00	5.39E-06	0.00
[A263] Prefabricated metal buildings and components	1.46E-06	0.00	3.28E-06	0.00
[A205] Boot and shoe cut stock and findings	1.20E-06	0.00	6.51E-07	0.00
[A390] Marking devices	1.09E-06	0.00	3.54E-06	0.00
[A339] Wiring devices	1.02E-06	0.00	4.17E-06	0.00
[A30] Chemical and fertilizer minerals	7.34E-07	0.00	8.38E-06	0.00
[A226] Concrete products, except block and brick	6.03E-07	0.00	1.67E-06	0.00
[A239] Steel wiredrawing and steel nails and spikes	3.29E-07	0.00	4.58E-07	0.00

Figure 5.4.1: Cumulative environmental impacts – example global warming

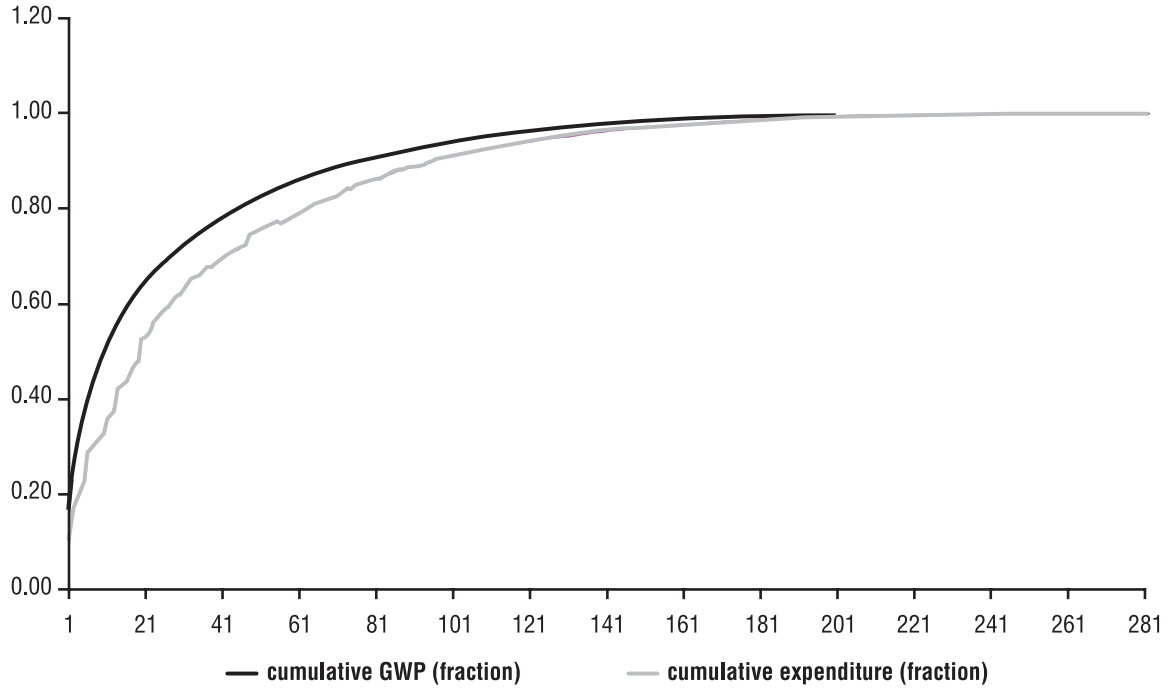


Table 5.4.2: Coverage of more than half of total environmental impacts

	Minimum number of product groupings covering more than half (≥50%) of an environmental impact	Percentage of all product groupings (%)	Percentage of all expenditures (%)
Abiotic depletion	7	2.5	30
Global warming	11	3.9	36
Ozone layer depletion	15	5.3	43
Human toxicity	12	4.3	40
Ecotoxicity	15	5.3	43
Photochemical oxidation	12	4.3	40
Acidification	12	4.3	34
Eutrophication	8	2.8	26

from the top, the difference is nearly two orders of magnitude.

Secondly, the scores per impact category for any product diverge substantially as well, in the order of a factor five between highest and lowest scores (the scores have been normalised on total EU-25 impact, so they indicate the share in total European impact in that category. They are, therefore, comparable between impact categories.).

5.4.3 Environmental impacts of products per euro spent

In this section the environmental impacts related to the final consumption of products are presented per euro spent. Again the top 35 and the bottom 10 product groupings are included for each impact category (Table 5.4.3, consisting again of eight sub-tables covering the different environmental impact categories).

Figure 5.4.2: The different environmental impacts related to the final consumption of products (full set) and aggregated scores, product groupings ordered as to increasing aggregate score

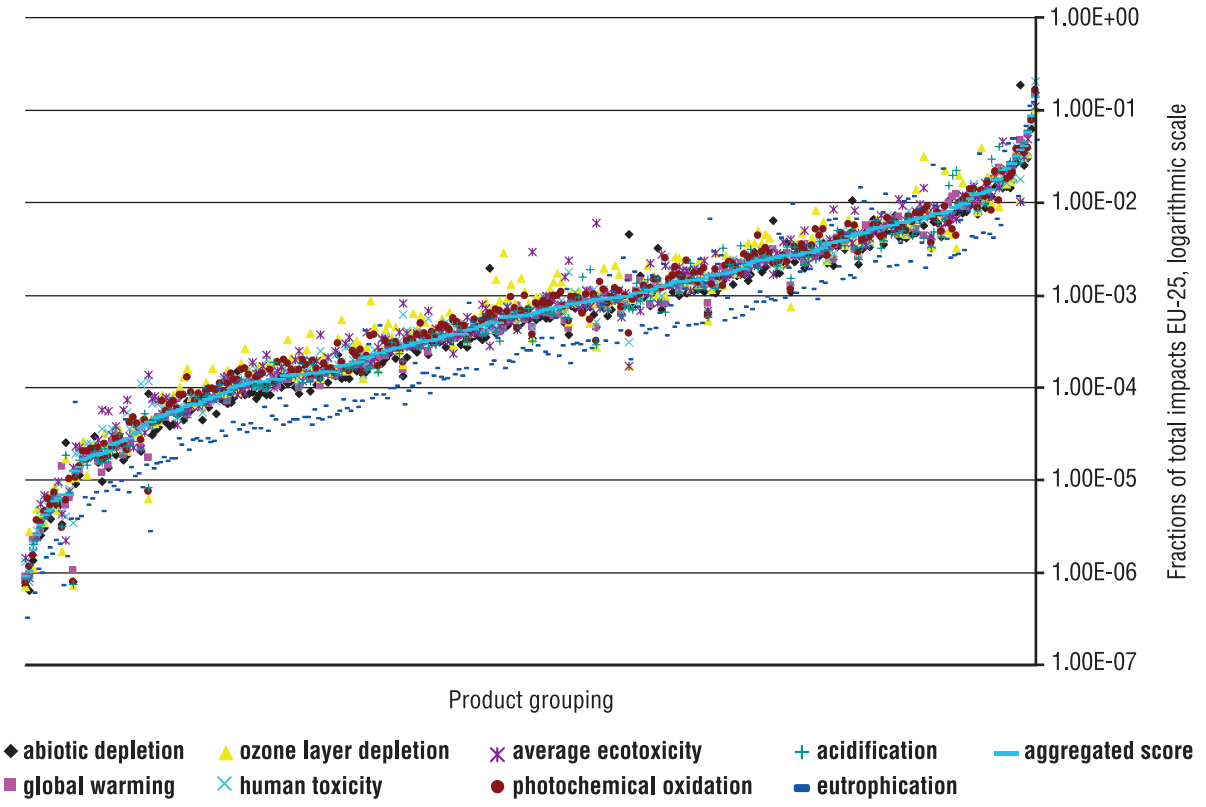


Figure 5.4.3: Scores per euro, for all product groupings over all impact categories, product groupings ordered as to increasing aggregate score

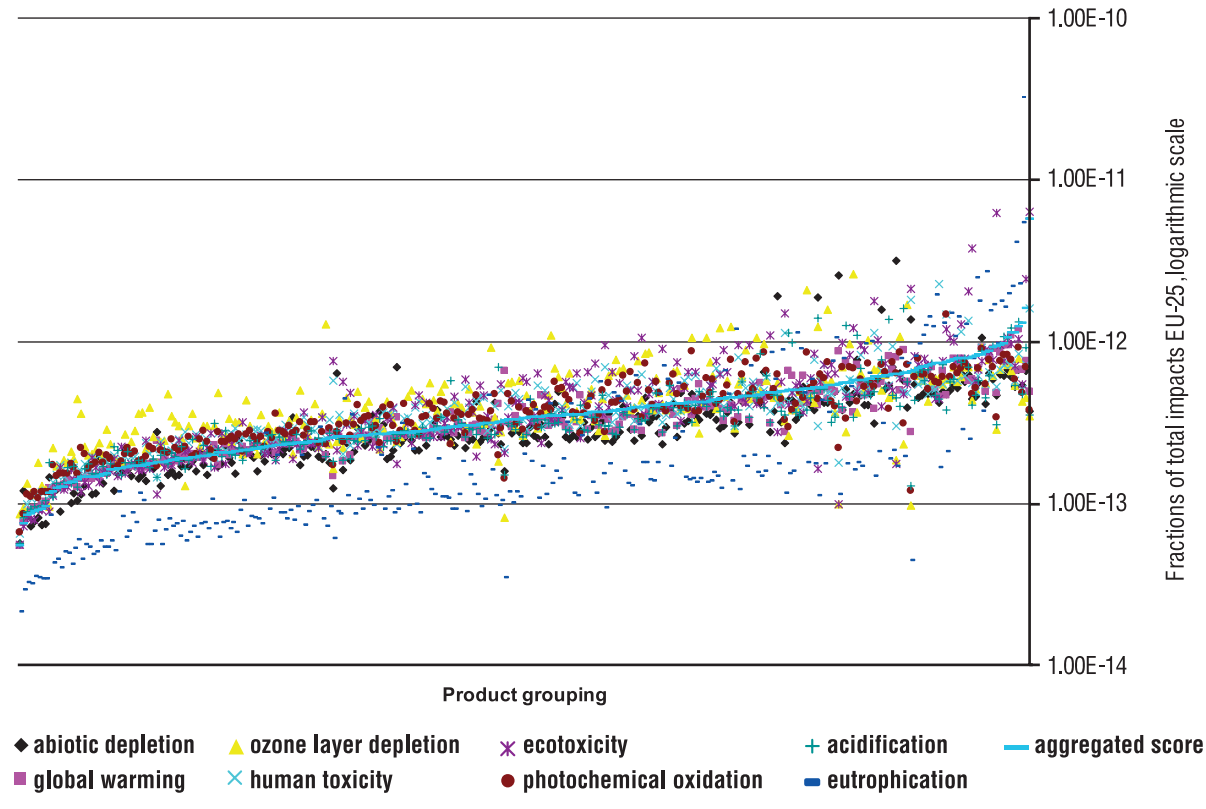


Table 5.4.3: Environmental impact per euro of product consumed

Sub-table 5.4.3a: Abiotic depletion	**Impact per euro**
Top 35	*Expressed as fraction of EU-25 total*
[A257] (Heating with) heating equipment, except electric and warm air furnaces	3.19E-12
[A25] (Use of) crude petroleum and natural gas	2.60E-12
[A194] Lubricating oils and greases	1.92E-12
[A195] Products of petroleum and coal, n.e.c.	1.90E-12
[A175] Nitrogenous and phosphatic fertilizers	1.59E-12
[A24] Coal	1.37E-12
[A475] Postal service	1.06E-12
[A331] (Use of) household cooking equipment	7.82E-13
[A354] (Driving with) motor vehicles and passenger car bodies	7.01E-13
[A403] Air transportation	6.99E-13
[A53] Sausages and other prepared meat products	6.76E-13
[A56] Natural, processed, and imitation cheese	6.74E-13
[A78] Sugar	6.64E-13
[A178] Adhesives and sealants	6.50E-13
[A72] Prepared feeds, n.e.c.	6.41E-13
[A239] Steel wiredrawing and steel nails and spikes	6.40E-13
[A182] Chemicals and chemical preparations, n.e.c.	6.38E-13
[A399] Local and suburban transit and interurban highway passenger transportation	6.36E-13
[A50] Small arms ammunition	6.30E-13
[A59] Fluid milk	6.27E-13
[A54] Poultry slaughtering and processing	6.17E-13
[A52] Meat packing plants	6.05E-13
[A4] Miscellaneous livestock	5.93E-13
[A337] (Use of) electric lamp bulbs and tubes	5.77E-13
[A58] Ice cream and frozen desserts	5.67E-13
[A71] Dog and cat food	5.56E-13
[A49] Small arms	5.55E-13
[A92] Roasted coffee	5.53E-13
[A332] (Use of) household refrigerators and freezers	5.42E-13
[A93] Edible fats and oils, n.e.c.	5.41E-13
[A68] Flour and other grain mill products	5.38E-13
[A70] Prepared flour mixes and doughs	5.34E-13
[A65] Prepared fresh or frozen fish and seafoods	5.30E-13
[A55] Creamery butter	5.24E-13
[A10] Fruits	5.22E-13
Bottom 10	
[A454] Professional sports clubs and promoters	1.04E-13
[A319] Office machines, n.e.c.	1.01E-13
[A316] Calculating and accounting machines	8.94E-14
[A458] Doctors and dentists	8.32E-14
[A469] Religious organizations	8.26E-14
[A419] Insurance carriers	7.86E-14
[A418] Security and commodity brokers	7.51E-14
[A417] Credit agencies other than banks	7.46E-14
[A416] Banking	7.31E-14
[A434] Personnel supply services	5.70E-14

Table 5.4.3: Environmental impact per euro of product consumed (cont.)

Sub-table 5.4.3b: Global warming	**Impact per euro**
Top 35	*Expressed as fraction of EU-25 total*
[A53] Sausages and other prepared meat products	1.21E-12
[A52] Meat packing plants	1.11E-12
[A56] Natural, processed, and imitation cheese	9.65E-13
[A54] Poultry slaughtering and processing	9.58E-13
[A475] Postal service	9.23E-13
[A4] Miscellaneous livestock	9.03E-13
[A337] (Use of) electric lamp bulbs and tubes	8.91E-13
[A25] (Use of) crude petroleum and natural gas	8.85E-13
[A59] Fluid milk	8.69E-13
[A72] Prepared feeds, n.e.c.	8.35E-13
[A332] (Use of) household refrigerators and freezers	8.19E-13
[A257] (Heating with) heating equipment, except electric and warm air furnaces	8.11E-13
[A239] Steel wiredrawing and steel nails and spikes	7.97E-13
[A93] Edible fats and oils, n.e.c.	7.90E-13
[A78] Sugar	7.57E-13
[A333] (Washing with) household laundry equipment	7.44E-13
[A331] (Use of) household cooking equipment	7.30E-13
[A55] Creamery butter	7.19E-13
[A58] Ice cream and frozen desserts	7.07E-13
[A2] Poultry and eggs	6.94E-13
[A71] Dog and cat food	6.87E-13
[A354] (Driving with) motor vehicles and passenger car bodies	6.81E-13
[A68] Flour and other grain mill products	6.71E-13
[A57] Dry, condensed, and evaporated dairy products	6.70E-13
[A340] (Use of) household audio and video equipment	6.64E-13
[A70] Prepared flour mixes and doughs	6.62E-13
[A30] Chemical and fertilizer minerals	6.62E-13
[A67] Frozen specialties, n.e.c.	6.52E-13
[A1] Dairy farm products	6.47E-13
[A208] Leather gloves and mittens	6.41E-13
[A92] Roasted coffee	6.35E-13
[A65] Prepared fresh or frozen fish and seafoods	6.23E-13
[A66] Frozen fruits, fruit juices, and vegetables	6.22E-13
[A334] (Use of) electric housewares and fans	6.18E-13
[A77] Frozen bakery products, except bread	5.95E-13
Bottom 10	
[A316] Calculating and accounting machines	1.25E-13
[A461] Other medical and health services	1.15E-13
[A418] Security and commodity brokers	1.03E-13
[A417] Credit agencies other than banks	9.75E-14
[A419] Insurance carriers	9.50E-14
[A469] Religious organizations	9.24E-14
[A416] Banking	9.17E-14
[A458] Doctors and dentists	8.69E-14
[A436] Detective and protective services	7.71E-14
[A434] Personnel supply services	5.53E-14

Table 5.4.3: Environmental impact per euro of product consumed (cont.)

Sub-table 5.4.3c: Ozone layer depletion	**Impact per euro**
Top 35	*Expressed as fraction of EU-25 total*
[A176] (Household use of) pesticides and agricultural chemicals, n.e.c.	2.64E-12
[A140] Household furniture, n.e.c.	2.09E-12
[A205] Boot and shoe cut stock and findings	1.71E-12
[A110] Nonwoven fabrics	1.58E-12
[A432] Miscellaneous repair shops	1.29E-12
[A201] Miscellaneous plastics products, n.e.c.	1.25E-12
[A195] Products of petroleum and coal, n.e.c.	1.25E-12
[A279] Fabricated metal products, n.e.c.	1.23E-12
[A431] Beauty and barber shops	1.10E-12
[A182] Chemicals and chemical preparations, n.e.c.	1.09E-12
[A350] Magnetic and optical recording media	1.07E-12
[A192] Paints and allied products	1.07E-12
[A156] Bags, except textile	1.06E-12
[A206] Shoes, except rubber	1.03E-12
[A109] Cordage and twine	9.73E-13
[A178] Adhesives and sealants	9.72E-13
[A187] Drugs	9.28E-13
[A475] Postal service	9.24E-13
[A155] Paper coating and glazing	8.97E-13
[A143] Metal household furniture	8.55E-13
[A188] Soap and other detergents	8.53E-13
[A53] Sausages and other prepared meat products	7.92E-13
[A72] Prepared feeds, n.e.c.	7.79E-13
[A393] Non-durable household goods (incl. 'brooms and brushes')	7.76E-13
[A199] Rubber and plastics footwear	7.65E-13
[A54] Poultry slaughtering and processing	7.58E-13
[A336] (Use of) household appliances, n.e.c.	7.44E-13
[A56] Natural, processed, and imitation cheese	7.22E-13
[A58] Ice cream and frozen desserts	7.05E-13
[A106] Carpets and rugs	7.03E-13
[A50] Small arms ammunition	6.99E-13
[A71] Dog and cat food	6.95E-13
[A93] Edible fats and oils, n.e.c.	6.94E-13
[A200] Fabricated rubber products, n.e.c.	6.84E-13
[A189] Polishes and sanitation goods	6.82E-13
Bottom 10	
[A221] Vitreous china table and kitchenware	1.29E-13
[A418] Security and commodity brokers	1.23E-13
[A416] Banking	1.16E-13
[A419] Insurance carriers	1.15E-13
[A25] (Use of) crude petroleum and natural gas	9.92E-14
[A24] Coal	9.75E-14
[A16] Greenhouse and nursery products	9.58E-14
[A436] Detective and protective services	9.50E-14
[A434] Personnel supply services	8.61E-14
[A30] Chemical and fertilizer minerals	8.16E-14

Table 5.4.3: Environmental impact per euro of product consumed (cont.)

