ENVIRONMENTAL IMPACT OF PRODUCTS (EIPRO)

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

IPTS/ESTO project

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Summary of the final report
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1 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.

2 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.

3 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.

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

4 Methodology

4.1 Definitions of product aggregates

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 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.

4.2 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).

4.3 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.

5 Analysis of existing studies

5.1 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

[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.

not at all identical. The review also showed that existing knowledge did not give a full picture of consumption in the EU-25.

5.2 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, 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.

5.3 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 – 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 – 3. Outside this set covering 80 % of the impact, there are still a large number of product groupings (30 – 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
  - housebuilding
- However, the results of the different studies show no conformity for the 'mid-range' of product groupings.

6 New environmental input-output analysis model for the EU-25

6.1 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.

6.2 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.

6.3General 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 goupings 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).

6.4Detailed 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.

7 Final results for each functional area of consumption

7.1 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 – 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 4-12 % of all products (CP01-12). The results reflect the impact of the full production chain, including the different phases of agricultural production.

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 20-35 % 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 – 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.

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

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 – 5 % to the environmental impacts of all products. Some results point to service providers, e.g. hairdressers, insurance agents, and government services.

7.2 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. From those 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.

8 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 – 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 – 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 – 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.