Sub-table 5.4.3d: Human toxicity	Impact per euro
Top 35	*Expressed as fraction of EU-25 total*
[A236] Nonmetallic mineral products, n.e.c.	2.27E-12
[A24] Coal	1.83E-12
[A14] Miscellaneous crops	1.61E-12
[A177] Gum and wood chemicals	1.49E-12
[A50] Small arms ammunition	1.36E-12
[A239] Steel wiredrawing and steel nails and spikes	1.16E-12
[A380] Jewelry, precious metal	1.14E-12
[A250] Nonferrous wiredrawing and insulating	1.14E-12
[A354] (Driving with) motor vehicles and passenger car bodies	9.40E-13
[A49] Small arms	9.31E-13
[A475] Postal service	9.27E-13
[A53] Sausages and other prepared meat products	8.48E-13
[A243] Primary metal products, n.e.c.	8.34E-13
[A347] Storage batteries	7.99E-13
[A263] Prefabricated metal buildings and components	7.77E-13
[A56] Natural, processed, and imitation cheese	7.54E-13
[A267] Crowns and closures	7.30E-13
[A78] Sugar	7.26E-13
[A52] Meat packing plants	7.21E-13
[A54] Poultry slaughtering and processing	7.20E-13
[A382] Silverware and plated ware	6.98E-13
[A268] Metal stampings, n.e.c.	6.88E-13
[A59] Fluid milk	6.78E-13
[A175] Nitrogenous and phosphatic fertilizers	6.61E-13
[A92] Roasted coffee	6.54E-13
[A72] Prepared feeds, n.e.c.	6.51E-13
[A66] Frozen fruits, fruit juices, and vegetables	6.42E-13
[A279] Fabricated metal products, n.e.c.	6.40E-13
[A392] Fasteners, buttons, needles, and pins	6.33E-13
[A182] Chemicals and chemical preparations, n.e.c.	6.25E-13
[A4] Miscellaneous livestock	6.23E-13
[A58] Ice cream and frozen desserts	6.23E-13
[A71] Dog and cat food	6.16E-13
[A276] Steel springs, except wire	6.16E-13
[A93] Edible fats and oils, n.e.c.	6.11E-13
Bottom 10	
[A461] Other medical and health services	1.36E-13
[A418] Security and commodity brokers	1.20E-13
[A417] Credit agencies other than banks	1.18E-13
[A419] Insurance carriers	1.12E-13
[A16] Greenhouse and nursery products	1.12E-13
[A416] Banking	1.08E-13
[A469] Religious organizations	1.08E-13
[A458] Doctors and dentists	9.97E-14
[A436] Detective and protective services	8.58E-14
[A434] Personnel supply services	6.58E-14

Table 5.4.3: Environmental impact per euro of product consumed (cont.)

Sub-table 5.4.3e: Ecotoxicity	**Impact per euro**
Top 35	*Expressed as fraction of EU-25 total*
[A14] Miscellaneous crops	6.43E-12
[A11] Tree nuts	6.25E-12
[A80] Salted and roasted nuts and seeds	3.81E-12
[A78] Sugar	2.47E-12
[A24] Coal	2.14E-12
[A50] Small arms ammunition	2.07E-12
[A250] Nonferrous wiredrawing and insulating	1.81E-12
[A380] Jewelry, precious metal	1.50E-12
[A239] Steel wiredrawing and steel nails and spikes	1.28E-12
[A176] (Household use of) pesticides and agricultural chemicals, n.e.c.	1.21E-12
[A177] Gum and wood chemicals	1.20E-12
[A117] Housefurnishings, n.e.c.	1.11E-12
[A392] Fasteners, buttons, needles, and pins	1.06E-12
[A56] Natural, processed, and imitation cheese	1.06E-12
[A79] Chocolate and cocoa products	1.06E-12
[A53] Sausages and other prepared meat products	1.05E-12
[A49] Small arms	1.03E-12
[A93] Edible fats and oils, n.e.c.	1.02E-12
[A106] Carpets and rugs	9.93E-13
[A52] Meat packing plants	9.77E-13
[A382] Silverware and plated ware	9.58E-13
[A113] Hosiery, n.e.c.	9.55E-13
[A243] Primary metal products, n.e.c.	9.51E-13
[A59] Fluid milk	9.50E-13
[A347] Storage batteries	9.50E-13
[A116] Curtains and draperies	9.07E-13
[A81] Candy and other confectionery products	8.95E-13
[A97] Food preparations, n.e.c.	8.92E-13
[A112] Women's hosiery, except socks	8.88E-13
[A72] Prepared feeds, n.e.c.	8.72E-13
[A263] Prefabricated metal buildings and components	8.51E-13
[A109] Cordage and twine	8.38E-13
[A92] Roasted coffee	8.19E-13
[A115] Apparel made from purchased materials	8.12E-13
[A77] Frozen bakery products, except bread	7.96E-13
Bottom 10	
[A25] (Use of) crude petroleum and natural gas	9.96E-14
[A418] Security and commodity brokers	9.71E-14
[A469] Religious organizations	9.25E-14
[A417] Credit agencies other than banks	9.19E-14
[A16] Greenhouse and nursery products	9.00E-14
[A458] Doctors and dentists	8.16E-14
[A416] Banking	8.11E-14
[A419] Insurance carriers	8.00E-14
[A436] Detective and protective services	7.23E-14
[A434] Personnel supply services	5.62E-14

Table 5.4.3: Environmental impact per euro of product consumed (cont.)

Sub-table 5.4.3f: Photochemical oxidation	**Impact per euro**
Top 35	*Expressed as fraction of EU-25 total*
[A177] Gum and wood chemicals	1.47E-12
[A53] Sausages and other prepared meat products	9.23E-13
[A475] Postal service	9.08E-13
[A192] Paints and allied products	8.77E-13
[A140] Household furniture, n.e.c.	8.61E-13
[A178] Adhesives and sealants	8.59E-13
[A182] Chemicals and chemical preparations, n.e.c.	8.56E-13
[A54] Poultry slaughtering and processing	8.33E-13
[A56] Natural, processed, and imitation cheese	8.29E-13
[A208] Leather gloves and mittens	7.89E-13
[A156] Bags, except textile	7.84E-13
[A201] Miscellaneous plastics products, n.e.c.	7.82E-13
[A72] Prepared feeds, n.e.c.	7.78E-13
[A52] Meat packing plants	7.77E-13
[A59] Fluid milk	7.61E-13
[A354] (Driving with) motor vehicles and passenger car bodies	7.55E-13
[A155] Paper coating and glazing	7.55E-13
[A110] Nonwoven fabrics	7.53E-13
[A58] Ice cream and frozen desserts	7.44E-13
[A206] Shoes, except rubber	7.39E-13
[A188] Soap and other detergents	7.33E-13
[A175] Nitrogenous and phosphatic fertilizers	7.28E-13
[A205] Boot and shoe cut stock and findings	7.27E-13
[A93] Edible fats and oils, n.e.c.	7.05E-13
[A4] Miscellaneous livestock	7.05E-13
[A78] Sugar	7.05E-13
[A109] Cordage and twine	7.00E-13
[A106] Carpets and rugs	6.98E-13
[A50] Small arms ammunition	6.94E-13
[A239] Steel wiredrawing and steel nails and spikes	6.89E-13
[A71] Dog and cat food	6.85E-13
[A176] (Household use of) pesticides and agricultural chemicals, n.e.c.	6.82E-13
[A161] Paperboard containers and boxes	6.60E-13
[A352] Truck and bus bodies	6.54E-13
[A66] Frozen fruits, fruit juices, and vegetables	6.48E-13
Bottom 10	
[A24] Coal	1.21E-13
[A417] Credit agencies other than banks	1.19E-13
[A419] Insurance carriers	1.18E-13
[A16] Greenhouse and nursery products	1.18E-13
[A418] Security and commodity brokers	1.18E-13
[A458] Doctors and dentists	1.14E-13
[A416] Banking	1.11E-13
[A469] Religious organizations	1.08E-13
[A436] Detective and protective services	8.60E-14
[A434] Personnel supply services	6.70E-14

Table 5.4.3: Environmental impact per euro of product consumed (cont.)

Sub-table 5.4.3g: Acidification	**Impact per euro**
Top 35	*Expressed as fraction of EU-25 total*
[A337] (Use of) electric lamp bulbs and tubes	1.61E-12
[A195] Products of petroleum and coal, n.e.c.	1.41E-12
[A332] (Use of) household refrigerators and freezers	1.37E-12
[A53] Sausages and other prepared meat products	1.34E-12
[A333] (Washing with) household laundry equipment	1.26E-12
[A52] Meat packing plants	1.23E-12
[A340] (Use of) household audio and video equipment	1.14E-12
[A331] (Use of) household cooking equipment	1.11E-12
[A54] Poultry slaughtering and processing	1.09E-12
[A56] Natural, processed, and imitation cheese	1.07E-12
[A334] (Use of) electric housewares and fans	9.84E-13
[A59] Fluid milk	9.61E-13
[A4] Miscellaneous livestock	9.49E-13
[A78] Sugar	9.27E-13
[A475] Postal service	8.72E-13
[A335] (Use of) household vacuum cleaners	8.54E-13
[A55] Creamery butter	7.96E-13
[A58] Ice cream and frozen desserts	7.85E-13
[A175] Nitrogenous and phosphatic fertilizers	7.74E-13
[A239] Steel wiredrawing and steel nails and spikes	7.51E-13
[A2] Poultry and eggs	7.35E-13
[A57] Dry, condensed, and evaporated dairy products	7.27E-13
[A50] Small arms ammunition	7.03E-13
[A343] (Use of) communication equipment	7.00E-13
[A243] Primary metal products, n.e.c.	6.84E-13
[A67] Frozen specialties, n.e.c.	6.81E-13
[A1] Dairy farm products	6.74E-13
[A208] Leather gloves and mittens	6.55E-13
[A72] Prepared feeds, n.e.c.	6.15E-13
[A161] Paperboard containers and boxes	6.15E-13
[A49] Small arms	5.91E-13
[A93] Edible fats and oils, n.e.c.	5.86E-13
[A71] Dog and cat food	5.80E-13
[A342] (Use of) telephone and telegraph apparatus	5.80E-13
[A77] Frozen bakery products, except bread	5.76E-13
Bottom 10	
[A454] Professional sports clubs and promoters	1.27E-13
[A461] Other medical and health services	1.11E-13
[A418] Security and commodity brokers	1.05E-13
[A417] Credit agencies other than banks	9.78E-14
[A419] Insurance carriers	9.58E-14
[A416] Banking	9.35E-14
[A469] Religious organizations	9.24E-14
[A458] Doctors and dentists	8.93E-14
[A436] Detective and protective services	8.18E-14
[A434] Personnel supply services	5.68E-14

Table 5.4.3: Environmental impact per euro of product consumed (cont.)

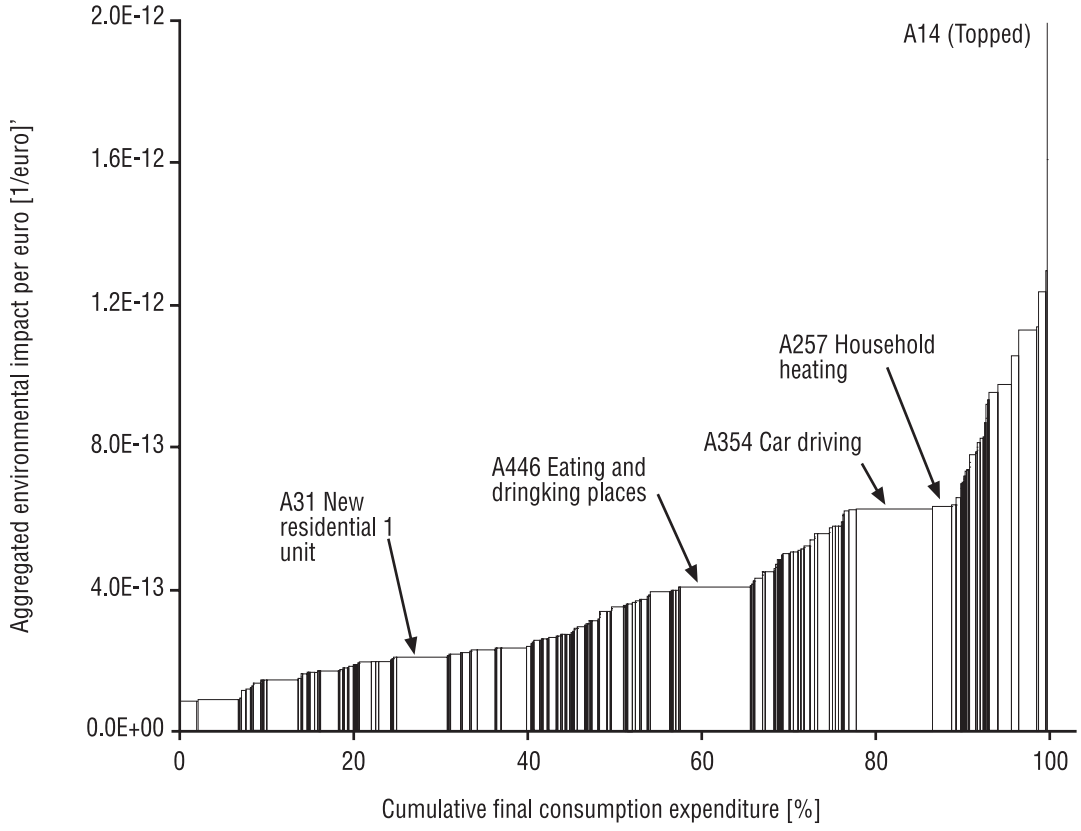
Sub-table 5.4.3h: Eutrophication	**Impact per euro**
Top 35	*Expressed as fraction of EU-25 total*
[A14] Miscellaneous crops	3.20E-11
[A78] Sugar	5.77E-12
[A68] Flour and other grain mill products	5.42E-12
[A70] Prepared flour mixes and doughs	4.11E-12
[A97] Food preparations, n.e.c.	2.73E-12
[A69] Cereal breakfast foods	2.50E-12
[A53] Sausages and other prepared meat products	2.30E-12
[A52] Meat packing plants	2.21E-12
[A56] Natural, processed, and imitation cheese	1.99E-12
[A95] Macaroni, spaghetti, vermicelli, and noodles	1.96E-12
[A71] Dog and cat food	1.80E-12
[A59] Fluid milk	1.79E-12
[A4] Miscellaneous livestock	1.69E-12
[A54] Poultry slaughtering and processing	1.63E-12
[A72] Prepared feeds, n.e.c.	1.55E-12
[A79] Chocolate and cocoa products	1.51E-12
[A1] Dairy farm products	1.43E-12
[A55] Creamery butter	1.42E-12
[A57] Dry, condensed, and evaporated dairy products	1.32E-12
[A58] Ice cream and frozen desserts	1.28E-12
[A77] Frozen bakery products, except bread	1.27E-12
[A2] Poultry and eggs	1.24E-12
[A75] Bread, cake, and related products	1.20E-12
[A76] Cookies and crackers	1.14E-12
[A67] Frozen specialties, n.e.c.	1.11E-12
[A93] Edible fats and oils, n.e.c.	1.09E-12
[A7] Feed grains	1.07E-12
[A63] Dehydrated fruits, vegetables, and soups	1.01E-12
[A81] Candy and other confectionery products	9.80E-13
[A208] Leather gloves and mittens	9.72E-13
[A11] Tree nuts	9.71E-13
[A96] Potato chips and similar snacks	9.08E-13
[A64] Pickles, sauces, and salad dressings	8.97E-13
[A117] House furnishings, n.e.c.	8.69E-13
[A92] Roasted coffee	8.16E-13
Bottom 10	
[A316] Calculating and accounting machines	4.02E-14
[A419] Insurance carriers	3.55E-14
[A469] Religious organizations	3.53E-14
[A30] Chemical and fertilizer minerals	3.48E-14
[A417] Credit agencies other than banks	3.46E-14
[A418] Security and commodity brokers	3.43E-14
[A458] Doctors and dentists	3.25E-14
[A416] Banking	3.22E-14
[A436] Detective and protective services	2.96E-14
[A434] Personnel supply services	2.15E-14

Also here it should be kept in mind that the tables present calculation results of a model that includes a number of assumptions and approximations, the implications of which are discussed in Section 5.5. The data also do not reflect possible improvements in the environmental performance of products in the most recent years and that further improvements may arise in the future. (For example, the air emissions of new cars per kilometre have been improving considerably.) The pure results should not be used in an isolated way to draw final conclusions about the impact of products. For conclusions about the impacts of products see Chapter 6, which makes a cross-cutting analysis between these results and those of other studies presented in Chapter 4 including the qualitative aspects of the models involved.

Figure 5.4.3 illustrates the different environmental impacts per euro of the full set of products in one graph, in analogy with the presentation in Figure 5.4.2. When comparing the figures it becomes apparent that results per euro show much less inequality than those combined for the full expenditure, as the inequality of expenditure per product grouping has a separate contribution to overall inequality. Per euro, the inequality in terms of lowest 10% to highest 10% is less than one order of magnitude for most product groupings.

Figure 5.4.4 shows how the per euro impacts and the expenditure on the products together make up the total impact of a product grouping. Figure 5.4.5 does the same but zooming in on the top 35 product groupings. In these figures, the expenditure is shown on the x-axis, ordered as to increasing environmental impact per euro, and the aggregated environmental score per euro on the y-axis. In this way, the area covered is a measure of the total environmental impact of the product groupings concerned. It is the visibly white areas that have bigger shares in the total; the more or less black areas are product groupings close together because their spending volume is small.

Figure 5.4.4: Environmental impact of final consumption, in ascending order of impact per euro: full set of product groupings

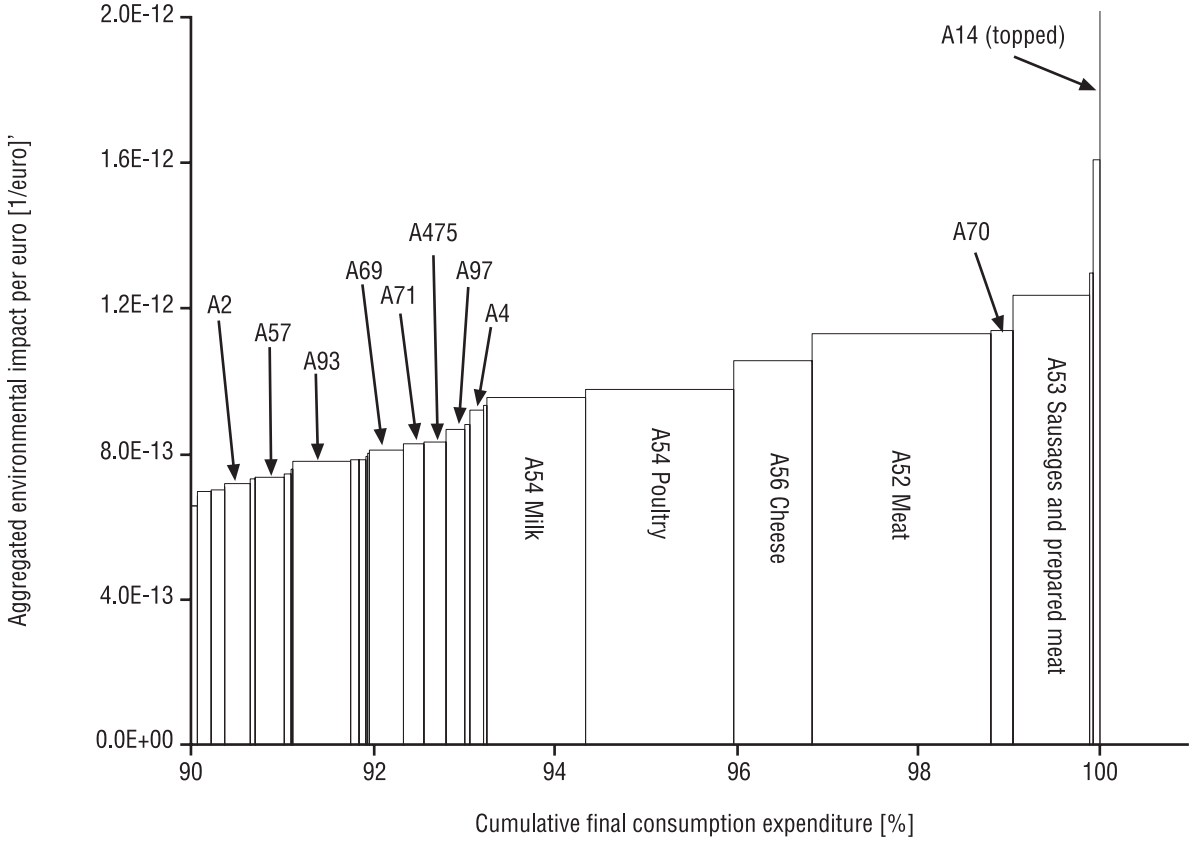


Figures 5.4.4 and 5.4.5 have been included for illustrative purposes, i.e. to show how the environmental impacts per Euro and the expenditures on a product grouping together explain the total environmental impacts. Merely for such theoretical demonstration, a weighted one-point score of the environmental impacts of the product groupings was calculated using the weighting factors developed in a stakeholder panel procedure in a project for the Dutch Government and the Dutch oil and gas production branch (see Annex 5.1.2). Since there is no general agreement on which weightings to apply, the one-point score has not been used in this report for drawing conclusions about which products have the greatest environmental impact. Therefore, all other analysis and interpretations in this report are based on the values for the individual, non-aggregated environmental impact categories.

5.4.4 Environmental effects of consumption: aggregation to COICOP level 1

To allow for comparison of the outcomes with the more aggregate studies on products surveyed in Chapter 4, the detailed outcomes per product given here can be grouped together and added into broader consumption areas by using the aggregate consumption areas as specified in the UN-based COICOP[33] classification of products. For this purpose, the BEA classification as used in CEDA EU-25 has first to be transformed into the relevant categories of COICOP level 3. Then further aggregation to level 2 and to level 1 in principle is a simple addition. However, in practice it is complicated by the fact that the functional aggregation used in this study does not fully link to the COICOP structure. One major example of non-matching groups relates to electricity use. In our model, electricity is distributed over all products

Figure 5.4.5: Environmental impact of final consumption, in ascending order of impact per euro: top 35 product groupings



33 Classification of Individual Consumption according to Purpose. See table 5.3.9.1.1 in the annex

using electricity, which is in CP05 *Furnishings, household equipment and routine maintenance of the house, and in* CP12 *Miscellaneous goods and services*. However, in COICOP electricity is included under CP04 *Housing, water, electricity, gas and other fuels*. In the practice of other studies, it seems that also these studies do not stick to the underlying COICOP definition, even if the COICOP categories are used. Note further that another distortion may be caused since we included public expenditure (some 25% of the total) in this study by simply scaling up private expenditure. The results of the aggregation are given in Table 5.4.4 and presented graphically in Figure 5.4.6. It should be kept in mind that data given here are cradle-to-grave data. For example, the environmental impacts of 'food', include among other things, all the corresponding impacts of agricultural production.

5.5 Interpretation of results

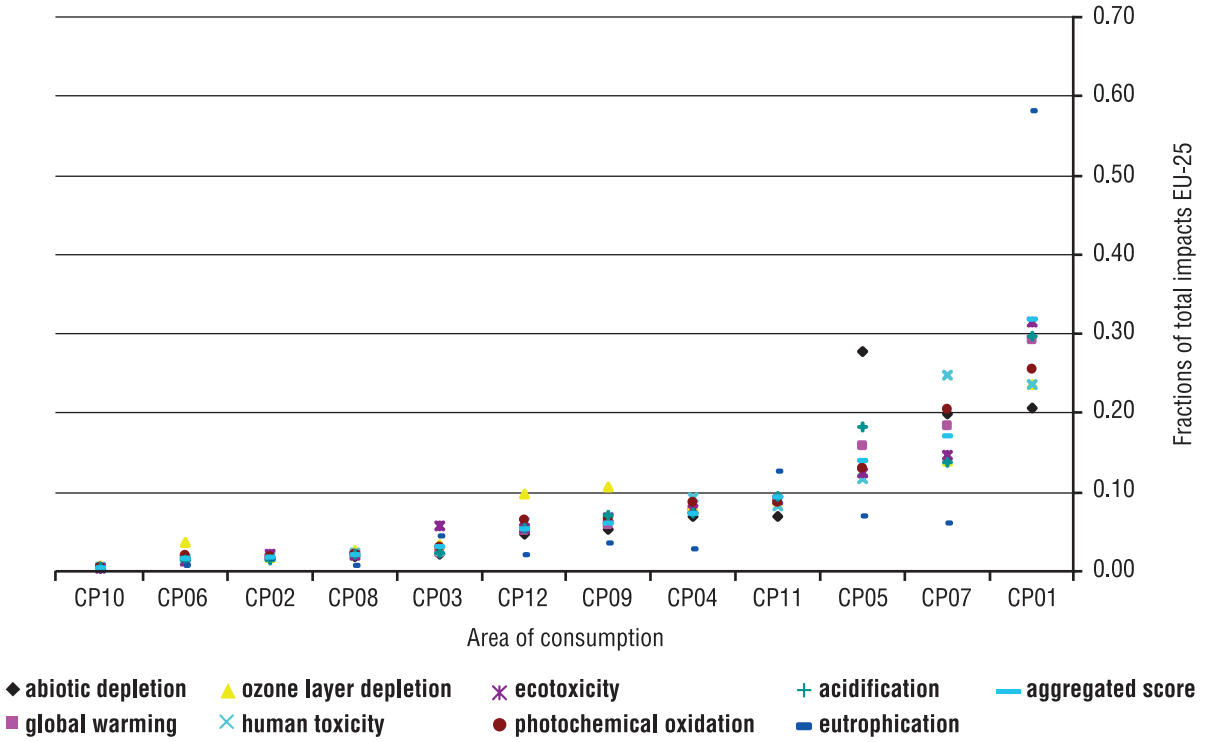
5.5.1 Introduction

The work of Funtowicz and Ravetz (1990) regarding the NUSAP method can serve as a guideline for the interpretation in the context of policy support. It has been expanded for the European Environment Agency, with a more direct link to environmental policy, together with Funtowicz *et al.* (1999) in a long tradition developed at the European Commission's Joint

Table 5.4.4: Scores per consumption area at COICOP level 1 for all impact categories, and total final expenditure in the EU-25

Area of consumption	Abiotic depletion	Global warming	Ozone layer depletion	Human toxicity	Ecotoxicity	Photo-chemical oxidation	Acidification	Eutrophica-tion	Private and public expenditure
	Environmental impacts expressed as fractions of the EU-25 totals								
CP01 Food and non-alcoholic beverages	0.206	0.293	0.236	0.236	0.316	0.255	0.297	0.581	0.166
CP02 Alcoholic beverages, tobacco and narcotics	0.016	0.017	0.018	0.019	0.022	0.019	0.015	0.016	0.027
CP03 Clothing and footwear	0.022	0.024	0.035	0.027	0.057	0.032	0.024	0.045	0.031
CP04 Housing, water, electricity, gas and other fuels	0.070	0.077	0.082	0.094	0.079	0.088	0.074	0.029	0.131
CP05 Furnishings, household equipment and routine maintenance of the house	0.278	0.159	0.124	0.117	0.125	0.131	0.183	0.070	0.120
CP06 Health	0.015	0.016	0.037	0.017	0.014	0.020	0.015	0.007	0.039
CP07 Transport	0.199	0.185	0.140	0.248	0.147	0.204	0.138	0.061	0.141
CP08 Communications	0.019	0.021	0.026	0.024	0.021	0.023	0.023	0.007	0.040
CP09 Recreation and culture	0.053	0.060	0.107	0.066	0.068	0.067	0.071	0.035	0.091
CP10 Education	0.004	0.005	0.007	0.006	0.005	0.006	0.006	0.002	0.014
CP11 Restaurants and hotels	0.070	0.091	0.090	0.084	0.090	0.088	0.096	0.126	0.096
CP12 Miscellaneous goods and services	0.047	0.052	0.098	0.063	0.055	0.065	0.055	0.021	0.103

Figure 5.4.6: Scores per consumption area (COICOP level 1) for all impact categories, areas ordered as to increasing aggregate score



Research Centre. This approach distinguishes between applied science with low uncertainties; professional consultancy, with middle level uncertainties; and post-normal science, characterised by highly uncertain relations, which can be captured only partially. Clearly, we are in the post-normal situation where not only the system's uncertainties are high but also the decision stakes. However, the result of this report is not intended for specific product policies but in helping gain a perspective on such policies in a generic way. For actual policies, substantial additional information will have to be acquired.

How can the quality of results be assessed in this context? In this situation, a baseline scientific uncertainty analysis is hardly applicable, nor is the baseline of uncertainty analysis in the NUSAP approach directly applicable, as the results covers only part of the policy preparation process. A practical approach is used as indicated in the P for Pedigree part of the NUSAP method, distinguishing between the input data being used; and the model transforming them into the output data, as results of the study. By thoroughly analysing the inputs and the model, by involving judgement of external specialists, the validity and reliability of results are assessed, ultimately as a validation for the purpose these results are intended for.

5.5.2 Reliability of input data: analysis and conclusions

Analysis

The US input-output table and EU countries final demand data form the core for the technology relations in the analysis in this project. These data are gathered and processed in a long and well established scientific and administrative tradition. Both the US and EU data come from an accounting framework which is internationally standardised by the UN and covered by thousands of publications yearly. However, the US data are updated regularly, while this is not generally the case for Europe. The most consistent data set available at the start of the study, by OECD, only covered part of EU-15 for 1990. So we had to use the structure

of the 1990 tables that were available to cover EU-25, and we adapted the volume to 1992. For fast growing sectors, there will be an underestimation, and for declining industries an overestimation of their volumes in the European economy. No quantification of these developments is possible at the moment, as this would imply availability of a revised set of tables. As the OECD tables are quite aggregate, the effect of shifts will probably not be very substantial. There is a clear need for improved economic data. In a similar vein, we had to work with restrictions on data available with regard to final demand in the EU-25. Due to the absence of detailed data, we had to estimate the final demand per expenditure category for government and the 10 new EU Member States by extrapolation of final (private) consumption expenditure in the EU-15.

EU and US data on environmental interventions have a much more diverse background with a less clear pedigree. Many US data have a background in the TRI, the Toxic Release Inventory, in which firms above a certain size have to report publicly on their emissions. The confidence in these data is not only based on the public nature of these data, but also on the legal system in the US, where non-reporting may lead to liability suits with proof reversal.

In Europe sources are more diverse. In the Netherlands, a similarly detailed inventory is made, but on the basis of confidential reporting, called the Emission Registry. Its encompassing nature allows for generalisations where studies on specific emissions have been available for other European countries. The availability of environmental intervention data for Europe is still quite limited. All available European data have been gathered in one consistent framework in a previous study, for the central government of the Netherlands, using methods of technology transfer to arrive at the EU-15 level (van Oers *et al.* 2001). In this study, these have been upgraded to the level of EU-25 on the basis of technology transfer assumptions. How confident can we be in the totals for Europe as given by van Oers? No similar encompassing study on Europe is available for comparison. Again it is not statistics, but a pedigree related analysis which indicates that indeed the data are reasonable.

Using the Europeanised technology framework of CEDA, with European final demand, we applied the US emission coefficients to compute total emissions in EU-25. These have been compared to the independently derived EU-25 totals of van Oers. The similarity in outcomes is quite reasonable, see Figure 5.4.1 in Annex 5.4. On average EU-25 emissions were around 10% lower than the US-based emissions. As the EU has a larger population and a somewhat lower income per head, this seems reasonable. This relation gives confidence in the emission data, and derived also in the similarity of the underlying processes. Disentangling the complex overlapping relations between emissions would be a very useful task.

The nomenclature is mainly organised around CAS[34] numbers, but due to different levels of aggregation of substances covered by CAS numbers there can be substantial overlap. For example, emissions of xylene may also be covered under ortho- para- or meta-xylene, each with its own CAS number. Emissions differed most with regard to pesticides, which may well be due to differences between US and Europe in actual practice, but may also be a consequence of the fact that a good detailed study of pesticide use was only available for England, referred to in the study by van Oers. Though not reliable at the level of individual emissions, the aggregation of the twelve hundred environmental interventions analysed into eight impact categories seems to lead to stable scores, at that aggregate level.

At the basic data gathering level, some mistakes are more probable than others. We found cases of confusion between nitrous oxide (N_2O) and nitrogen oxide (NO_x), so this substance is a good candidate for further checks in future work.

34 A number assigned by the Chemical Abstracts Service that uniquely identifies a chemical substance.

Conclusions on reliability of input data

It is not independent measurements and statistical analyses which give support to accepting the data used in this study as adequate, but pedigree aspects. Others have used part of the data in different contexts, with much statistical analysis on underlying partial data sets there. For the environmental data, the background is less well developed and fewer specification methods have been developed, except for energy related emissions. However, there confidence comes from the fact that independent US and EU emission data applied to the same technology system give the same ratios between totals per substance.

Alternative input data are not available at EU level. All data which can be found have been used in this study. Only new studies on data can improve on this situation. For the purpose of this study, and in the model as is being applied, the data seem adequate, on the condition that when drawing conclusions, specific obvious limitations are taken into account (e.g. lack of product-specific data on government expenditure).

5.5.3 Validity of the model: analysis and conclusion

Analysis

The analysis of emissions based on quantification of economic activities in monetary terms is quite different from the usage in LCA or in technology modelling in industry. In the latter case, the link to reality seems closer. That indeed is true, but directly at the disadvantage of not being able to describe the technology of the economy as a whole. So, for gaining a perspective on the environmental effects of products from a total EU-25 perspective, there is no other choice than to opt for input-output modelling. To cover the use and disposal phase, as is required in the context of IPP, the input-output model has been expanded.

Because of the difficult data situation and the time limitations of the study, deviations from the ideal model were necessary in its practical implementation. Two types of technology transfer in modelling play a central role in assessing the model validity, the transfer from US to EU and from EU-15 to EU-25. Next, the unexpected flaws in classification systems are indicated. Finally, the validity of the environmental models used in quantifying environmental effects at the impact category level is discussed.

One main point in the quantified analysis is the question in how far the US detailed sector model differs from the European situation. As the detailed European model is lacking – that is the reason why we applied the US model – it is not possible to make a direct comparison. What might be done, as an academic exercise, is to compare the US and EU-25 structure at a more aggregate level, where European data are available. This surely would lead to a number of differences. However, such a comparison would not be relevant for this study, as, exactly at this level, the structure of the US table has been Europeanised, first using the RAS method and next adapting some main difference with Europe at a detailed level, for example concerning the structure of energy resource inputs and agricultural inputs.

Checking against the available country level input-output tables, also at a more aggregate level, can hardly lead to a better insight. If the structures were dissimilar, this could have been expected and is not an indication of lacking quality.

The use of the US economic input-output data as the basis of transformation was the only viable solution for this study, given the importance of using disaggregated input-output tables. Weidema *et al.* (2005) find in their analysis that the level of uncertainty due to the aggregation of heterogeneous product groups in an aggregate input-output table is very high as compared to the difference between the same technologies in two different geographical areas. This suggests that the use of the detailed and correct sector information from a similar country is preferable to using aggregated sector information from the right country. This conclusion is drawn by the fact that production facilities for the same product often shares the same unit processes even if they are located in different geographical locations, while

production processes of different products clearly are more heterogeneous. The level of detail available in tables for some European countries are around 100 sectors, and the flows between countries are not specified. Using these country input-output tables as a basis for the analysis clearly would have lowered the quality of the study decisively.

Nevertheless, there are a number of aspects in which the current CEDA EU-25 model is lacking still, and can be improved, see the list in Annex 5.4.2. The main validity problem resides in the lack of precision in the definition of the BEA/CEDA categories combined with the lacking correspondence to the COICOP classification on which the consumer expenditure data are based. Having a detailed European input-output table linked to well defined consumer expenditure data could improve the validity of the model substantially, and allow for a more precise specification of reliability.

Doubts have been raised about the upscaling of EU-15 to EU-25. In the past, the economic structure and environmental performance of the new Member States were very different from that in the EU-15. However, these new Member States are in a state of rapid transition. Using such data from the past for developing possible future policies would hardly improve the model. So the model applied in arriving at EU-25 data is that of 'future technology transfer', not often encountered in science, but probably the best option here. Apart from the expectation that the future structure of these countries will not be too different in economic and environmental terms – not so strange an assumption giving the high level of investment in modern technology going on – there is quantitative argument why this way of modelling does not diminish validity. That is the simple fact that the quantitative influence of the new countries in an economic sense is still very limited, in the order of 5%.

The relevance of the eight environmental indicators is beyond doubt. Questions may be posed if more and different environmental aspects should also be covered, or if the underlying models for transforming environmental interventions of activities into contributions to impact categories might be improved. As to additional aspects which may need to be covered, one might think of aspects like noise, odour, and radiation, which clearly are relevant. Models for such aspects are available, but not always convincing as with noise, but systematic data are lacking. So if only for practical reasons, other environmental aspects had to be left out of account. Other models for the eight impacts might have been used. In Guinée *et al.* (2002), other options have been surveyed, and a reasoned choice for the ones being used here has been made. Mostly, the available models as developed in Scandinavia and Switzerland give similar outcomes. Only methods which combine impact assessment with evaluation, like the Swedish Environmental Priority Strategies in Product Development (EPS) system[35], may systematically give different overall outcomes. The Externalities of Energy (ExternE) system[36] also deviates and is not stable in time.

Conclusions on the validity of the model

The detailed input-output model used seems the most adequate for the purpose. Its representativeness for Europe seems reasonably safeguarded. The extension of EU-15 to EU-25 is well justified. The validity pertains to the products at the level of detail as analysed, not to more specific product types and ultimately brands. The problem-oriented indicators used have the most direct policy relevance.

35 See e.g. http://eps.esa.chalmers.se/system_rules.htm
36 See e.g. http://externe.jrc.es and www.externe.info.

5.5.4 Quality of CEDA EU-25 results

First a number of pedigree aspects of model-data combinations are discussed. Next, by combining the conclusions on reliability of data and validity of the model, we arrive at an overall view on the quality of the CEDA EU-25 results.

Pedigree aspects

The broad acceptance of the BEA input-output model and data for purposes of non-environmental policy support and the use in a broader economic analysis of OECD models and data on Europe as used in this study, support acceptance of the economic part of the model. The life cycle approach as used here is very generally accepted, both in policy and specifically IPP, as well as in ISO norms on LCA and environmental reporting. The environmental indicators used are broadly covering the different aspects of environmental policy, so that they can be used as an input into the policy process.

Alternative models

Alternative models also covering all of the activities in the EU are both more aggregate and lack encompassing coverage of environmental aspects. Economic models developed for the European Commission, like E3ME, have a potential for deeper analysis, taking into account market mechanisms and possibly some technology developments. However, they do so at more aggregated level only, as the same lack of data for an input-output analysis and quantification of environmental aspects holds true for these as well. It might even be argued that improvements in economic models such as these might be established by using the output of CEDA EU-25.

Overall validation

The overall evaluation of quality can not only be placed in an absolute framework but also in a comparative one. When looking for other currently available models, there seems to be no other models covering European consumption with the detail of this study in distinguishing products and the details of environmental interventions and impacts as analysed here at this time. This is partly due to the limited development of this type of modelling. Though substantial improvements on this study are achievable in the short term already, it seems highly improbable that the general conclusions on the structure of environmental effects will change as such in that sense that results are robust. It is in the analysis of specific products that a more detailed model may lead to deviating outcomes. As the sum totals of environmental interventions are well in line with major studies and data as reported by Eurostat – these have formed the basis of the quantified analysis – it is more differentiation and depth that can be added, not so much improvement of results.

The major weakness in the results does not lie in the general model and the input data and partial models being used, but in the lack of clear correspondence between, on the one hand, consumption expenditure categories as described in COICOP and, on the other, the make-and-use product categories which lie at the heart of BEA/CEDA categories.

The reliance on US data for detailing resource use and emissions over larger numbers of sectors is a particular feature of the approach. The method of technology transfer which has been applied seems adequate for general European Union policy support. For specific environmental policies, a more detailed European analysis would be most welcome but is basically unavailable. From a comparative point of view, the mixed EU-25/US model seems the most valid approach for policy support.

The lack of well developed software for the purpose of this type of modelling and analysis hampers the quality of studies in terms of sensitivity analysis, contribution analysis, Monte Carlo analysis, etc. For further use of these data, a better insight into the background of the results seems sensible. Because of this, further data improvement may take place as well.

5.6 Conclusions – on the CEDA EU-25 Products and Environment model

Overall, the following general conclusions can be drawn with regard to the environmental impact of products:

- The input-output based analysis of products gives an overview, which can hardly be created in any other way.
- The level of detail in the EU-25 input-output table of 478 production sectors corresponds to more than 280 groupings of products purchased by private consumers. The remaining products are sold as intermediates to other sectors or to government.
- The level of detail of more than 280 product groupings seems a good starting point for a further detailed analysis.
- Without focusing on specific products, it is clear that efforts in high scoring product groupings may have substantially higher potential for environmental impact improvement than those of lower scoring product groupings.
- Disregarding extremes, for total scores, the tenth and the ninetieth percentile differ roughly by a factor of fifteen, see Figure 5.4.2.
- Scores per product grouping on the eight impact categories, in terms of its share in total EU-25 scores per impact category, typically differ by a factor five between the highest and the lowest scoring impact category, see Figure 5.4.2.
- In the highest scoring product groupings, there is an increasing difference in relative score per impact category.
- The fallacy of disaggregation, which leads to seemingly lower importance for products split up into two or more sub-groupings, cannot be avoided at the level of totals. Using scores per euro does not have this disadvantage but loses sight of the volumes of activities involved.
- The scores per euro show a substantially smaller difference between product groupings, as indicated by the ratio between the tenth and ninetieth percentile, which is roughly a factor four, see Figure 5.4.3.
- Shifts in expenditure between high and low scoring product groupings per euro, are environmentally interesting.
- To a lesser extent, as with total scores, the high ranking products differ substantially in their scores per euro on specific impact categories. This implies that priorities on specific environmental themes (impact categories) may lead to different priorities in product policy.
- The combined economic and environmental analysis, as in Figure 5.4.4, seems a most adequate means for conveying the relative importance of a product grouping based on its environmental impact per euro times the volume of expenditure on the products.
- Some services belong to the highest scoring 35 product groupings; there is no general rule that services are environmentally superior to goods.

The following conclusions can be drawn with regard to the model and data used and developed:

- The model is adequate for the purpose, but as yet lacking in the detail required for specific policies, especially regarding disposal activities. Overall results would not change very much though due to the limited contribution of disposal services to the total scores.
- The need to rely on US data which have to be transformed into Europeanised data makes the analysis complicated and detracts from validity and reliability.
- Even without building up a full data set from basic statistical sources, the use of available data can be further developed as well as the modelling and estimation procedures.

Suggestions for such improvements are given in Annex 5.4.2.

- For the analysis of the environmental effects of products, high resolution input-output tables are needed.
- Other indicators can be added in comparison to the eight impact categories we took into account, most notably primary material inputs (allowing for calculating parameters such as Domestic Material Requirement), and land use (which can be seen as a proxy for biodiversity losses). Including land use requires solving the discussion about the very different methodologies proposed (see Section 4.4.7).
- Adding other regions of the world to the input-output model would enhance its applicability, as in a footprint analysis, in one consistent framework. This also would make more reliable estimates of impacts related to imports possible, particularly issues such as primary material use and land use which probably differ significantly between processes in the EU-25 and particularly in developing countries.
- The CEDA EU-25 model as developed can be used as a base model for further improved modelling, as required in detailing IPP and in implementing IPP based activities, as by firms and consumers.
- Dedicated software for an input-output analysis and a hybrid analysis of products would ease the task of quality assessment and reduce the time required for the analysis.
- A hybrid approach, combining monetary flows and physical flows could improve the modelling of waste management, and would be essential in detailing the analysis of specific products as for analysing improvement potentials.
- A hybrid approach is the key to cost-effective and reliable data generation, not only for government organisations, but also for firms, especially SMEs, e.g. when supporting product design activities.

The following remarks can be made regarding the availability of primary European data:

- The lack of broad and detailed data on environmental impacts of economic activities in the European Union seems a serious hindrance to effective prioritisation and development of environmental policies.
- On a comparative basis, the EU lags substantially behind the US and Japan in the availability of detailed economic input-output data.
- The categories in which consumption data are specified and input-output tables are constructed should link systematically at the most detailed level considered, to avoid the now usual lack of systematic correspondence between them in all applied studies.
- It would be desirable that government expenditure data be recorded in a structure compatible with and of equal detail as private consumption expenditure data.
- The data registry on environmental interventions might best be systematised primarily on the basis of CAS numbers, reckoning with the problem of aggregation levels which can be used when describing substances.
- IPP and resource policy to a large extent require the same data format and the same data, both in preparation and implementation.
- Improvements on the basis of more systematically combining currently available data are possible in the short to medium term; fundamental improvements require a revision of data gathering methods at the country and EU levels.

6. Final comparison and concluding discussion on EIPRO

6.1 Introduction

Based on the previous two chapters (Chapters 4 and 5), it is possible to draw conclusions on the products that have the greatest environmental impact. These chapters have compared the results of seven individual studies (Chapter 4) and produced a detailed analysis on the basis of the CEDA EU-25 Products and Environment model (Chapter 5). All together there are eight sources characterising the environmental impacts of products. Each of these sources has used, to a certain extent, a different methodology and approach, particularly with regard to:

- The choice of the functional unit and system boundaries. In general, the studies analysed the total life cycle impacts with regard to the total amount of goods and services consumed in a specific region. However, there are differences with regard to:
  - The region covered. Several studies cover just a single EU Member State (e.g. Nemry *et al.* (2002): Belgium; Nijdam and Wilting (2003): the Netherlands; Moll et al., 2004: Germany; Weidema *et al.* (2005) and Dall *et al.* (2002): Denmark). The others cover a few cities in different EU Member States (Kok et al, 2003) and the EU-15 (Labouze et al, 2003), whereas the CEDA EU-25 Products and Environment model in Chapter 5 covers the EU-25.
  - Final consumption activities included. Most studies focus on final *consumer (private household)* expenditure only, whereas others also attempt to include final governmental expenditure to fully cover the final demand in a country or region.
  - System boundaries. Not all studies (particularly the bottom-up studies) cover investment in underlying infrastructure needed for producing goods and services consumed.
- Disaggregating final demand. When differentiating final demand for smaller groupings of products and services, most studies use their own lists, which are not always directly comparable. For instance, the study of Moll *et al.* (2004) does not combine the purchase of petrol or electricity with e.g. cars or refrigerators to functional expenditure categories such as 'car driving' or 'food cooling'.
- The inventory of environmental interventions (emissions and use of natural resources). The following major differences exist:
  - First, the studies reviewed and performed use two fundamentally different approaches for data inventories. The so-called 'bottom-up' studies look for products that can be seen as representative for a consumption category and use LCA data for that product to estimate the total environmental interventions related to the consumption of the related product grouping. The so-called 'top-down' studies begin with 'input-output' tables produced by statistical agencies. These tables, in the form of matrices, describe the purchases of each industrial sector's products by all other sectors. Available input-output tables have different degrees of aggregation (between some 30 and 500 sectors or products). Some also contain data about the emissions and resource use of each sector. This information can then be used to calculate the environmental impacts of products covering the full production chains.

- Second, since the studies cover different geographical areas and use different approaches, the sources for producing the data inventories on emissions and resource uses are rather diverse.

- Impact assessment. For a number of impact categories the impact assessment has become quite standardised in LCA, and for them there are no major differences between studies (e.g. for global warming, photochemical oxidation, acidification, eutrophication, ozone depletion). However, for other categories standardisation is less well developed due to scientific and other complexities. Such categories were either not covered by these studies, or quite diverging impact assessment methods were used (e.g. for depletion or resources and land use).

All this implies that a very broad spectrum of approaches, assumptions, and data sources is covered by the reviewed studies and our own analysis. There is a broad range in variations in consumer expenditure, ways of grouping products, production technologies and related emission/resource use data, impact assessment methods, etc., related to a specific product grouping. This allows for conclusions that are more reliable than those that are based on only one study. Results that are confirmed by most of the different studies can therefore be considered as very robust. This is fully possible up to the level of disaggregation reached in most studies, i.e. up to some 30 product groupings. Nijdam and Wilting (2003) distinguished some 70 product groupings, Weidema *et al.* (2005) distinguished some 100 product groupings and the CEDA EU-25 work (with 280 product groupings) even went deeper; again one may assume that if all these three studies more or less give the same results at these more detailed level they will be robust. Since CEDA EU-25 is so much more detailed than the rest, only at the most detailed level of CEDA EU-25 is there no possibility of comparison and validation with other work, so that conclusions have to be drawn more cautiously here.

This chapter will now present the overall results of the EIPRO study. We will do so in the following order:

- Section 6.2: Despite the variations in methodologies and approaches applied, certain environmental impacts are likely not to be covered well in the studies that we reviewed or performed ourselves. This implies that specific products may be of relevance for IPP, whereas this does not show clearly from our work.
- Section 6.3: Both Chapter 4 as Chapter 5 drew conclusions at a high level of aggregation of products, i.e. functional areas of consumption such as 'housing', 'clothing' and 'feeding'. Such functional areas with the highest environmental impact are discussed in this section.
- Section 6.4: Several studies reviewed in Chapter 4 and the CEDA work in Chapter 5 also allows the drawing of conclusions at lower levels of aggregation. This point is discussed in this section.
- Section 6.5: Ends with overall conclusions.

6.2 Completeness in results

As argued in Section 6.1, it is unlikely that a product grouping showing up as being important in most or all studies reviewed will be a 'false positive', i.e. just targeted as a result of flaws in data and methods. On the other hand, one has to consider the possibility of 'false negatives', the opposite to false positives. These are product groupings that would in fact be relevant, but do not show up as such in the studies reviewed and the work done here. This can happen if there are methodological weaknesses that apply to a number or even the majority of the studies, which make impacts of certain products largely 'invisible'. Basically, there can be two fundamental reasons for such (unintended) invisibility:

1. The product as such is not 'visible'. This can be the case if, when classifying the products,

the product is not defined as an item on its own. In many of the studies reviewed, and the CEDA EU-25 work, this is among others the case for the following product categories:

- *Packaging*. Often this material is grouped together with the product for which the packaging is used. Despite having been a policy priority for a long time, packaging does not show up in many of the reviewed studies for this reason.
- *Products mainly used from business to business (B2B)*. Almost all studies reviewed focused on final consumer (and sometimes government) expenditure[37]. The impacts related to goods and services only exchanged between business sectors are accounted for only indirectly, i.e. being part of the life cycle of the products finally consumed. However, much of the B2B expenditures concern products that may be as relevant for IPP as final consumer products, or even identical to them. Examples include copiers, paper, business air travel, passenger car transport, etc.

2. The emissions/resource use and/or subsequent impact assessment is 'invisible'. This can happen if the emission and resource use inventory is too incomplete, or the subsequent impact assessment method is not reliable. It is unlikely that this will happen with emissions and resources that form big mass flows in the system, and where the magnitude of the impact is largely related to these mass flows. Experience from LCAs shows that in this respect, categories such as global warming, acidification, eutrophication, and other energy related impacts tend to be reasonably robust (and often related). However, other impact categories can be rather problematic:

- *Human and ecotoxic impacts*. Small mass flows (with dioxins as an extreme example) can have high impacts, and many substances can play a role in these impact categories. So without a very complete emission inventory, some impacts may be missed. This problem is even aggravated by the fact that the impact assessment method generally applied in all studies reviewed is a generic one, which does not take into account direct, semi-direct and/or local exposure of man and environment to substances. Hence, all studies will structurally miss the topic of products containing chemicals that may pose risks when used by consumers. Studies will also have trouble in assessing the potential relevance of products containing heavy metals such as cadmium or lead; the issue of slow and local losses by leaching of metal from various places in the life cycle is usually not well covered.
- *Impacts related to the waste stage*. In many studies, including the CEDA EU-25 model, the modelling of the waste stage is rather simple. There is little differentiation between waste management categories, and potential benefits of recycling are not always made visible. Furthermore, particularly for products containing heavy metals or other persistent, toxic materials, the long-term effects related to slow releases from landfill are usually neglected. Hence, products currently targeted

37 The Weidema *et al*. (2005) study is the only one that tried to identify the processes with the largest environmental impact (i.e. the life cycle impact related to the use of all products from a specific process, hence including the B2B use). Yet, since this study was built up from a Danish production part and a production for import part, this study was also not able to give an integrated overview of impacts related to products used in both parts of the model.

mainly for their effects in the waste stage, such as packaging and electrical and electronic goods, stay invisible with respect to their environmental impacts in most studies.

- *Impacts related to activities that tend to be underreported in emission records.* For institutional reasons, emissions of some activities are not always covered in full in emission record systems. For instance, for international air and sea travel, the problem exists as to which country the emissions generated should be allocated: origin, destination, or transit. Currently, for instance for international air travel, the convention is to include only emissions of take-off and landing in national emission record systems. Emissions for the international stretch are not allocated at all. This implies that emissions of air travel tend to be underreported (compare, e.g. Collins et al., 2005; RCEP, 2002).
- *Impact categories which mainly have an effect at local level.* Generic impact assessment methods do not deal well with local impacts. Topics such as water use may be a problem in one region, but not in another. So in general from the generic studies reviewed and also from the new modelling, one cannot expect a sound assessment of life cycle impacts of products for such environmental themes.
- *Other 'difficult' impact categories.* The assessment of impacts on biodiversity and the use of biotic resources are still problematic in life cycle impact assessment, and hence such environmental themes are not commonly applied in studies as reviewed here. This may imply that, for instance, issues such as the impact of fish and fish products on fish resources or the use of tropical timber products on biodiversity and tropical wood resources is not well covered.

6.3 Conclusions at COICOP level 1 (12 functional areas)

A qualitative comparison across all studies and most of the environmental themes considered in these studies is given in Table 6.3.1. A quantitative comparison across five studies and the CEDA EU-25 model on the contributions of each COICOP category to global warming potential or energy use (which usually are strongly related indicators)[38] is given in Table 6.3.2. In the studies that were included systematically, 'food and beverage consumption', 'transport' and 'housing' are consistently the most important consumption categories – both across the different studies and the different impact categories.

First, we will look at the robustness of the conclusions that can be drawn at the level of functional areas of consumption, e.g. housing, personal care, clothing, etc. In statistical data on consumer expenditure in the EU, consumption activities are classified on the basis of the so-called COICOP[39] list developed by the UN. This list consists of several levels of detail, and the highest level (COICOP level 1) consists of 12 categories, which in most cases are equivalent to function-oriented areas of consumption. Both Chapters 4 and Chapter 5 produce results at this level; the comparison of these results is given in table 6.3.1. A short explanation of how this table is built-up follows:

38 The table could not include the study of Weidema *et al.* (2005). They only reported the top scoring products on each environmental theme, and hence no totals per COICOP category could be calculated. The work of Moll *et al.* (2004) was not included, since their study included a lot of intermediate products for exports, which makes it difficult to compare their results with those of studies that only include the final private (and government) expenditure in a country.

39 Classification of Individual Consumption by Purpose.

- For each COICOP category, the first 10 rows give (in percent) the contribution to the environmental impact per impact category according to the CEDA EU-25 exercise (Chapter 5). Apart from this, the expenditure (both in euro as in per cent of the total) per COICOP category is mentioned[40].
- The following rows do the same in principle, though in more qualitative terms. They show if there is agreement in the importance (+) or high importance (++) of the contribution of a COICOP category to an impact category according to the studies reviewed in Chapter 4[41].
- Since, in Chapter 4, conclusions were drawn for COICOP categories 1 and 2 as well as categories 4 and 5 combined, Table 6.3.1 also has combined these COICOP categories for the CEDA EU-25 results.
- Concerning the impact categories, global warming, photochemical oxidation, acidification and eutrophication are covered in both Chapter 4 and Chapter 5. From LCAs, it is well known that abiotic resource depletion is often dominated by fossil energy use. These five impact categories are shown in the first columns and allow for direct comparison of the results from Chapters 4 and 5 per COICOP category. In the next four columns, impact categories and information is mentioned that is only given in Chapter 4 or Chapter 5, and which hence cannot be compared across these chapters (i.e. human toxicity, ecotoxicity, the percentage expenditure and absolute expenditure in Chapter 5; and water use, land use, resource use and waste generation in Chapter 4.).

  It is striking how robust the results of the studies reviewed and the CEDA EU-25 exercise are at this COICOP level 1, in fact independently of the impact categories considered[42]. Per COICOP category the following can be noted:

- **CP01 and 02 Food and beverages.** The contribution of this area of consumption is in CEDA EU-25 results consistently some 20 – 30% of the total impacts per category (with the exception of eutrophication, which is almost 60%). This is in line with the overall picture from Chapter 4: food and beverage consumption are consistently among the top three, except in studies where this consumption area, for a variety of reasons, was not included comprehensively in the calculations, which was the case in the work of Nemry *et al.* (2002), Labouze *et al.* (2003) and Weidema *et al.* (2005). It has to be noted that, in the COICOP classification, the appliances and energy used for cooking are placed in separate categories, i.e. CP05 and CP04. Also, eating in restaurants and hotels is not included; the COICOP list places this in a separate category CP11. This largely explains some apparent quantitative differences between different analyses. For instance, 'feeding' in Nijdam and Wilting (2003) contributes to many impact categories in the 20 – 40% range, but this includes restaurants, domestic appliances, and energy use for storage and cooking. In the CEDA EU-25 work feeding (CP01 and CP02) dominates most impact categories, particularly if one would include expenditure in restaurants and the like (CP11). In that sense CEDA EU-25 is an exception, since in most other studies housing (CP04 and CP05) dominates. With many other studies ending up with some 30% of the total impacts on, e.g. global warming for feeding, CEDA EU-25 ends up close to 40% (including CP11).

40 We decided to compare individual impact categories only, and not to aggregate impact categories. Though various approaches have been proposed (abatement costs, panel methods), this tends to be quite controversial. For instance, the ISO 14040 standard on LCA does not allow weighting in comparative studies disclosed to public.

41 This part of the table has copied the essentials from Table 4.5.1.

42 As discussed in Chapter 5, the scores on human and ecotoxicological impacts for a variety of reasons may not be as reliable as the scores in other categories.

Table 6.3.1: Comparison of results from Chapters 4 and 5 per COICOP category (level 1)

COICOP Category	Abiotic depletion (ADP)	Global warming (GWP)	Photo-chemical oxidation (POCP)	Acidification (AC)	Eutrophication (EUT)	Human toxicy potential (HTP)	Ecotoxicity	Expenditure (%)	Expenditure (Euro)
CEDA EU-25 Results (chapter 5)									
=> CP01+CP02 Food and beverages, tobacco and narcotics	22.2%	31.1%	27.4%	31.2%	59.7%	25.5%	33.7%	19.3%	4.85E+11
CP03 Clothing and footwear	2.2%	2.4%	3.2%	2.4%	4.5%	2.7%	5.7%	3.1%	6.74E+10
=> CP04+CP05: Housing, furniture, equipment and utility use	34.8%	23.6%	21.9%	25.7%	9.9%	21.0%	20.4%	25.1%	6.31E+11
CP06 Health	1.5%	1.6%	2.0%	1.5%	0.7%	1.7%	1.4%	3.9%	9.78E+10
=> CP07 Transport	19.9%	18.5%	20.4%	13.8%	6.1%	24.8%	14.7%	14.1%	3.55E+11
CP08 Communications	1.9%	2.1%	2.3%	2.3%	0.7%	2.4%	2.1%	4.0%	1.02E+11
CP09 Recreation and culture	5.3%	6.0%	6.7%	7.1%	3.5%	6.6%	6.8%	9.1%	2.30E+11
CP10 Education	0.4%	0.5%	0.6%	0.6%	0.2%	0.6%	0.5%	1.4%	3.48E+10
CP11 Restaurants and hotels	7.0%	9.1%	8.8%	9.6%	12.6%	8.4%	9.0%	9.6%	2.42E+11
CP12 Miscellaneous goods and services	4.7%	5.2%	6.5%	5.5%	2.1%	6.3%	5.5%	10.3%	2.60E+11
Combined results from seven other studies (chapter 4)	**Energy use**	**GWP**	**POCP**	**AC**	**EUT**	**Water**	**Land use**	**Resource**	**Waste**
=> CP01+CP02 Food and beverages	++[4,5,6]	+(+)[3,5]	+[1,3,5]	++[1,3]	++[3]	++[3,5]	++/+[4,5]	++[3,5]	+(+)[1,4,5]
CP03 Clothing and footwear		+(-)[3]	+(-)[1,3]	+(-)[3]	+[3]	+(-)[3]		+[1,3]	+(-)[4]
=> CP04+CP05: Housing, furniture, equipment and utility use									
CP04.1-04.3 Construction – Residential dwellings	+(-)[2,5]	+[2,5]	+[1,5]			++[3,5]	++/+[2,5]	+(+)[1,2,5]	++[1,2]
CP04.4 Water supply, misc. services to dwellings					+(+)[2,3]				
CP04.5 Energy for heating / hot water	++[1,2,4,5,6]	++[1,2,3,5]	+(-)[2,3]				+(+)[1,4,5] (energy related)	+(+)[1,2,5]	
CP04.5 Energy for lighting	+(-) [1,2,4]						+(-)[4]		
CP05.1.1.Furniture				+(-)[1]			+(-)[4,5]		+(-)[4]

++ : agreement on high relevance
+ : agreement on relevance, but not with the highest contributors
+(-) : disagreement or relevance not clear from this analysis, results from EIPRO project should give clarity on this
Indication of the studies that agree on the importance of the product category: (1) Labouze et al.(2003), (2) Nemry et al. (2002), (3) Nijdam and Wilting (2003), (4) Dall et al. (2002), (5) Moll et al. (2004), (6) Kok et al. (2003)

Table 6.3.1: Comparison of results from Chapters 4 and 5 per COICOP category (level 1) (cont.)

	COICOP Category	Abiotic depletion (ADP)	Global warming (GWP)	Photo-chemical oxidation (POCP)	Acidification (AC)	Eutrophication (EUT)	Human toxicy potential (HTP)	Ecotoxicity	Expenditure (%)	Expenditure (Euro)
	CP05.3 Household appliances	+(-) [1,5]	+(-)[1]	+(-)[5]				+(-)[1,5]	+(+)[1,5]	
	- Food storage, preparation, dishwashing			+(-)[3]				+(-)[4] (non-energy)		
	- Maintenance clothes and textiles	+(-)[4]						+(-)[4] (energy, non-energy)		
	- Audio, TV, computer etc.							+(-)[4] (non-energy)		
	CP06 Health care									
=>	CP07 Transport (personal vehicles only)	++[1,2,4,5,6]	++[1,2,3,5]	++[1,2,3,5]				++[1,2,4,5]	++[1,2,3,5]	+(-)[2]
	CP08 Communications									
	CP09 Recreation and culture									
	CP10 Education									
	CP11 Restaurants and hotels			+(-)[3]	+(-)[3]	+(-)[3]	+(-)[3]		+(-)[3]	
	CP12 Miscellaneous goods and services									
	Not in COICOP: Office appliances (including paper use)	+(-)[5]						+(-)[2]		+(+)[1,2]
	Not in COICOP: Household packaging							+(-)[2] (synthetic) - [1,2] (depletion)	+(-)[1,2]	++[1,2]

++ : agreement on high relevance
+ : agreement on relevance, but not with the highest contributors
+(-) : disagreement or relevance not clear from this analysis, results from EIPRO project should give clarity on this
Indication of the studies that agree on the importance of the product category: (1) Labouze et al.(2003), (2) Nemry et al. (2002), (3) Nijdam and Wilting (2003), (4) Dall et al. (2002), (5) Moll et al. (2004), (6) Kok et al. (2003)

Table 6.3.2: Quantitative comparison of results from Chapters 4 and 5 per COICOP category (level 1) on global warming potential (GWP) / direct and indirect energy use

COICOP	Study	Dall et al.	Kok et al.	Labouze et al.	Nemry et al.	Nijdam and Wilting	CEDA EU-25
	Indicator	Energy	Energy	GWP	GWP	GWP	GWP
	Main approach	Bottom-up	Hybrid	Bottom-up	Bottom-up	input-output	input-output
CP01-02	Food	26.2%	13.0%	*Incomplete*	*3.6% - only food packaging, no food*	22.1%	31.0%
CP03	Clothing	1.3%	2.2%	*3.3%*	*1.3%*	6.5%	2.4%
CP04-05	Housing	40.8%	54.3%	*58.8%*	*53.5%*	33.4%	23.6%
CP06	Health		1.8%		*0.3%*	0.3%	1.6%
CP07	Transport	19.5%	18.3%	*29.6%*	*32.9%*	17.3%	18.5%
CP08	Communication			*0.0%*	*2.9%*	0.0%	2.1%
CP09	Recreation	7.2%	8.1%	*0.0%*		15.1%	6.0%
CP10	Education		1.8%			0.7%	0.5%
CP11	Restaurants					2.8%	9.1%
CP12	Miscellaneous	5.1%	0.4%	*1.3%*	*5.4%*	1.8%	5.2%
	TOTAL	100.0%	100.0%	*100.0%**	*100.0%**	100.0%	100.0%

** The Labouze and Nemry total is a 'different' 100% since they do not cover all expenditures, most notably food*

This may imply that CEDA EU-25 scores food on average one third higher than other studies.

- **CP03 Clothing and footwear.** According to both Chapter 4 and Chapter 5, this area of consumption is not as important as the aforementioned top three, but it comes soon after. As for CP01 and CP02, CP03 does not include appliances and energy use for clothes washing. The 2 – 6% contribution found in CEDA EU-25 for most impact categories is roughly in line with the contributions found in, e.g. Nijdam and Wilting (2003; 5 – 10% of total) particularly if one takes into account that Nijdam and Wilting includes washing, which in the CEDA EU-25 work counts for another 2% contribution on most impact categories. In comparison, the Weidema *et al.* (2005) total for clothes purchase and washing of around 2% seems to be a bit low. Interestingly enough, all these three sources estimate that the production and purchase of clothing is a relevant factor in comparison to clothes washing. Many LCAs done for clothes have suggested that the energy and water use for washing in the use phase are the dominant causes for environmental impacts related to clothes use. The reasons for this remains to be clarified.
- **CP04 and CP05 Housing.** The combined categories covering housing include expenditures on the house itself, heating, electricity, domestic appliances, furniture, etc. In virtually all studies, this area of consumption is the most important contributor to environmental impacts of final consumer expenditures (except, as discussed above, in the CEDA EU-25 work). In general, the studies reviewed in Chapter 4 indicate that housing is the most relevant, also in comparison with transport (particularly if energy use for all appliances in the house is included). For a more detailed discussion on the relevance of underlying sub-expenditures we refer to the next section.
- **CP06 Health.** This category does not show up as being of high relevance in Chapter 4. A factor to consider is that healthcare often combines private-public expenditure and hence not covered or covered in full in the underlying studies. This effect is also visible in the CEDA EU-25 work that indicates a 4% consumer expenditure on health. In general, developed countries tend to spend some

10% or more of their national income on their health system.

- **CP07 Transport.** In the CEDA EU-25 work, this category shows up as being among the top three, with food (CP01 and CP02) and housing (CP04 and CP05). Contributions to environmental impact categories are about 15 – 25% (except for eutrophication, which is dominated by food). This is well in line with the studies reviewed in Chapter 4. For instance, the Weidema *et al.* (2005) study reports a contribution to global warming potential of 14% for car driving alone, and the Nijdam and Wilting (2002) study ends up with a contribution of about 16% of car driving to global warming potential[43].
- **CP08 Communication.** This is not seen as very relevant both in Chapter 4 or Chapter 5. This category includes electrical and electronic equipment; we refer to Section 6.2 for an explanation that this study does not cover potentially relevant impacts well for such equipment, e.g. related to hazardous substances and the waste stage.
- **CP09 Recreation and culture.** According to the CEDA EU-25 work, this category may be, with clothing and footwear, among the most important of the 'rest' after the top three. It has to be noted that transport (for e.g. holidays) as far as *directly paid* by final consumers is not included – that is included under CP07 – except for transport that is part of package tours or similar expenditure. The studies reviewed in Chapter 4 usually do not indicate that recreation and culture is relevant, but most probably because hotel services and holiday transport are not part of such categories.
- **CP10 Education.** Neither Chapter 4 nor Chapter 5 see this as relevant. It has to be noted that education-related transport is not included in this category.
- **CP11 Restaurants and hotels.** Both Chapter 4 and Chapter 5 see this is as moderately relevant.
- **CP12 Other.** In Chapter 5 this is a residual category. Since many items that cannot be classified under CP01 – 11 end up here, this is a sizeable category. Any underlying relevant products will be discussed in Section 6.4.

Furthermore, as already indicated in Section 6.2, several studies reviewed in Chapter 4 point to intermediate products such as office equipment and packaging. In an analysis that rigorously takes integrated final consumer expenditure as a starting point they will not become visible; nevertheless such products may still be a relevant attention point.

Overall, the comparison of Chapter 4 and Chapter 5 gives a very robust result at the level of functional areas of consumption (COICOP level 1). It is confirmed that food, housing, and transport are consistently the most important categories and tend to be responsible together for 70 – 80% of the life cycle environmental impact (at 60 – 70% of the total expenditure). This conclusion is based on the whole life cycle of products including the full production chains[44]. Table 6.3.1 also shows:

- Food (CP01 and CP02), clothing (CP03), and to a lesser extent transport (CP07) have a relatively high impact per euro spent (contributions to impacts are 1.5 times higher than the contributions to expenditure)
- Housing (CP04 plus CP05), and restaurants and hotels (CP11) have an average impact per euro spent;
- The other areas, such as Health (CP06), Communication (CP08) and Education (CP11) have a relatively low impact per euro spent.

43 Note that this activity category is particularly prone to definition problems. Some studies show transport activities as a whole, others just car driving, and others do not show transport as a category in itself but allocate the transport to the final functional needs to which transport contributes. For instance, in Nijdam and Wilting (2003), car transport is divided between activity categories such as 'Work and education' and 'Leisure'.

44 For example, agricultural production is a main source of the environmental impacts attributed to food.

6.4 Conclusions below COICOP Level 1

6.4.1 Introduction

In Chapter 4, seven studies were reviewed and in Chapter 5 an additional new modelling of the environmental impacts of products was carried out. Most of this work just reaches a limited additional level of detail discussed in the former section.

However, there are three pieces of research that give a significantly more detailed insight in impacts of final consumption according to different product groupings: Nijdam and Wilting (2003) – with some 80 product groupings, Weidema *et al.* (2005) – with some 100 product groupings, and the CEDA EU-25 work presented in Chapter 5. Given this situation, a detailed comparison is made here between these three studies, with occasional references to the other studies reviewed, whenever they provide relevant information.

These three studies have four impact categories in common (i.e. impact categories which were reported, in a comparable way, in each study). They concern i) global warming potential, ii) acidification, iii) eutrophication, and iv) photochemical oxidation (photochemical ozone creation potential). It is well known that particularly global warming potential, acidification and photochemical ozone formation, and to a lesser extent eutrophication usually have a strong relationship since these impact categories are dominated by energy consuming processes. The main point with eutrophication is that (non-energy related) processes in agriculture (animals, fertiliser use) also have a high contribution to this impact category (leading here to the dominance of COICOP 1 'food').

Given the above, we feel that a full comparison on all four impact categories would lead to a very repetitive discussion. Hence we will discuss each COICOP category once, and indicate any specificity for individual impact categories when relevant. Since the COICOP categories related to Food (CP01+CP02), Housing (CP04+CP05) and Transport (CP07) dominate all impact categories, these will be discussed in more detail than others.

For the results of the calculations with the CEDA EU-25 model, we also assemble a list that includes the top-ranking products at the most detailed level across all the eight environmental impact categories covered.

6.4.2 Approach and overview

Tables 6.4.1 to 6.4.4 give a detailed overview of the areas of final consumption per COICOP category that contribute to the total scores on global warming, photochemical oxidation (ozone creation), acidification and eutrophication according to the studies of Nijdam and Wilting (2003), Weidema *et al.* (2005) and ourselves (Chapter 5). The tables were produced as follows:

- The CEDA EU-25 results (see Annex 5) were first sorted by COICOP category, and subsequently within each COICOP category on the relevant environmental theme score. In order to keep the table manageable, the lowest scoring product groupings were combined into one new category.
- To each product grouping in Nijdam and Wilting (2003) and Weidema *et al.* (2005), see Annex 4, a COICOP category was attached. This proved to be relatively straightforward; from the names of the product groupings used, it was usually quite clear to which COICOP category it should be allocated. After this, the same sorting procedure as for the CEDA EU-25 results was applied.
- Weidema *et al.* (2005) did not report results on all of their (circa) 100 product groupings, but just the top 15 or top 20 per impact category. So, where we can present for CEDA EU-25 and Nijdam and Wilting (2003) a full overview that totals up to 100% of the global warming potential score, for Weidema *et al.* (2005) the published data do only allow to give the full picture.

Table 6.4.1: Detailed comparison of three studies, % contribution to global warming potential

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
CP01-02	[A52] Meat packing plants	5.5%	Meat and meatware	4.2%	Meat purchase in DK, private consumption	1.7%
(Food etc.)	[A54] Poultry slaughtering and processing	3.9%	Milk, cheese, butter	3.9%	Fruit and vegetables in DK, except potatoes, private consump.	1.5%
	[A53] Sausages and other prepared meat products	2.5%	Cereals	3.8%		
	[A59] Fluid milk	2.4%	Potatoes, groceries, fruits	3.1%		
	[A56] Natural, processed, and imitation cheese	2.1%	Feeding - other	1.6%		
	[A93] Edible fats and oils, n.e.c.	1.3%	Jam, sweets	1.4%		
	[A86] Bottled and canned soft drinks	0.9%	Non-alcoholic beverages	1.1%		
	[A75] Bread, cake, and related products	0.9%	Fish and fish products	1.0%		
	[A66] Frozen fruits, fruit juices, and vegetables	0.7%	Coffee, tea, cacao	0.8%		
	[A98] Cigarettes	0.7%	Alcoholic beverages	0.7%		
	[A12] Vegetables	0.7%	Fat and oil	0.4%		
	[A92] Roasted coffee	0.7%				
	[A65] Prepared fresh or frozen fish and seafoods	0.6%				
	[A84] Wines, brandy, and brandy spirits	0.6%				
	[A57] Dry, condensed, and evaporated dairy products	0.6%				
	[A96] Potato chips and similar snacks	0.5%				
	[A10] Fruits	0.5%				
	[A81] Candy and other confectionery products	0.5%				
	[A69] Cereal breakfast foods	0.5%				
	[A2] Poultry and eggs	0.5%				
	30 Other categories, total:	4.4%				
	Subtotal	*31.1%*	*Subtotal*	*22.1%*		
CP03	[A115] Apparel made from purchased materials	1.6%	Clothes	4.2%	Clothing purchase and washing in DK, private consumption	2.1%
(Clothing etc.)	[A426] Laundry, cleaning, garment services, and shoe repair	0.3%	Shoes	1.2%		
	[A206] Shoes, except rubber	0.2%	Accessoires	0.9%		
	[A112] Women's hosiery, except socks	0.1%	Clothing - other	0.2%		
	[A199] Rubber and plastics footwear	0.1%				
	[A113] Hosiery, n.e.c.	0.1%				
	9 Other categories: total	0.1%				
	Subtotal	*2.4%*	*Subtotal*	*6.5%*		

Table 6.4.1: Detailed comparison of three studies, % contribution to global warming potential (continued)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
CP04-05	[A257] (Heating with) heating equipment, except electric and warm air furnaces	4.7%	Heating	9.2%	Dwellings and heating in DK, private consumption	7.7%
(Housing etc.)	[A31] New residential 1 unit structures, nonfarm	3.2%	Feeding - direct energy (gas, electricity)	3.5%	Personal hygiene in DK, private consumption	1.9%
	[A333] (Washing with) household laundry equipment	2.4%	Rent and mortgage	3.2%	Retirement homes, daycare, etc. in DK, public consumption	0.8%
	[A33] New additions & alterations, nonfarm, construction	1.8%	Energy, hot water	3.1%		
	[A332] (Use of) household refrigerators and freezers	1.8%	Electricity	2.4%		
	[A337] (Use of) electric lamp bulbs and tubes	1.2%	Furniture	1.9%		
	[A331] (Use of) household cooking equipment	1.0%	Kitchen appliances etc.	1.5%		
	[A42] Maintenance and repair of farm and nonfarm residential structures	0.7%	Shelter - other	1.4%		
	[A413] Water supply and sewerage systems	0.7%	Washing, drying, ironing	1.0%		
	[A34] New residential garden and high-rise apartments construction	0.7%	Taxes	0.8%		
	[A393] Non-durable household goods	0.5%	Flowers and plants (in house)	0.8%		
	[A106] Carpets and rugs	0.3%	Maintenance	0.5%		
	[A139] Wood household furniture, except upholstered	0.3%	Mattresses, linen	0.5%		
	[A149] Partitions and fixtures, except wood	0.3%	Personal care - water	0.5%		
	[A201] Miscellaneous plastics products, n.e.c.	0.3%	Living - other	0.5%		
	[A437] Miscellaneous equipment rental and leasing	0.2%	'Soft' flooring	0.4%		
	[A117] Housefurnishings, n.e.c.	0.2%	Lighting	0.3%		
	[A439] Other business services	0.2%	Decoration	0.3%		
	[A335] (Use of) household vacuum cleaners	0.2%	Painting	0.3%		
	[A142] Upholstered household furniture	0.2%	Curtains etc.	0.3%		
	[A334] (Use of) electric housewares and fans	0.2%	Electrical appliances	0.3%		
	[A17] Forestry products	0.2%	Cleaning attributions	0.2%		
	[A25] Crude petroleum and natural gas	0.2%	Resilient flooring	0.2%		
	[A429] Electrical repair shops	0.1%	Sun protection and wire-mesh windows	0.2%		
	[A144] Mattresses and bedsprings	0.1%	Services	0.1%		
	[A430] Watch, clock, jewelry, and furniture repair	0.1%	Washing, drying, ironing	0.0%		
	[A123] Fabricated textile products, n.e.c.	0.1%				
	[A148] Wood partitions and fixtures	0.1%				
	[A121] Automotive and apparel trimmings	0.1%				
	63 Other categories, total:	1.4%				
	Subtotal	*23.6%*	*Subtotal*	*33.4%*		

Table 6.4.1: Detailed comparison of three studies, % contribution to global warming potential (continued)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
CP06	[A187] Drugs	0.7%	Self medication	0.3%	Hospital services in DK, public consumption	0.8%
(Healthcare)	[A458] Doctors and dentists	0.4%				
	[A459] Hospitals	0.2%				
	[A461] Other medical and health services	0.1%				
	[A378] Ophthalmic goods	0.1%				
	Subtotal	*1.6%*	*Subtotal*	*0.3%*		
CP07	[A354] (Driving with) motor vehicles and passenger car bodies	15.0%	Mobility for leisure	8.1%	Car purchase and driving in DK, private consumption	6.0%
(Transport)	[A448] Automotive repair shops and services	1.2%	Commuting, private transport	8.0%	Transport services in DK, private consumption	1.5%
	[A447] Automotive rental and leasing, without drivers	0.6%	Commuting, public transport	0.4%	Car driving as fringe benefit and car related services	1.5%
	[A399] Local and suburban transit and interurban highway passenger transportation	0.4%	Mobility for 'living'	0.4%		
	[A403] Air transportation	0.3%	Transport (clothing 1)	0.2%		
	[A398] Railroads and related services	0.3%	Transport (clothing 2)	0.2%		
	13 Other categories totalling	0.7%				
	Subtotal	*18.5%*	*Subtotal*	*17.3%*		
CP08	[A407] Telephone, telegraph communications, and communications services n.e.c.	1.3%				
(Communication)	[A475] Postal Service	0.6%				
	[A343] (Use of) communication equipment	0.1%				
	[A342] (Use of) telephone and telegraph apparatus	0.1%				
	Subtotal	*2.1%*				
CP09	[A340] (Use of) household audio and video equipment	1.2%	Holidays	4.8%	Tourist expenditure by Danes travelling abroad, private cons.	3.7%
(Recreation etc.)	[A457] Other amusement and recreation services	0.9%	TV, radio ('brown goods'/electronics)	1.9%	Television, computer, etc. in DK, incl. use, private cons.	1.5%
	[A176] (Household use of) pesticides and agricultural chemicals, n.e.c.	0.4%	Garden, excluding furniture	1.2%		
	[A71] Dog and cat food	0.4%	Electricity	1.3%		
	[A428] Portrait photographic studios, and other miscellaneous personal services	0.3%	Newspapers, periodicals, books	1.2%		
	[A317] (Use of) electronic computers	0.2%	Games and toys	0.7%		
	[A408] Cable and other pay television services	0.2%	Telephone	0.7%		
	[A164] Book publishing	0.2%	Sports	0.6%		
	[A163] Periodicals	0.2%	Other	0.6%		
	[A318] (Use of) computer peripheral equipment	0.2%	Leisure - other	0.6%		
	[A162] Newspapers	0.2%	Smoking	0.5%		

Table 6.4.1: Detailed comparison of three studies, % contribution to global warming potential (continued)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
	[A456] Physical fitness facilities and membership sports and recreation clubs	0.1%	Pets	0.5%		
	[A175] Nitrogenous and phosphatic fertilizers	0.1%	CDs etc	0.4%		
	51 Other categories, total:	1.3%	Film and photo	0.3%		
	Subtotal	*6.0%*	*Subtotal*	*15.1%*		
CP10	[A465] Colleges, universities, and professional schools	0.3%	Books and educational tools	0.2%	Education and research, DK public consumption	1.5%
(Education)	[A464] Elementary and secondary schools	0.1%	Educational fees	0.2%		
	[A466] Private libraries, vocational schools, and educational services, n.e.c.	0.1%	Child care / 'kindergarten'	0.2%		
	[A471] Job training and related services	0.0%	Work - other	0.0%		
	Subtotal	*0.5%*	*Subtotal*	*0.7%*		
CP11	[A446] Eating and drinking places	8.1%	Restaurant, pub, etc.	2.8%	Catering, DK private consumption	1.5%
(Restaurants,	[A424] Hotels	0.6%				
hotels)	[A425] Other lodging places	0.4%				
	Subtotal	*9.1%*	*Subtotal*	*2.8%*		
CP12	[A431] Beauty and barber shops	1.2%	Personal care - other	0.5%	General public services, public order and safety affairs in DK	1.5%
(Miscellaneous)	[A419] Insurance carriers	1.1%	Toiletries	0.4%	Economic affairs and services, DK public consumption	1.5%
	[A336] (Use of) household appliances, n.e.c.	1.0%	Cosmetics and perfume	0.3%		
	[A422] Real estate agents, managers, operators, and lessors	0.4%	Hair care products	0.2%		
	[A191] Toilet preparations	0.3%	Barber and beauty services	0.2%		
	[A154] Sanitary paper products	0.3%	Hygienic paper	0.1%		
	[A188] Soap and other detergents	0.2%				
	23 Other categories, total	0.7%				
	Subtotal	*5.2%*	*Subtotal*	*1.8%*		
					Note: Weidema only reported the top 15 per impact category	

Table 6.4.2: Detailed comparison of three studies, % contribution to photochemical oxidation (ozone creation potential)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
CP01-02	[A52] Meat packing plants	3.9%	Cereals	2.4%	Meat purchase in DK, private consumption	1.2%
(Food etc.)	[A54] Poultry slaughtering and processing	3.4%	Potatoes, groceries, fruits	2.2%		
	[A59] Fluid milk	2.1%	Meat and meatware	1.9%		
	[A53] Sausages and other prepared meat products	1.9%	Milk, cheese, butter	1.7%		
	[A56] Natural, processed, and imitation cheese	1.8%	Feeding - other	1.0%		
	[A86] Bottled and canned soft drinks	1.2%	Alcoholic beverages	0.9%		
	[A93] Edible fats and oils, n.e.c.	1.2%	Jam, sweets	0.9%		
	[A75] Bread, cake, and related products	0.9%	Non-alcoholic beverages	0.8%		
	[A66] Frozen fruits, fruit juices, and vegetables	0.8%	Coffee, tea, cacao	0.5%		
	[A98] Cigarettes	0.8%	Fish and fish products	0.4%		
	[A92] Roasted coffee	0.7%	Fat and oil	0.3%		
	[A96] Potato chips and similar snacks	0.6%				
	[A84] Wines, brandy, and brandy spirits	0.6%				
	[A81] Candy and other confectionery products	0.6%				
	[A12] Vegetables	0.5%				
	[A57] Dry, condensed, and evaporated dairy products	0.5%				
	[A69] Cereal breakfast foods	0.5%				
	[A76] Cookies and crackers	0.4%				
	[A10] Fruits	0.4%				
	[A2] Poultry and eggs	0.4%				
	[A65] Prepared fresh or frozen fish and seafoods	0.4%				
	30 other categories, total:	3.9%				
	Subtotal	*27.4%*	*Subtotal*	*12.9%*		
CP03	[A115] Apparel made from purchased materials	2.2%	Clothes	5.0%	Clothing purchase in DK, private consumption	2.0%
(Clothing etc.)	[A426] Laundry, cleaning, garment services, and shoe repair	0.3%	Shoes	1.8%		
	[A206] Shoes, except rubber	0.3%	Accessoires	1.1%		
	[A112] Women's hosiery, except socks	0.1%	Clothing - other	0.3%		
	[A199] Rubber and plastics footwear	0.1%				
	[A113] Hosiery, n.e.c.	0.1%				
	[A209] Luggage	0.1%				
	8 other categories, total:	0.1%				
	Subtotal	*3.2%*	*Subtotal*	*8.1%*		
CP04-05	[A31] New residential 1 unit structures, nonfarm	3.8%	Feeding - direct energy (gas, electricity)	3.3%	Dwellings and heating in DK, private	7.1%
(Housing etc.)	[A257] (Heating with) heating equipment, except electric and warm air furnaces	3.8%	Heating	2.9%	Personal hygiene in DK, private consumption	2.5%
	[A33] New additions & alterations, nonfarm, construction	2.1%	Rent and mortgage	2.6%	Furniture & furnishing in DK, private consumption	1.0%

Table 6.4.2: Detailed comparison of three studies, % contribution to photochemical oxidation (ozone creation potential) (continued)

CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
[A333] (Washing with) household laundry equipment	1.1%	Painting and wallpaper	2.1%	Maintenance and repair of the dwellings in DK, private consump.	0.9%
[A42] Maintenance and repair of farm and nonfarm residential structures	0.9%	Furniture	2.0%		
[A332] (Use of) household refrigerators and freezers	0.8%	Shelter - other	1.8%		
[A393] Non-durable household goods	0.8%	Kitchen appliances etc.	1.8%		
[A34] New residential garden and high-rise apartments construction	0.7%	Cleaning attributions	0.8%		
[A413] Water supply and sewerage systems	0.6%	Living - other	0.6%		
[A331] (Use of) household cooking equipment	0.6%	Washing, drying, ironing	0.6%		
[A106] Carpets and rugs	0.6%	Energy, hot water	0.5%		
[A201] Miscellaneous plastics products, n.e.c.	0.5%	Maintenance	0.5%		
[A337] (Use of) electric lamp bulbs and tubes	0.4%	Mattresses, linen	0.5%		
[A139] Wood household furniture, except upholstered	0.4%	Taxes	0.4%		
[A117] Housefurnishings, n.e.c.	0.4%	'Soft' flooring	0.4%		
[A142] Upholstered household furniture	0.3%	Flowers and plants (in house)	0.4%		
[A437] Miscellaneous equipment rental and leasing	0.3%	Lighting	0.4%		
[A439] Other business services	0.3%	Electricity	0.4%		
[A149] Partitions and fixtures, except wood	0.3%	Electrical appliances	0.4%		
[A144] Mattresses and bedsprings	0.2%	Refurbishment	0.3%		
[A17] Forestry products	0.2%	Curtains etc.	0.3%		
[A123] Fabricated textile products, n.e.c.	0.2%	Personal care - water	0.2%		
[A429] Electrical repair shops	0.2%	Sun protection etc.	0.2%		
[A335] (Use of) household vacuum cleaners	0.2%	Resilient flooring	0.2%		
[A121] Automotive and apparel trimmings	0.2%	Services	0.1%		
[A430] Watch, clock, jewelry, and furniture repair	0.2%	Washing, drying, ironing	0.0%		
[A148] Wood partitions and fixtures	0.1%				
[A334] (Use of) electric housewares and fans	0.1%				
[A116] Curtains and draperies	0.1%				
[A143] Metal household furniture	0.1%				
[A145] Wood office furniture	0.1%				
[A32] New residential 2-4 unit structures, nonfarm	0.1%				
[A151] Furniture and fixtures, n.e.c.	0.1%				
59 other categories, total:	1.3%				
Subtotal	*22.0%*	*Subtotal*	*23.6%*		

Table 6.4.2: Detailed comparison of three studies, % contribution to photochemical oxidation (ozone creation potential) (continued)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al*. (2005)	
CP06	[A187] Drugs	0.9%	Self medication	0.2%	Hospital services in DK, public consumption	1.3%
(Healthcare)	[A458] Doctors and dentists	0.6%				
	[A459] Hospitals	0.2%				
	[A461] Other medical and health services	0.2%				
	[A378] Ophthalmic goods	0.1%				
	Subtotal	*2.0%*	*Subtotal*	*0.2%*		
CP07	[A354] (Driving with) motor vehicles and passenger car bodies	16.6%	Commuting, private transport	17.0%	Car purchase and driving in DK, private consumption	17.0%
(Transport)	[A448] Automotive repair shops and services	1.4%	Mobility for leisure	16.7%	Car driving for holiday abroad, private consumption	1.9%
	[A447] Automotive rental and leasing, without drivers	0.7%	Mobility for 'living'	0.8%	Transport services in DK, private consumption	0.9%
	[A399] Local and suburban transit and interurban highway passenger transportation	0.5%	Transport (clothing 1)	0.5%		
	[A352] Truck and bus bodies	0.2%	Transport (clothing 2)	0.3%		
	[A398] Railroads and related services	0.2%	Commuting, public transport	0.3%		
	[A403] Air transportation	0.2%				
	[A366] Search and navigation equipment	0.2%				
	[A362] Motorcycles, bicycles, and parts	0.2%				
	10 other categories, total:	0.3%				
	Subtotal	*20.5%*	*Subtotal*	*35.6%*		
CP08	[A407] Telephone, telegraph communications, and communications services n.e.c.	1.6%				
(Communication)	[A475] Postal Service	0.6%				
	[A342] (Use of) telephone and telegraph apparatus	0.1%				
	[A343] (Use of) communication equipment	0.1%				
	Subtotal	*2.3%*	*Subtotal*			
CP09	[A457] Other amusement and recreation services	1.0%	Holidays	4.7%	Tourist expenditures abroad, private, except car driving	2.1%
(Recreation etc.)	[A176] (Household use of) pesticides and agricultural chemicals, n.e.c.	0.8%	TV, radio ('brown goods'/electronics)	2.7%		
	[A340] (Use of) household audio and video equipment	0.5%	Newspapers, periodicals, books	1.2%		
	[A71] Dog and cat food	0.4%	Other	0.9%		
	[A428] Portrait photographic studios, and other miscellaneous personal services	0.3%	Games and toys	0.7%		
	[A164] Book publishing	0.3%	Garden, excluding furniture	0.6%		
	[A408] Cable and other pay television services	0.3%	Telephone	0.6%		
	[A163] Periodicals	0.3%	Sports	0.6%		
	[A177] Gum and wood chemicals	0.3%	Smoking	0.5%		
	[A317] (Use of) electronic computers	0.2%	CDs etc	0.5%		
	[A162] Newspapers	0.2%	Leisure - other	0.4%		
	[A318] (Use of) computer peripheral equipment	0.2%	Film and photo	0.3%		
	[A175] Nitrogenous and phosphatic fertilisers	0.1%	Electricity	0.3%		

Table 6.4.2: Detailed comparison of three studies, % contribution to photochemical oxidation (ozone creation potential) (continued)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al*. (2005)	
	[A456] Physical fitness facilities and membership sports and recreation clubs	0.1%	Pets	0.3%		
	[A385] Games, toys, and children's vehicles	0.1%				
	46 other categories, totalling:	1.5%				
	Subtotal	*6.8%*	*Subtotal*	*14.1%*		
CP10	[A465] Colleges, universities, and professional schools	0.3%	Books and educational tools	0.3%	Education and research, DK public consumption	1.3%
(Education)	[A464] Elementary and secondary schools	0.1%	Child care / 'kindergarten'	0.2%		
	[A466] Private libraries, vocational schools, and educational services, n.e.c.	0.1%	Educational fees	0.2%		
	[A471] Job training and related services	0.0%	Work - other	0.0%		
	Subtotal	0.6%	Subtotal	0.7%		
CP11	[A446] Eating and drinking places	7.8%	Restaurant, pub, etc.	1.7%	Catering, DK private consumption	1.1%
(Restaurants,	[A424] Hotels	0.6%				
hotels)	[A425] Other lodging places	0.4%				
	Subtotal	*8.8%*	*Subtotal*	*1.7%*		
CP12	[A419] Insurance carriers	1.4%	Toiletries	1.0%	General public services, public order and safety affairs in DK	1.5%
(Miscellaneous)	[A431] Beauty and barber shops	1.4%	Hair care products	0.9%	Economic affairs and services, DK public consumption	1.0%
	[A336] (Use of) household appliances, n.e.c.	1.1%	Cosmetics and perfume	0.5%		
	[A191] Toilet preparations	0.5%	Personal care - Other	0.4%		
	[A422] Real estate agents, managers, operators, and lessors	0.5%	Barber and beauty services	0.2%		
	[A154] Sanitary paper products	0.4%	Hygienic paper	0.1%		
	[A188] Soap and other detergents	0.4%				
	[A474] Social services, n.e.c.	0.2%				
	[A460] Nursing and personal care facilities	0.1%				
	20 other categories, total:	0.6%				
	Subtotal	*6.5%*	*Subtotal*	*3.2%*		

Table 6.4.3: Detailed comparison of three studies, % contribution to eutrophication

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
CP01-02	[A52] Meat packing plants	11.0%	Meat and meatware	14.1%	Meat purchase in DK, private consumption	9.0%
(Food etc.)	[A54] Poultry slaughtering and processing	6.7%	Milk, cheese, butter	12.9%	Bread and cereals purchase in DK, private consumption	1.2%
	[A59] Fluid milk	4.9%	Potatoes, groceries, fruits	11.1%	Fruit and vegetables in DK, except potatoes, private consump.	1.1%
	[A53] Sausages and other prepared meat products	4.8%	Cereals	10.4%	Ice cream, chocolate and sugar products in DK, private cons.	0.9%
	[A56] Natural, processed, and imitation cheese	4.3%	Feeding - other	4.6%		
	[A75] Bread, cake, and related products	3.3%	Jam, sweets	3.9%		
	[A70] Prepared flour mixes and doughs	2.5%	Coffee, tea, cacao	3.2%		
	[A69] Cereal breakfast foods	2.3%	Non-alcoholic beverages	2.3%		
	[A93] Edible fats and oils, n.e.c.	1.8%	Fat and oil	1.2%		
	[A97] Food preparations, n.e.c.	1.4%	Alcoholic beverages	0.7%		
	[A76] Cookies and crackers	1.2%	Fish and fish products	0.4%		
	[A96] Potato chips and similar snacks	1.2%				
	[A57] Dry, condensed, and evaporated dairy products	1.1%				
	[A81] Candy and other confectionery products	1.0%				
	[A78] Sugar	1.0%				
	[A92] Roasted coffee	0.9%				
	[A2] Poultry and eggs	0.9%				
	[A86] Bottled and canned soft drinks	0.8%				
	[A10] Fruits	0.8%				
	[A66] Frozen fruits, fruit juices, and vegetables	0.7%				
	[A68] Flour and other grain mill products	0.7%				
	[A4] Miscellaneous livestock	0.6%				
	[A82] Malt beverages	0.6%				
	[A84] Wines, brandy, and brandy spirits	0.5%				
	25 other categories, total:	4.7%				
	Subtotal	*59.7%*	*Subtotal*	*64.8%*		
CP03	[A115] Apparel made from purchased materials	3.6%	Clothes	3.8%	Clothing purchase and washing in DK, private consumption	1.5%
(Clothing etc.)	[A206] Shoes, except rubber	0.2%	Shoes	0.7%		
	[A426] Laundry, cleaning, garment services, and shoe repair	0.2%	Accessoires	0.6%		
	[A112] Women's hosiery, except socks	0.2%	Clothing - other	0.2%		
	[A113] Hosiery, n.e.c.	0.1%				
	10 other categories, total:	0.2%				
	Subtotal	*4.5%*	*Subtotal*	*5.4%*		

Table 6.4.3: Detailed comparison of three studies, % contribution to eutrophication (continued)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
CP04-05	[A31] New residential 1 unit structures, nonfarm	1.2%	Flowers and plants (in house)	1.3%	Dwellings and heating in DK, private consumption	2.1%
(Housing etc.)	[A257] (Heating with) heating equipment, except electric and warm air furnaces	1.0%	Rent and mortgage	0.9%	Personal hygiene in DK, private consumption	0.9%
	[A393] Non-durable household goods	0.8%	Furniture	0.9%	Retirement homes, day-care etc. in DK, public consumption	0.6%
	[A33] New additions & alterations, nonfarm, construction	0.7%	Mattresses, linen	0.5%	Toilet flush in DK, private	0.6%
	[A117] Housefurnishings, n.e.c.	0.7%	'Soft' flooring	0.4%		
	[A106] Carpets and rugs	0.7%	Curtains etc.	0.3%		
	[A333] (Washing with) household laundry equipment	0.6%	Kitchen appliances etc.	0.3%		
	[A332] (Use of) household refrigerators and freezers	0.4%	Resilient flooring	0.2%		
	[A142] Upholstered household furniture	0.3%	Taxes	0.2%		
	[A337] (Use of) electric lamp bulbs and tubes	0.3%	Cleaning attributions	0.1%		
	[A42] Maintenance and repair of farm and nonfarm residential structures	0.3%	Living - other	0.1%		
	[A331] (Use of) household cooking equipment	0.2%	Refurbishment	0.1%		
	[A34] New residential garden and high-rise apartments construction	0.2%	Heating	0.1%		
	[A116] Curtains and draperies	0.2%	Washing, drying, ironing	0.1%		
	[A17] Forestry products	0.2%	Maintenance	0.1%		
	[A123] Fabricated textile products, n.e.c.	0.2%	Sun protection etc.	0.1%		
	[A413] Water supply and sewerage systems	0.2%	Shelter - other	0.1%		
	[A121] Automotive and apparel trimmings	0.2%	Lighting	0.1%		
	[A144] Mattresses and bedsprings	0.1%	Electrical appliances	0.1%		
	[A139] Wood household furniture, except upholstered	0.1%	Painting and wallpaper	0.1%		
	[A430] Watch, clock, jewelry, and furniture repair	0.1%	Feeding - direct energy (gas, electricity)	0.0%		
	[A149] Partitions and fixtures, except wood	0.1%	Energy, hot water	0.0%		
	[A201] Miscellaneous plastics products, n.e.c.	0.1%	Personal care - water	0.0%		
	[A437] Miscellaneous equipment rental and leasing	0.1%	Electricity	0.0%		
	[A439] Other business services	0.1%	Services	0.0%		
	[A182] Chemicals and chemical preparations, n.e.c.	0.1%	Washing, drying, ironing	0.0%		
	[A120] Pleating and stitching	0.1%				
	[A335] (Use of) household vacuum cleaners	0.1%				
	[A334] (Use of) electric housewares and fans	0.1%				
	63 other categories, total:	0.6%				
	Subtotal	*9.9%*	*Subtotal*	*6.2%*		

Table 6.4.3: Detailed comparison of three studies, % contribution to eutrophication (continued)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
CP06	[A187] Drugs	0.4%	Self medication	0.1%		
(Healthcare)	[A458] Doctors and dentists	0.2%				
	[A459] Hospitals	0.1%				
	[A461] Other medical and health services	0.1%				
	[A378] Ophthalmic goods	0.0%				
	Subtotal	*0.7%*	*Subtotal*	*0.1%*		
CP07	[A354] (Driving with) motor vehicles and passenger car bodies	4.8%	Mobility for leisure	0.6%	Car purchase and driving in DK, private consumption	3.0%
(Transport)	[A448] Automotive repair shops and services	0.4%	Commuting, private transport	0.6%		
	[A447] Automotive rental and leasing, without drivers	0.2%	Commuting, public transport	0.1%		
	[A398] Railroads and related services	0.2%	Mobility for 'living'	0.0%		
	[A399] Local and suburban transit and interurban highway passenger transportation	0.2%	Transport (clothing 1)	0.0%		
	[A403] Air transportation	0.1%	Transport (clothing 2)	0.0%		
	12 other categories, total	0.2%				
	Subtotal	*6.0%*	*Subtotal*	*1.2%*		
CP08	[A407] Telephone, telegraph communications, and communications services n.e.c.	0.5%				
(Communication)	[A475] Postal Service	0.2%				
	[A343] (Use of) communication equipment	0.0%				
	[A342] (Use of) telephone and telegraph apparatus	0.0%				
	Subtotal	*0.7%*	*Subtotal*			
CP09	[A71] Dog and cat food	1.0%	Holidays	4.0%	Tourist expenditures by Danes travelling abroad, private cons.	3.3%
(Recreation etc.)	[A457] Other amusement and recreation services	0.6%	Garden, excluding furniture	2.1%	Pet food and veterinarian services in DK, private consumption	0.6%
	[A340] (Use of) household audio and video equipment	0.3%	Smoking	1.4%		
	[A176] (Household use of) pesticides and agricultural chemicals, n.e.c.	0.2%	Pets	0.8%		
	[A72] Prepared feeds, n.e.c.	0.2%	Newspapers, periodicals, books	0.7%		
	[A428] Portrait photographic studios, and other miscellaneous personal services	0.1%	TV, radio ('brown goods'/electronics)	0.5%		
	[A164] Book publishing	0.1%	Leisure - other	0.3%		
	[A408] Cable and other pay television services	0.1%	Sports	0.3%		
	[A163] Periodicals	0.1%	Other	0.2%		
	[A317] (Use of) electronic computers	0.1%	CDs etc	0.2%		
	[A162] Newspapers	0.1%	Games and toys	0.2%		
	[A175] Nitrogenous and phosphatic fertilizers	0.1%	Telephone	0.1%		
	[A318] (Use of) computer peripheral equipment	0.1%	Film and photo	0.1%		

Table 6.4.3: Detailed comparison of three studies, % contribution to eutrophication (continued)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
	50 other categories, total	0.6%	Electricity	0.0%		
	Subtotal	*3.5%*	*Subtotal*	*10.7%*		
CP10	[A465] Colleges, universities, and professional schools	0.1%	Books and educational tools	0.1%	Education and research, DK public consumption	0.6%
(Education)	[A464] Elementary and secondary schools	0.0%	Child care / 'kindergarten'	0.1%		
	[A466] Private libraries, vocational schools, and educational services, n.e.c.	0.0%	Educational fees	0.1%		
	[A471] Job training and related services	0.0%	Work - other	0.0%		
	Subtotal	*0.2%*	*Subtotal*			
CP11	[A446] Eating and drinking places	12.1%	Restaurant, pub, etc.	5.2%	Catering, DK private consumption	1.9%
(Restaurants,	[A424] Hotels	0.3%				
hotels)	[A425] Other lodging places	0.2%				
	Subtotal	*12.6%*	*Subtotal*	*5.2%*		
CP12	[A431] Beauty and barber shops	0.5%	Personal care - other	5.7%	General public services, public order and safety affairs in DK	0.7%
(Miscellaneous)	[A419] Insurance carriers	0.4%	Toiletries	0.1%		
	[A336] (Use of) household appliances, n.e.c.	0.3%	Barber and beauty services	0.1%		
	[A422] Real estate agents, managers, operators, and lessors	0.1%	Hygienic paper	0.1%		
	[A154] Sanitary paper products	0.1%	Cosmetics and perfume	0.1%		
	[A191] Toilet preparations	0.1%	Hair care products	0.1%		
	[A188] Soap and other detergents	0.1%				
	[A474] Social services, n.e.c.	0.1%				
	[A460] Nursing and personal care facilities	0.1%				
	[A472] Child day care services	0.1%				
	[A473] Residential care	0.1%				
	18 other categories, total	0.2%				
	Subtotal	*2.2%*	*Subtotal*	*6.2%*		

Table 6.4.4: Detailed comparison of three studies, % contribution to acidification

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
CP01-02	[A52] Meat packing plants	6.1%	Meat and meatware	7.5%	Meat purchase in DK, private consumption	3.4%
(Food etc.)	[A54] Poultry slaughtering and processing	4.5%	Milk, cheese, butter	6.8%	Bread and cereals in DK, private consumption	0.6%
	[A53] Sausages and other prepared meat products	2.8%	Cereals	3.8%	Fruit and vegetables in DK, except potatoes, private consump.	0.5%
	[A59] Fluid milk	2.6%	Potatoes, groceries, fruits	3.1%	Ice cream, chocolate and sugar products in DK, private cons.	0.5%
	[A56] Natural, processed, and imitation cheese	2.3%	Fish and fish products	2.8%		
	[A93] Edible fats and oils, n.e.c.	1.0%	Feeding - other	2.0%		
	[A86] Bottled and canned soft drinks	0.9%	Jam, sweets	1.6%		
	[A75] Bread, cake, and related products	0.8%	Non-alcoholic beverages	1.5%		
	[A66] Frozen fruits, fruit juices, and vegetables	0.6%	Coffee, tea, cacao	0.9%		
	[A57] Dry, condensed, and evaporated dairy products	0.6%	Alcoholic beverages	0.9%		
	[A98] Cigarettes	0.6%	Fat and oil	0.5%		
	[A2] Poultry and eggs	0.5%				
	[A81] Candy and other confectionery products	0.5%				
	[A92] Roasted coffee	0.5%				
	[A12] Vegetables	0.5%				
	[A84] Wines, brandy, and brandy spirits	0.5%				
	[A65] Prepared fresh or frozen fish and seafoods	0.5%				
	[A96] Potato chips and similar snacks	0.4%				
	[A69] Cereal breakfast foods	0.4%				
	[A76] Cookies and crackers	0.4%				
	[A4] Miscellaneous livestock	0.4%				
	28 other categories, total:	3.8%				
	Subtotal	*31.2%*	*Subtotal*	*31.5%*		
CP03	[A115] Apparel made from purchased materials	1.7%	Clothes	5.5%	Clothing purchase in DK, private consumption	1.3%
(Clothing etc.)	[A426] Laundry, cleaning, garment services, and shoe repair	0.3%	Shoes	1.8%		
	[A206] Shoes, except rubber	0.2%	Accessoires	1.3%		
	[A112] Women's hosiery, except socks	0.1%	Clothing - other	0.3%		
	[A199] Rubber and plastics footwear	0.1%				
	[A113] Hosiery, n.e.c.	0.1%				
	8 other categories, total:	0.1%				
	Subtotal	*2.4%*	*Subtotal*	*8.9%*		
CP04-05	[A333] (Washing with) household laundry equipment	4.0%	Rent and mortgage	3.4%	Dwellings and heating in DK, private consumption	4.3%
(Housing etc.)	[A31] New residential 1 unit structures, nonfarm	3.0%	Furniture	2.7%	Personal hygiene in DK, private consumption	1.3%
	[A332] (Use of) household refrigerators and freezers	3.0%	Kitchen appliances etc.	2.2%	Retirement homes, day-care etc. in DK, public consumption	0.6%

Table 6.4.4: Detailed comparison of three studies, % contribution to acidification (continued)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
	[A257] (Heating with) heating equipment, except electric and warm air furnaces	2.7%	Feeding - direct energy (gas, electricity)	1.8%	Furniture & furnishing in DK, private consumption	0.5%
	[A337] (Use of) electric lamp bulbs and tubes	2.2%	Heating	1.2%		
	[A33] New additions & alterations, nonfarm, construction	1.8%	Electricity	1.1%		
	[A331] (Use of) household cooking equipment	1.5%	Maintenance	0.8%		
	[A42] Maintenance and repair of farm and nonfarm residential structures	0.7%	Energy, hot water	0.8%		
	[A34] New residential garden and high-rise apartments construction	0.7%	Washing, drying, ironing	0.7%		
	[A413] Water supply and sewerage systems	0.6%	Living - other	0.7%		
	[A393] Non-durable household goods	0.5%	Mattresses, linen	0.6%		
	[A335] (Use of) household vacuum cleaners	0.3%	Flowers and plants (in house)	0.6%		
	[A334] (Use of) electric housewares and fans	0.3%	Lighting	0.5%		
	[A106] Carpets and rugs	0.3%	Taxes	0.5%		
	[A139] Wood household furniture, except upholstered	0.3%	'Soft' flooring	0.5%		
	[A149] Partitions and fixtures, except wood	0.3%	Shelter - Other	0.5%		
	[A437] Miscellaneous equipment rental and leasing	0.2%	Electrical appliances	0.5%		
	[A201] Miscellaneous plastics products, n.e.c.	0.2%	Refurbishment	0.4%		
	[A439] Other business services	0.2%	Curtains etc.	0.4%		
	[A117] Housefurnishings, n.e.c.	0.2%	Cleaning attributions	0.3%		
	[A142] Upholstered household furniture	0.2%	Personal care - water	0.3%		
	[A17] Forestry products	0.2%	Painting and wallpaper	0.3%		
	[A429] Electrical repair shops	0.1%	Resilient flooring	0.3%		
	[A430] Watch, clock, jewelry, and furniture repair	0.1%	Sun protection etc.	0.3%		
	[A144] Mattresses and bedsprings	0.1%	Services	0.1%		
	[A123] Fabricated textile products, n.e.c.	0.1%	Washing, drying, ironing	0.0%		
	[A148] Wood partitions and fixtures	0.1%				
	[A121] Automotive and apparel trimmings	0.1%				
	65 other categories, total:	1.4%				
	Subtotal	*25.7%*	*Subtotal*	*21.5%*		
CP06	[A187] Drugs	0.7%	Self medication	0.3%	Hospital services in DK, public consumption	0.6%
(Healthcare)	[A458] Doctors and dentists	0.5%				
	[A459] Hospitals	0.2%				
	[A461] Other medical and health services	0.1%				
	[A378] Ophthalmic goods	0.1%				
	Subtotal	*1.5%*	*Subtotal*	*0.3%*		

Table 6.4.4: Detailed comparison of three studies, % contribution to acidification (continued)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
CP07	[A354] (Driving with) motor vehicles and passenger car bodies	10.3%	Mobility for leisure	7.2%	Car purchase and driving in DK, private consumption	5.0%
(Transport)	[A448] Automotive repair shops and services	1.3%	Commuting, private transport	7.1%	Transport services in DK, private consumption	1.0%
	[A447] Automotive rental and leasing, without drivers	0.5%	Commuting, public transport	0.4%		
	[A399] Local and suburban transit and interurban highway passenger transportation	0.5%	Mobility for 'living'	0.3%		
	[A398] Railroads and related services	0.3%	Transport (clothing 1)	0.2%		
	[A403] Air transportation	0.2%	Transport (clothing 2)	0.1%		
	[A366] Search and navigation equipment	0.2%				
	11 other categories, total:	0.5%				
	Subtotal	*13.8%*	*Subtotal*	*15.4%*		
CP08	[A407] Telephone, telegraph communications, and communications services n.e.c.	1.4%				
(Communication)	[A475] Postal Service	0.5%				
	[A343] (Use of) communication equipment	0.2%				
	[A342] (Use of) telephone and telegraph apparatus	0.2%				
	Subtotal	*2.3%*				
CP09	[A340] (Use of) household audio and video equipment	2.0%	Holidays	4.8%	Tourist expenditures by Danes travelling abroad, private cons.	3.3%
(Recreation etc.)	[A457] Other amusement and recreation services	1.0%	TV, radio ('brown goods'/electronics)	2.7%		
	[A176] (Household use of) pesticides and agricultural chemicals, n.e.c.	0.4%	Newspapers, periodicals, books	1.5%		
	[A71] Dog and cat food	0.3%	Garden, excluding furniture	0.9%		
	[A428] Portrait photographic studios, and other miscellaneous personal services	0.3%	Pets	0.8%		
	[A317] (Use of) electronic computers	0.3%	Games and toys	0.8%		
	[A164] Book publishing	0.3%	Sports	0.7%		
	[A408] Cable and other pay television services	0.3%	Other	0.6%		
	[A163] Periodicals	0.2%	Electricity	0.6%		
	[A162] Newspapers	0.2%	Telephone	0.6%		
	[A318] (Use of) computer peripheral equipment	0.2%	Smoking	0.6%		
	[A175] Nitrogenous and phosphatic fertilizers	0.2%	CDs etc	0.6%		
	[A456] Physical fitness facilities and membership sports and recreation clubs	0.1%	Leisure - other	0.5%		
	[A379] Photographic equipment and supplies	0.1%	Film and photo	0.5%		
	[A451] Video tape rental	0.1%				
	[A72] Prepared feeds, n.e.c.	0.1%				
	[A385] Games, toys, and children's vehicles	0.1%				
	[A450] Motion picture services and theaters	0.1%				
	[A177] Gum and wood chemicals	0.1%				
	[A387] Sporting and athletic goods, n.e.c.	0.1%				

Table 6.4.4: Detailed comparison of three studies, % contribution to acidification (continued)

	CEDA EU-25 (Chapter 5)		Nijdam and Wilting (2003)		Weidema *et al.* (2005)	
	[A452] Theatrical producers (except motion picture), bands, orchestras and entertainers	0.1%				
	[A356] Aircraft	0.1%				
	[A156] Bags, except textile	0.1%				
	40 other categories, total:	0.7%				
	Subtotal	*7.2%*	*Subtotal*	*16.1%*		
CP10	[A465] Colleges, universities, and professional schools	0.3%	Books and educational tools	0.3%	Education and research, DK public consumption	0.9%
(Education)	[A464] Elementary and secondary schools	0.1%	Child care / 'kindergarten'	0.2%		
	[A466] Private libraries, vocational schools, and educational services, n.e.c.	0.1%	Educational fees	0.2%		
	[A471] Job training and related services	0.0%	Work - other	0.0%		
	Subtotal	*0.6%*	*Subtotal*	*0.8%*		
CP11	[A446] Eating and drinking places	8.5%	Restaurant, pub, etc.	3.6%	Catering, DK private consumption	1.1%
(Restaurants,	[A424] Hotels	0.6%				
hotels)	[A425] Other lodging places	0.5%				
	Subtotal	*9.6%*	*Subtotal*	*3.6%*		
CP12	[A431] Beauty and barber shops	1.3%	Toiletries	0.5%	General public services, public order and safety affairs in DK	1.1%
(Miscellaneous)	[A419] Insurance carriers	1.1%	Personal care - other	0.4%	Economic affairs and services, DK public consumption	0.8%
	[A336] (Use of) household appliances, n.e.c.	1.0%	Cosmetics and perfume	0.3%		
	[A422] Real estate agents, managers, operators, and lessors	0.4%	Hair care products	0.3%		
	[A154] Sanitary paper products	0.4%	Barber and beauty services	0.2%		
	[A191] Toilet preparations	0.3%	Hygienic paper	0.2%		
	[A188] Soap and other detergents	0.2%				
	[A460] Nursing and personal care facilities	0.1%				
	[A474] Social services, n.e.c.	0.1%				
	[A470] Other membership organizations	0.1%				
	[A380] Jewelry, precious metal	0.1%				
	[A443] Legal services	0.1%				
	17 other categories, total	0.4%				
	Subtotal	*5.6%*	*Subtotal*	*1.9%*		

Furthermore, a list is produced that brings together the results across all COICOP categories and eight impact categories at the most detailed level. This list builds on the tables in Chapter 5, where the products were ranked separately for each of eight environmental impact categories, based on the results of the calculations with the CEDA EU-25 model. The number of products necessary to cover just more than 50% of the total environmental impacts range from seven to fifteen for the eight different impact categories covered in the detailed analysis. Drawing together these top products from the all the lists for the individual impact categories into a single overall list leads to a selection of 22 products. In the following they are listed in alphabetical order:

- [A115] Apparel made from purchased materials
- [A448] Automotive repair shops and services
- [A431] Beauty and barber shops
- [A354] (Driving with) motor vehicles and passenger car bodies
- [A187] Drugs
- [A446] Eating and drinking places
- [A93] Edible fats and oils, n.e.c.
- [A59] Fluid milk
- [A257] (Heating with) heating equipment, except electric and warm air furnaces
- [A52] Meat packing plants
- [A56] Natural, processed, and imitation cheese
- [A33] New additions & alterations, nonfarm, construction
- [A31] New residential 1 unit structures, nonfarm
- [A457] Other amusement and recreation services
- [A54] Poultry slaughtering and processing
- [A53] Sausages and other prepared meat products
- [A407]Telephone,telegraphcommunications, and communications services n.e.c.
- [A337] (Use of) electric lamp bulbs and tubes
- [A336] (Use of) household appliances, n.e.c.
- [A332] (Use of) household refrigerators and freezers
- [A176] (Use of) pesticides and agricultural chemicals, n.e.c.
- [A333] (Washing with) household laundry equipment

Such detailed results must be used with special caution because they are based on a single model, instead of being supported by a number of studies, and rankings from an individual model alone are not sufficient to decide about priorities for measures to protect the environment. They are, however, useful information for prioritising further deeper analysis and research, including of environmental improvement potentials.

6.4.3 Discussion per main COICOP category

Products under CP01 and CP02 – Food and beverages, tobacco and narcotics

Meat and meat products (including meat, poultry, sausages or similar) can be singled out for their high environmental importance within this area of consumption. This conclusion is supported by both the CEDA EU-25 analysis and the Nijdam and Wilting (2003) study. The estimated contribution of these products to global warming potential ranges from about 4 to 12% of all products or 19 to 38% of the consumption area CP01+02. Such importance of meat and meat products is also confirmed according to most other impact categories, for instance acidification. An especially high weight of these products has been found for eutrophication (14 to 23% of the impact potential of all products). This product grouping is so important, due to its relatively high impact per euro (CEDA EU-25; Weidema *et al.* 2005) in combination with a sizeable expenditure. The results reflect that the environmental impacts

of the full production chain, including the different phases of agricultural production, are taken into account.

The second important product grouping here are dairy products. The contribution of milk, cheese and butter to total global warming potential is estimated at 4% in the Nijdam and Wilting study. In CEDA EU-25 this corresponds to fluid milk (2.4%), cheese (2.1%) and dry, condensed and other diary products (0.6%). Also for these products the contribution to eutrophication turns out as particularly high (10 – 13% of all products).

After these two main groupings, a variety of other food products follow (plant-based food products, soft drinks, alcoholic drinks, etc.) with lower levels of environmental impacts for most impact categories. The exception is the score on photochemical oxidation in the Nijdam and Wilting (2003) study, which puts cereals, potatoes and groceries on top. The reasons for these differences are not clear. CEDA EU-25 lists in descending order of importance:

- [A93] Edible fats and oils, n.e.c.
- [A86] Bottled and canned soft drinks
- [A75] Bread, cake, and related products
- [A66] Frozen fruits, fruit juices, and vegetables
- [A98] Cigarettes
- [A12] Vegetables
- [A92] Roasted coffee
- [A65] Prepared fresh or frozen fish and seafoods
- [A84] Wines, brandy, and brandy spirits
- [A57] Dry, condensed, and evaporated dairy products
- [A96] Potato chips and similar snacks
- [A10] Fruits
- [A81] Candy and other confectionery products
- [A69] Cereal breakfast foods
- [A2] Poultry and eggs

Nijdam and Wilting list:

- Potatoes, groceries, fruits
- Feeding – other
- Jam, sweets
- Non-alcoholic beverages
- Fish and fish products
- Coffee, tea, cacao
- Alcoholic beverages
- Fat and oil

It is likely that, at this level, the way that products have been aggregated is decisive for their ranking. For instance, CEDA EU-25 distinguishes a grouping 'dry, condensed and evaporated diary products', which in the Nijdam and Wilting study are included under 'milk, cheese, butter', as discussed above. As far as the product names are directly comparable, it seems that the scores on impact categories are reasonably comparable between Nijdam and Wilting (2003) and CEDA EU-25 as well. See for instance for global warming potential:

- Potatoes, groceries, fruits (3.1%) versus frozen fruits (0.7%), vegetables (0.7%), potato chips (0.5%),
- Fish and fish products (1%) versus prepared fresh or frozen fish and seafood (0.6%),
- Alcoholic beverages (0.7%) versus wines, brandy and brandy spirits (0,6%),
- Non-alcoholic beverages (1%) versus bottled and canned soft drinks (0.9%).

With regard to food, the Weidema *et al.* (2005) study seems to deviate significantly from the generic pattern. Just two product groupings are visible under the COICOP 01 and 02 categories. The score for Meat (1.5% on global warming potential, but this pattern is similar for other impact categories) is very much below not only the values reported by Nijdam and Wilting (2003) and in CEDA EU 25, but also those reported in other studies (e.g. Labouze et al, 2003: 5.4%).

This is probably due to the particular approach used in this study, which is based on marginal impacts. A further limitation to the comparison is that Weidema *et al.* (2005) did not report impact scores on all 100 product groupings they included, so it may be that meat-related product categories are still 'hidden' in their non-reported scores. However, their reported results seem to point at some structural differences in estimating the contribution to environmental impacts of meat in specific and probably food in general[45].

Note that, as indicated, though the conclusions seem rather robust across impact categories, there may be fewer applied impact categories where rankings can differ significantly. In this COICOP category, we would like to mention particularly fish and fish products, which probably would dominate an impact category concerning fish resources.

Products under CP03 – Clothing

As indicated in Section 6.3, there are some deviations in the absolute importance of this area of consumption between studies. However, in all studies it only comes after the three main areas of consumption for all impact categories.

When we look in more detail, we see that the most detailed work, CEDA EU-25 and by Nijdam and Wilting (2003), comes up with the same ranking for all impact categories:

- Clothes (responsible for 60 – 70% of the impact in this COICOP category);
- Shoes;
- Accessories;
- Other.

Clothes as such are clearly the dominant contributor.

Products under CP04 – 05 – Housing, furniture, equipment and utility use

As discussed in Chapter 4 and Section 6.3, this is another very dominant area of consumption with regard to environmental impacts. Household heating is consistently one of the most important contributers for all impact categories, in all studies. The exception is for eutrophication in Nijdam and Wilting (2003)[46]. However, the absolute relevance differs between studies. For instance, for global warming potential CEDA EU-25 reports about 5% (with forestry products, oil and gas as fuels). Nijdam and Wilting (2003) report some 9% and Weidema *et al.* (2005) some 8%. The other studies reviewed cannot help to give a decisive conclusion here: they all suggest much higher contributions to global warming potential (see, e.g. the 16% 'space heating – domestic' in Labouze *et al.* (2003) or the 30% for 'interior climate' in Nemry *et al.* (2002)). With the EEA (2004) reporting a direct global warming potential contribution of energy use in the households (heating, cooking and warm water generation with gas combined) of some 10%, it seems that the Nijdam and Wilting (2003) and Weidema *et al.* (2005) values are the most accurate.

Residential structures (or rent and mortgage), which is not distinguished specifically in Weidema *et al.* (2005) also have a high score on most impact categories in CEDA EU-25 and Nijdam and Wilting (2003). The contribution is 3-4% to most themes, except Eutrophication (some 1%). This product grouping scores also high on impact categories such as Total Material Requirement which is also mentioned in other studies such as Nemry *et al.* (2002) and Moll *et al.* (2004).

Concerning the other product groupings, the comparison is in many ways complicated by the fact that CEDA EU-25, Nijdam and Wilting (2003) and Weidema *et al.* (2005) defined their product

45 This seems related to another result of the Weidema *et al.* (2005) study, i.e. that they find that cheese and milk, cream, and yoghurt are among the 20 products with the lowest global warming potential per euro (or in their case: Danish Kronor) spent (see Table 1.21, page 49). This is contrary to the other studies we reviewed.

46 The reason for this is not entirely clear. On eutrophication, in the Nijdam and Wilting (2003) study, a product grouping dominates that is not present in any other study (flowers and plants).

groupings in such different ways. For instance, in Nijdam and Wilting (2003) electricity purchase is defined separately and is important. In CEDA EU-25, the electricity is allocated to the appliances that use it, and hence electricity as a product is invisible. When one takes this into account, the differences between the different studies are relatively limited. Next to the house heating and construction of the house comes a string of other energy-consuming products and processes in the house. A check of some easily comparable items shows that the values (with global warming potential as an example, but the same pattern can be found for photochemical oxidation and acidification) in the most detailed pieces of work, CEDA EU-25 and Nijdam and Wilting (2003), fit rather well:

- A332 Use of household refrigerators (1.8%) plus A331 Use of household cooking equipment (1%) is in line with Feeding – direct energy use (3.5%),
- A333 Washing with household laundry equipment (2.4%) is in line with Washing, drying, ironing (1%) if one acknowledges that part of the electricity use is not included in the latter).

Also a comparison of the most important product groupings after house heating and residential construction in CEDA EU-25 and Nijdam and Wilting (2003) for global warming potential, acidification and photochemical oxidation show great similarities.

CEDA EU-25 reports the next eight groupings in its top ten:

- [A333] (Washing with) household laundry equipment
- [A33] New additions and alterations, non-farm, construction
- [A332] (Use of) household refrigerators and freezers
- [A337] (Use of) electric lamp bulbs and tubes
- [A331] (Use of) household cooking equipment
- [A42] Maintenance and repair of farm and non-farm residential structures
- [A413] Water supply and sewerage systems
- [A34] New residential garden and high rise apartments construction
- [A393] Non-durable household goods

Apart from heat generation and house construction Nijdam and Wilting report the following groupings in their top ten:

- Feeding – direct energy (gas, electricity)
- Energy, hot water
- Electricity
- Furniture
- Kitchen appliances etc.
- Shelter – other
- Washing, drying, ironing
- Taxes
- Flowers and plants (in house)

In summary, despite the absolute difference in the contribution of household heating the overall picture is clear. In COICOP category 04 and 05 the energy use for heating, hot water, and electric appliances is by far the dominating contribution to global warming potential, acidification, and photochemical oxidation, directly followed by the construction of housing as such. The ranking on eutrophication is not decisive. On indicators related to total material use, house construction scores highest.

It has to be noted that other priorities than the ones presented here may apply to a number of not commonly used, but in certain discussions relevant impact categories. For instance, in COICOP categories 04 and 05, wood use is an important factor. Wooden products are likely to score high when the aim is to protect biodiversity or (biotic) natural resources, but since hardly any of the studies reviewed used this indicator, this does not show up in this study.

Products under CP06 – Healthcare

In all studies, healthcare is responsible for just a minor fraction of the different impact categories (global warming potential, photochemical oxidation, eutrophication, acidification). This may be underestimated, since a lot of the healthcare expenditure is not paid via households. The total values reported in CEDA EU-25 and Nijdam and Wilting (2003) are well in line. Only CEDA EU-25 gives a further sub-division of contributing product groupings (including services):

- [A187] Drugs (about 50% of the total in this category)
- [A458] Doctors and dentists
- [A459] Hospitals
- [A461] Other medical and health services
- [A378] Ophthalmic goods

In a way it may be surprising that medicines in themselves cause higher life cycle impacts than, e.g. the use of hospitals. This may have to do with the point made above – final consumers may pay for medicines, but hospitals may be paid for via other channels – and this result needs further verification.

Products under CP07 – Transport

Transport is the remaining top three consumption areas with regard to environmental impacts. Typically, contributions are some 15% to global warming potential and acidification in most studies, whereas contributions to eutrophication are lower (2 – 5%) and photochemical oxidation higher (20 – 35%)[47].

Within transport, all studies reviewed consistently indicate cars as the dominant contributor. Indeed, Nijdam and Wilting (2003) almost only explicitly mention car transport activities. They decided to split up transport activities (mainly car driving) to purpose, which is a different classification principle as followed by CEDA EU-25 and Weidema *et al.* (2005). Again, CEDA EU-25 gives the most detailed results, with the following ranking consistently showing up for the four impact categories reviewed:

- [A354] (Driving with) motor vehicles and passenger car bodies (contributing to 80% of the impacts in COICOP category 07)
- [A448] Automotive repair shops and services
- [A447] Automotive rental and leasing, without drivers
- [A399] Local and suburban transit and interurban highway passenger transportation
- [A352] Truck and bus bodies
- [A398] Railroads and related services
- [A403] Air transportation
- [A366] Search and navigation equipment
- [A362] Motorcycles, bicycles, and parts

Public ground transport tends to contribute not more than some 4 – 5% to the total impacts in this level 1 COICOP category, or some 0.5% of the total impacts on most categories.

It should be kept in mind that the studies do not reflect possible improvements in the environmental performance of products in the most recent years and that further improvements may arrive in the future. (For example, air emissions of new cars per kilometre have been improving considerably.)

With regard to air transport in the studies reviewed, definition problems may be at stake. The air transport part of package holidays is not

47 See, e.g. for global warming potential the following results: CEDA EU-25 (A354 Driving with motor vehicles; A448 Automotive repair shops and services and A447 Automotive rental and leasing) 18%), Kok *et al.* (2002: 18%), Labouze *et al.* (2003: 17%) and Nijdam and Wilting (2003: 17%). Only Weidema *et al.* (2005) with 6% is clearly lower. A 20% contribution to global warming potential of EU-25 of direct emissions from car transport is reported by EEA (2004). From this EEA value, about 10% has to be subtracted for the sake of comparison, since a main part of car transport is business and truck travel and the studies reviewed look at final consumption only, but another few per cent has to be added again since the studies reviewed look at life cycle impacts including emissions for car and petrol production, etc. The 15% for global warming potential reported by most studies hence seems well in line with the EEA value.

included and may not be visible. Air transport paid in a B2B context (i.e. business trips) is by definition not covered. Intercontinental air transport may not be included properly in consumer expenditure statistics, since it is not clearly defined in which geographical area the expenditure is made. All this implies that the results with regard to air transport reported in Table 6.4.1 must be treated with care.

Products under CP08 – Communication

This area of consumption is of minor relevance in all impact categories (< 2% of the total). Only CEDA EU-25 gives a further specification of products and services contributing to the impacts of this COICOP category:

- [A407]Telephone,telegraphcommunications, and communications services n.e.c.
- [A475] Postal service
- [A343] (Use of) communication equipment
- [A342] (Use of) telephone and telegraph apparatus

In CEDA EU-25, 'postal service' has a rather high impact per euro on most impact categories (see Table 5.4.3; mostly in the top 10 or top 25). It is only due to the rather low expenditure on this service category, that it does not score high. This result needs further validation before drawing clear conclusions on it.

Products under CP09 – Recreation

When comparing the work of Nijdam and Wilting (2003) and Weidema *et al.* (2005) with CEDA EU-25, it becomes apparent that CEDA EU-25 does not report any impact related to tourism or holidays. This has in part to do with the fact that for the CEDA EU-25 work, the COICOP expenditure categories had to be transformed into a US categorisation (the so-called BEA categories of the Bureau of Economic Analysis). It appeared that 'package holidays' were an expenditure category relevant in COICOP that could not be linked to a similar and comparable BEA category. This implies that this specific consumption activity is not well covered in CEDA EU-25. As a consequence the total impacts on this COICOPs category tend to be higher in the Nijdam and Wilting study than in CEDA EU-25 (15% versus 6% on global warming potential, photochemical oxidation and acidification and 10% versus 2 – 3% on eutrophication).

Again, CEDA EU-25 and Nijdam and Wilting (2003) give the most detailed sub-division of this COICOP category. The comparison of these two studies, however, is plagued by definition problems. For instance, the Nijdam and Wilting study groups a variety of products under the header 'recreation' (and hence CP09), that in the CEDA EU-25 work are classified under CP04 – 05 (housing), for instance appliances such as TVs, radios and the related electricity use. Furthermore, both studies clearly use rather different definitions for their product groupings.

For global warming potential, CEDA EU-25 lists the following:

- [A340] (Use of) household audio and video equipment
- [A457] Other amusement and recreation services
- [A176] (Household use of) pesticides and agricultural chemicals, n.e.c.
- [A71] Dog and cat food
- [A428] Portrait photographic studios, and other miscellaneous personal services
- [A317] (Use of) electronic computers
- [A408] Cable and other pay television services
- [A164] Book publishing
- [A163] Periodicals
- [A318] (Use of) computer peripheral equipment
- [A162] Newspapers
- [A456] Physical fitness facilities and membership sports and recreation clubs

- [A175] Nitrogenous and phosphatic fertilizers

Nijdam and Wilting (2003) list the following for global warming:

- Holidays
- TV, radio ('brown goods'/electronics)
- Garden, excluding furniture
- Electricity
- Newspapers, periodicals, books
- Games and toys
- Telephone
- Sports
- Other
- Leisure – other
- Smoking
- Pets
- CDs, etc.
- Film and photo

Hence, apart from the holiday issue already mentioned, there is agreement that Household audio and video equipment is the most important. The rankings are somewhat different for photochemical oxidation and eutrophication. For photochemical oxidation in CEDA EU-25, pesticides (often formulated with organic solvents) become more important. For eutrophication in CEDA EU-25, pet food and in Nijdam and Wilting (2003) pets become more important.

Products under CP10 – Education

This category has a low relevance on all impact categories in absolute terms (generally below 1%). A problem in the analysis is that much expenditure on education is made via governmental funding, and this is not well covered in most of the studies reviewed (including CEDA EU-25). Potential impacts of education are mainly related to transport to and from the educational institute, and residential heating. CEDA EU-25 and Nijdam and Wilting (2003) give a further sub-division, with quite different categorisations. CEDA EU-25 lists in descending relevance:

- [A465] Colleges, universities, and professional schools
- [A464] Elementary and secondary schools
- [A466] Private libraries, vocational schools, and educational services, n.e.c.
- [A471] Job training and related services

And Nijdam and Wilting (2003) give as their ranking:

- Books and educational tools
- Educational fees
- Child care / 'kindergarten'
- Work – other

Products under CP11 – Restaurants, hotels

Only in CEDA EU-25 does this appear to be an important contributor to global warming potential, acidification and eutrophication. Other studies such as Nijdam and Wilting (2003) and Weidema *et al.* (2005) do report global warming potential contributions for this area of consumption, but they tend to be a factor 3 – 4 lower (9 – 12% of the total in CEDA EU-25 versus 2 – 5% of the total in other studies). The result in CEDA EU-25 needs further validation.

Only CEDA EU-25 gives a further specification per product grouping in this COICOP category. In descending order of importance it concerns:

- [A446] Eating and drinking places
- [A424] Hotels
- [A425] Other lodging places

Note again that the fact that business-to-business expenditures are not included in virtually all studies reviewed (so that business travel lacks) can distort the relevance of this area of consumption.

Products under CP12 – Miscellaneous

In this category a variety of product groupings result, depending on how good the original product or expenditure classification could be linked to one of the other COICOP categories. Differences between studies here have hence probably more to do with differences in classifications of products, than that they necessarily point at other fundamental differences in approaches in the studies. Typically, this 'leftover' category contributes some 2-5% to an impact category. Interestingly, in both CEDA EU-25 and in the Weidema *et al.* (2005) study, several service providers (barber shops, insurance carriers, government services) dominate this COICOP category.

6.5 Impacts per euro spent and other conclusions

6.5.1 Impacts per euro spent

Sections 6.3 and 6.4 mainly drew conclusions on the basis of the total impact per product grouping or COICOP category. Another way of drawing conclusions is to take the impact per euro spent into account.

Conclusions about the ranking of products in terms of their impacts per euro have to be made more cautiously than concerning the ranking of their total impact. The main point is that of the studies we reviewed and of the new analysis done in this project, only the work of Nijdam and Wilting (2003), Weidema *et al.* (2005) and CEDA EU-25 in Chapter 5 give a transparent result regarding impact per euro. The type of systematic comparison across a large number of studies we did in Section 6.3 is hence not possible in here.

As concluded in Section 6.4, the Nijdam and Wilting study and CEDA EU-25 had four environmental impact categories in common: global warming potential, acidification, eutrophication and photochemical oxidation (photochemical ozone creation potential). In general, it appears that in both studies, food products and the use of energy, mainly for house heating and electrical appliances, for most environmental themes show up as having the highest impacts per euro. For global warming potential, CEDA EU-25 shows food products at the top whereas in the Nijdam and Wilting work, the use of energy come before food. For acidification, the sequence is reversed. For eutrophication, in both analyses Food and food products are at the top. For photochemical oxidation, the top rankers in both studies are a mix of diverse products[48].

6.5.2 Impacts of shifts in consumption structures

On the basis of insights in the impacts per euro per product grouping, conclusions can be drawn about the scope for environmental improvement by changes of consumption patterns (i.e. spending income on products and services with a lower impact per euro). As shown in Chapter 5, the difference in environmental impact per euro between the product groupings ranked as number 10 from the highest or the lowest end, is in general about a factor 5. Or from another perspective: the product grouping ranked number 10 has about twice the impact per euro as the product grouping ranked number 180 (the median). So even if in the extreme case top-50% percentile of expenditure (leaving the top-10 apart) would be re-directed to expenditure on product groupings within the 50% with lower impacts, it is unlikely this would result of an environmental improvement of much more than a factor 2 (leaving the top 10 apart).

It also appears that shifting from a 'material society' to a 'service society' in itself may not be the panacea it is sometimes thought to be. Both Chapter 4 and Chapter 5 show that there are many service-related categories (healthcare, restaurants, etc.) among the top 60-percentiles of environmental impacts in the different studies. This reflects that what is sold as a service is, in

48 This analysis is based on comparing the impact per euro rankings in Table 5.4.3a-h in Chapter 5 (CEDA EU-25) and Annex 2 of the original report of Nijdam and Wilting (2003)

most cases, an 'envelope' around a set of products generated via a life cycle of very material-oriented production processes.

In summary, a shift in consumption structures, among others from products to services, has some potential for improvements with regard to the environmental impacts generated from our society. However, in order to reach far-reaching targets such as 'factor 4', important reductions in the life cycle impacts of the products must be realised as well, either as a shift within product groups towards lower environmental impact products or through eco-efficient innovations in the products and in the processes involved.

6.5.3 The focus question: How many products cover the most of the impact?

Sections 6.3 and 6.4 focused on identification of the products with the greatest environmental impacts. But how much of the total life cycle impact of consumption do they cover? This study, particularly Chapter 5, suggests that a limited number of products are responsible for a big share of the environmental impacts. Chapter 5 showed that that consistently, over all environmental impact categories, an 80 – 20 rule applies (see Figure 5.4.1). Some 20% of the product groupings appear to cause some 80% of the environmental impact. In Chapter 5, this concerns some 60 product groupings[49].

In Figure 5.4.1 the product groupings are ranked on the x-axis according to their total impact, the highest first, and the cumulative total is given after each extra product on the y-axis. Given a certain pool of products, this ranking method gives the lowest *number* of product groupings that make up in total the 80-percentile. An alternative way of ranking products was suggested by de Vries and te Riele (2005). They ranked product groupings on the x-axis according to their impact per euro, and showed the total cumulative impacts after each extra product grouping on the y-axes. Their method of ranking inevitably gives a somewhat larger number of product groupings that makes up the 80-percentile[50].

6.4 Reflections on the approaches used and further work

In our view, this study shows that the top-down approach, where environmental input-output tables formed the basis for an assessment of the environmental impacts of products, is very powerful for an assessment of impacts of products from a macro-perspective. It allows combining a high level of detail with giving the full picture. It appears worthwhile to develop this approach further.

Suggestions for further work can be divided in two categories:

a) further work that can refine the analysis of the present study;

b) more fundamental work with regard to a European environmental input-output table.

Concerning point a), the following elements stand out:

- The inclusion of government expenditure can be improved. Several studies reviewed in Chapter 4 only concentrated on final consumption by private households. For our own model in Chapter 5, a main problem was that in the EU-25 (or EU-15) only statistics on household consumptions are available at a high level of detail; and that the classification of government expenditures are much less elaborated. Additional work could be undertaken to make an analysis of government expenditure for the EU-25 according to the same categorisations as used for households.

49 Several studies reviewed in Chapter 4 do not show a 80 – 20 rule. This is probably caused by the fact that most studies deal with functional areas of consumption or consumption domains, and hence have a much lower level of detail. The few underlying key products are not visible in themselves, but distributed over the different major categories which has a levelling effect.

50 After all, some of the products with a high impact per euro may be sold in (very) low volumes, so the total contribution to the total impact of consumption may not be large.

- Most studies reviewed, including the analysis in Chapter 5, have focused on *final consumption* of products only. It seems obvious that products used in a business-to-business context can also be of relevance for IPP. In principle, with input-output based models, it is possible to generate this additional perspective.

Concerning point b), given the potential of input-output approaches to support IPP but also other policies in the area of sustainable production and consumption, we think it would be very valuable to develop a structural environmental input-output table for the EU-25 at a high level of detail. In the US and Japan, such tables already exist and China is developing them. The current work in Chapter 5 necessarily had to be based on Europeanised foreign data. Though this did not compromise the results of this study with regard to its objectives, it is obvious that having a truly European table is preferable. For such an improvement of the data situation, roughly three strategies, each with a different time horizon and required effort, can be put forward:

1. Apart from the refinements suggested under a), some additional improvements and particularly further automation in the calculation procedures could be implemented in the CEDA EU-25 model. A list of suggestions is made in Annex 5.1.2. This can result in an easy to operate, reliable and flexibly adaptable model for the EU-25 giving results at a disaggregation level of some 500 product groupings[51]. This could be a solution for providing policy support in the short term (time horizon: 2-3 years).
2. Building a detailed environmental input-output table, giving results at a disaggregation level of some 500 product groupings, fully based on European data, making use of data gathering procedures in that area that are already operational. This might be realised in a time frame of 3 years or more.
3. Developing specifications for an 'ideal' Environmental input-output model for the EU-25, which would also require new data reporting procedures from, e.g. data already available at the level of EU Member States to a European entity such as Eurostat. While this approach may give the highest quality and detail, this is also the only option that seems realistic for a longer time horizon (5 year or more).

51 'Adaptable' in the sense, that new insights on e.g. emission factors within an industry sector, expenditures on product groupings, etc. can be easily implemented and that the subsequent changes in results are virtually instantly available. This would allow using the model in a much more interactive way than is possible now.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre