STUDY ON EXTERNAL ENVIRONMENTAL EFFECTS RELATED TO THE LIFE CYCLE OF PRODUCTS AND SERVICES

FINAL REPORT

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FOREWORD

The purpose of the study is to give a broad overview of environmental impacts related to the life cycle of product or service categories and to identify clear patterns.

There are still a lot of uncertainties regarding the quantification of external cost and their level of internalisation, due to the current state of the art of LCAs carried out at a macro-economic level as well as of monetarisation and environmental taxes applied to LCAs. It is important to view this study in its function to give a broad overview. Necessarily, this limits the amount of detailed analysis that could be applied on individual data. Therefore, most of the detailed figures presented in this report should not be seen as definitive.

However, several trends and more qualitative results are quite robust. In the conclusions drawn, we pointed out these quite robust results. Other results may need substantial rework before they can be used as a background for policy decisions. Nevertheless, they are interesting as an attempt to test the original methodology developed in this study.

We are grateful to the many experts who provided us with their help and comments at different key steps of the report's preparation.

EXECUTIVE SUMMARY

CONTENT

1. CONTEXT AND OBJECTIVES OF THE STUDY

■ In the past decade, environmental policymakers around the world have increasingly been looking at ways to improve the environmental performance of products across their life cycle. In February 2001, the European Commission launched a debate on these issues by means of the Green Paper on Integrated Product Policy IPP.

■ In that context, the European Commission, DG Environment, has commissioned the present study on external environmental effects related to the life cycle of products and services.

The purpose of the study is to give a good overview of the environmental impacts (both physical impacts and monetary quantification as far as possible) related to the various product groups which together make our economy and to identify clear patterns. The study also gives an overview of the distribution of these impacts across the various stages of the life cycle of these product groups and includes case studies on specific products and/or product-service systems.

This analysis includes two parts:

- analysis of the entire economy split into categories of products and services: this analysis included the monetarisation of the environmental impacts. This should allow identifying the importance of product categories with respect to the overall environmental impact of our economy. It should also give a basis to prioritise policy measures with a view to achieving a maximum environmental improvement.
- analysis of 18 case studies focusing on specific products or services with, for each of them, the comparison between alternative options fulfilling the same functions. The higher the differences between options, the more likely policy measures can lead to a significant environmental improvement.

The results are structured in a way to provide support for decision making in the prioritisation in the field of IPP.

***Caveats*: This study has to be seen as a pioneer work in the field of IPP, combining for the first time several dimensions –environmental impacts, external cost, life cycles, entire economy. Time and resource limitations only allowed an overview based on available knowledge. This study is based on a considerable amount of data which have been manipulated and aggregated (LCA data, external cost factors, environmental taxes…). Not all data and hypotheses could be verified and there are still many uncertainties. The results of this work offer a framework for prioritisation of potential policy measures. Before planning concrete measures it may however be useful and necessary to refine and review data and hypotheses. The study also gives a new methodological framework suitable for future in-depth works.**

2. A Specific Methodology Developed

■ The specificity of the methodology developed in this study is that it aims at integrating, for the first time and based on the current state of the scientific knowledge, four dimensions of IPP:

- all the major potential **environmental impacts** associated to products and services.

  In this study, an attempt is made to derive a simplified Life Cycle Assessment addressing product systems on a **macro-economic level** (i.e. integrating consumption patterns in the European Union), which can be called **"market-oriented LCA"**.

  The LCAs performed follow to a very large extent the ISO 14040 standards and are based on various existing life cycle inventory (LCI) database.

  The **functional unit** considered is the **quantity of products / services consumed to fulfil the demand of European consumers per year** (time reference: 1999).

- the **external costs** of these environmental impacts.

  Externalities are the costs imposed on society and the environment that are not accounted for by the producers and consumers, i.e. that are not included in market prices. They include damage to the natural and built environment, such as effects of air pollution on health, buildings, crops, forests and global warming; occupational disease and accidents; and reduced amenity from visual intrusion of plant or emissions of noise.

  In this study, environmental impacts assessed from LC Inventory inputs and outputs were monetarised. No ready-for-use database about external cost factors exist today in such a macro-economic and LCA-context. External cost factors used in this study were predominantly derived from existing cost factors resulting from "impact pathway" approaches.

- the different stages constituting the **life cycle** of products and services.

  The use of a life cycle-oriented approach in the framework of the IPP is justified by the fact that product and service categories present contrasted life cycle patterns.

- the main product and service categories constituting the **entire European economy**.

  34 categories of final products and services were selected in order to cover most of the entire economy with a view to presenting homogenous product groups for the purpose of policy making and to minimising double counting. They were classified according to a new classification of products and services defined for the purpose of the study, constituted of 13 families ("food and beverage", "clothing and footwear", "housing", "transport", "communication, recreation and culture"…).

■ An attempt was made to compare the degree of environmental externalities with the level of already existing environmental taxes:

- **Environmental taxes** were quantified, being considered as an attempt to internalise external effects, ideally aiming at prices to reflect the environmental impacts of products.

  To calculate the overall environmental taxes for the whole life cycle of a given product or service, we multiplied each environmental tax applying to a given LC inventory flow (inputs or outputs) with the flow quantified in the LCI. Because environmental taxes vary according to the country, **three countries** were considered and, for each of them, a catalogue of taxes in a format compatible with LCI was established.

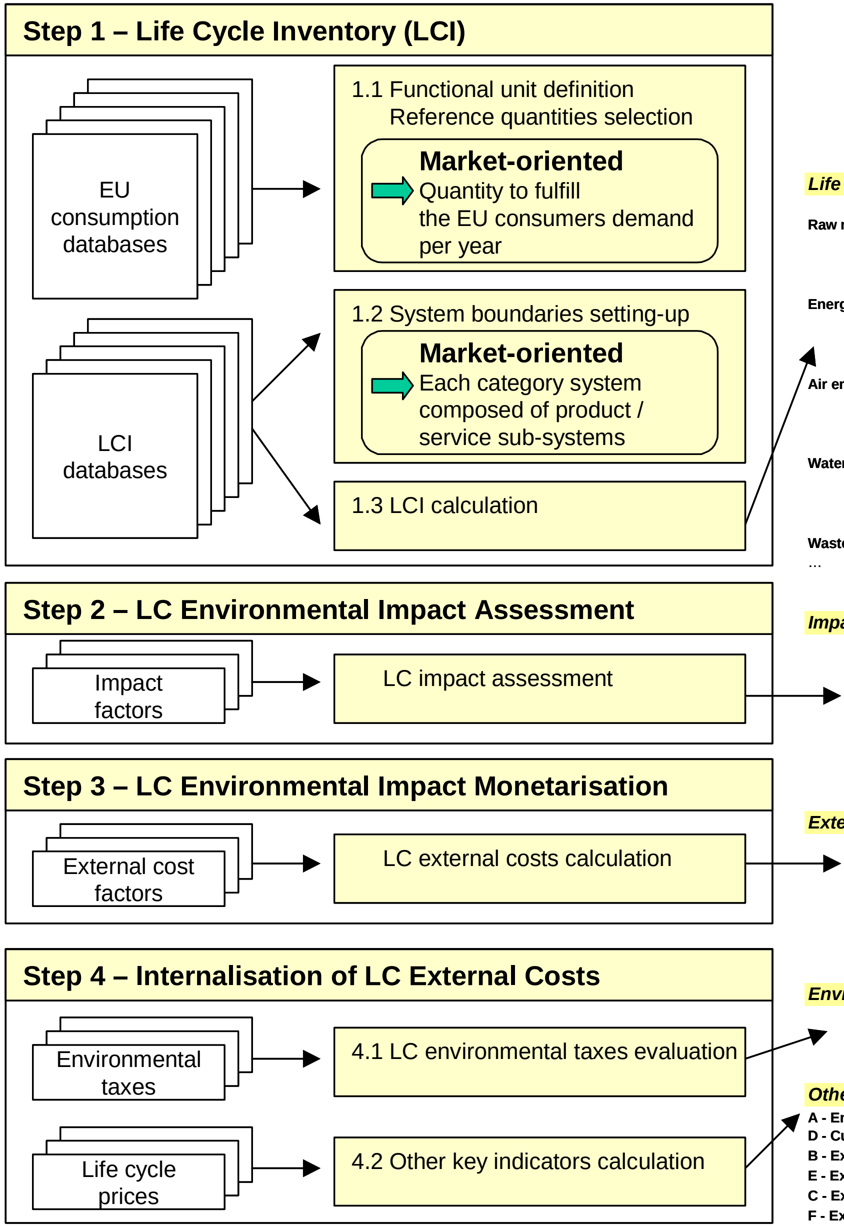
  Existing exemptions and variety of rates were taken into account through a range of minimum and maximum rates. This range was applied to all the categories, without further distinction made. This constitutes a rough approximation.

- The price considered is the **life cycle price**.

  It does not take into account only the selling price of the product or service paid by the consumer to the producer or retailer but also includes all the expenditures that the consumer will have to pay when using the product and then disposing of it at the end of its life. For each category, the life cycle prices were approximated with the average European households expenditures.

Life cycle price = Selling price + Use & End-of-life expenditures

Four-Step Methodology to Assess Environmental Impacts and Externalities of Products and Services Life Cycle at the Macro-Economic Level



Outputs for Each Product or Service Category

Life cycle inventory (LCI)		Total			Sub-system 1			...		
		Prod.	Use	End life	Prod.	Use	End life	Prod.	Use	End life
Raw materials										
(r) Barium Sulphate	kg									
(r) Bauxite	kg									
(r) ...	kg									
Energy consumption										
E Feedstock Energy	MJ									
E Fuel Energy	MJ									
E ...	MJ									
Air emissions										
(a) Acetaldehyde	g									
(a) Acetic Acid	g									
(a) ...	g									
Water emissions										
(w) Acids	g									
(w) Alcohol	g									
(w) ...	g									
Waste	kg									
...	...									

Impact assessment		Total			Sub-system 1			...		
		Prod.	Use	End life	Prod.	Use	End life	Prod.	Use	End life
Depletion of NRR	kg antimony eq.									
Global warming	g CO_2 eq.									
Air acidification	g SO_2 eq.									
Eutrophication	g PO4 eq.									
Human toxicity	g eq. 1-4-dichlorobenzene									
...	...									

External costs		Total			Sub-system 1			...		
		Prod.	Use	End life	Prod.	Use	End life	Prod.	Use	End life
Global warming	Euros									
Air acidification	Euros									
Human toxicity	Euros									
...	Euros									
Total ext cost	Euros									

Environmental Taxes		Total			Sub-system 1			...		
		Prod.	Use	End life	Prod.	Use	End life	Prod.	Use	End life
Total environmental taxes	Euros									

Other key indicators		Total			Sub-system 1			...		
		Prod.	Use	End life	Prod.	Use	End life	Prod.	Use	End life
A - Env[tal] taxes / External Cost	%									
D - Current Internalisation Level	high/low									
B - Ext Cost Not Internalised/ LC Price	%									
E - Ext Cost Not Internalised/ LC Price	high/low									
C - External Cost / LC price	%									
F - External Cost / LC price	high/low									

3. ATTEMPT FOR KEY IPP INDICATORS

Four families of IPP indicators were developed and tested in the study to help:

- summarising the huge number of figures gathered in such a work,
- key actors in their decision-making process.

- Indicators to characterise the representativeness of the results

- "Economic representativeness indicator": this indicator aims at assessing the representiveness of the studied categories compared to the whole economy that is supposed to be covered.

  Overall, between 60% and 75% of all expenditures made by individuals are represented by the various categories included in the analysis).

- "Environmental representativeness": the objective is to assess the representativeness of the environmental impacts quantified in this study with a bottom-up approach compared to the total impacts generated at the European level assessed through top-down approaches.

  This also gave a high degree of representativeness. For example, the global warming impacts related to the product groups covered by the study and calculated by adding the contribution of all categories considered represents between 80 to 95% of the overall global warming effects assessed by the Environmental European Agency.

- Environmental indicators

The environmental impacts selected include those linked to resources consumption (non renewable resources depletion), air emissions (global warming, air acidification, photochemical oxidation…), water releases (eutrophication). They encompass human health and ecotoxicological aspects.

- External cost indicator

The total external cost, resulting from the monetarisation of the various environmental impacts generated by the life cycle studied, is assessed.

- Key indicators about external costs internalisation

As a first attempt, six key indicators were defined to analyse the internalisation of external costs into prices.

Intermediary Indicators *Indicators **quantified** from data calculated in the study*	**Decision-Making Oriented Indicators** *Indicators derived from intermediary indicators* *and expressed with **semi-quantitative scale to compare categories***
A-Indicator = % of environmental taxes compared to external cost By calculating the percentage that the environmental taxes represent compared to the external cost, it gives information on the **current level of internalisation reached**[1]: - A-indicator **> or = 100%**: this means that the environmental taxes are higher than the external cost and thus, that external cost can be considered being **already totally internalised**, - A-indicator **< 100%**: this means that **only a part** of the external cost can be considered being **already internalised**.	**D-Indicator = current level of internalisation reached** D-Indicator is directly dependent on A-indicator value: - D-Indicator = relatively high if A-Indicator > or = 100%, - D-Indicator = relatively medium for intermediary values of A-indicator, - D-Indicator = relatively low if A-Indicator << 100%.
B-Indicator = % of external cost not yet internalised compared to life cycle price The external cost not yet internalised is taken equal to: - 0 if 100% of external cost is already internalised (i.e. if A-indicator > or = 100%). - External cost minus environmental taxes if less than 100% of external cost is already internalised (i.e. if A-indicator < 100%; in that case, environmental taxes are lower than external cost).	**E-Indicator = importance of externalities not yet internalised compared to the overall life cycle price** E-Indicator is directly dependent on B-indicator value: - E-indicator = relatively high for the highest values of B-indicator, - E-indicator = relatively medium for intermediary values of B-indicator, - E-indicator = relatively low for the lowest values of B-indicator.
C-Indicator = % of external cost compared to life cycle price The comparison of the orders of magnitude of both external cost and life cycle allows to check if the external cost is higher or lower than the life cycle price and if their difference is important or not. - C-Indicator > 100% means that external cost is higher than LC price, - C-Indicator < 100% means that external cost is lower than LC price.	**F-Indicator = importance of externalities compared to the overall life cycle price** F-Indicator is directly dependent on C-indicator value: - F-indicator = relatively high for the highest values of C-indicator, - F-indicator = relatively medium for intermediary values of C-indicator, - F-indicator = relatively low for the lowest values of C-indicator.

[1] The hypothesis being indeed that the environmental taxes are the means to internalise external cost.

4. MAIN LIMITS OF THE STUDY

The methodology and the calculation tool developed in this project proved to fit well to this first quantification exercise and constitute a robust framework for further quantifications.

The difficulties faced during the study were thus mostly linked to the interpretation of the results, because of several uncertainties characterising numerous input data.

The limits of the study come from three main sources:

- Environmental impacts: limits are due to several issues, including the lack of available data about all the categories under consideration, a heterogeneous and not always very good level of reliability and accuracy of the available inventory datasets, the calculation modelling used to describe the physical phenomena linked to the environmental impacts, the temporal / geographical / technological representativeness of the data.

  Furthermore, as in LCA studies in general, uncertainties about toxicity and ecotoxicity are likely to be high.

- External cost: apart from the uncertainties which are directly linked to the monetarisation methods themselves (and which are not discussed in this project), some limits occur when combining results from monetarisation and LCA, in particular potential global impacts (LCA) with actual location and source-specific external cost factors (monetarisation).

  Besides, ranges were used for external costs to reflect the diversity of values existing in literature for the environmental impacts moneratised. But **actual external costs are likely to be higher than those assessed in this study** because first cost factors do not exist today for all the environmental impacts quantified in LCAs (they concern more air emissions than eutrophication or depletion of resources for instance) and secondly several environmental impacts are not quantified in LCA and then not monetarised (noise, odor, nature conservation, land disturbance, disamenity[2], risk of accidents…). As a consequence, **the max values presented do not correspond to actual maximums**.

- Environmental taxes: **actual environmental taxes are likely to be closer to the lowest values of the ranges assessed rather than the highest values**.

  This directly results from the way the ranges were built, in a context where available tax data were not in a format compatible with LCA: a tax factor was determined for each main input and output quantified in LC inventory and then applied to all the categories. Existing exemptions and variety of rates were taken into account through a range: the min corresponds to the minimum rates and the max corresponds to the maximum rates (without taking into account specific exemptions and subsidies applying to some categories and flows[3]).

  As a consequence, **the max value of the environmental tax range corresponds to a true maximum value (as if all the maximum rates would apply to all categories and flows) but is not reachable (because of exemptions and subsidies).**

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[2] Local nuisance impacts including odour, noise, dust, litter….

[3] This work would require an important and dedicated research program.

5. KEY RESULTS OF THE ANALYSIS OF THE ENTIRE ECONOMY THROUGH CATEGORIES

- Preliminary comment

One should keep in mind that the results presented below concerning the relative contribution of the various categories are dependent on the classification selected at the beginning of the study. The major point to be mentioned is probably the fact that environmental impacts (and associated external costs) linked to the distribution of products are not systematically accounted for in the product categories concerned. Instead, a specific category, “Transport”, was considered separately. As indicated below, “Transport” is one of the two major contributors at the European level. If this category would have been split between all the other categories, the contribution of these would have been higher. It is not easy at that stage to predict how the relative contribution of each category would be modified.

A more comprehensive analysis based on industrial or activity sectors (chemical industry, packaging industry, leather industry, transport…) would be likely to bring interesting results, given a large proportion of these sectors are common to numerous products or services categories and when focusing primarily on products or services groups as in this study, the impacts of these industrial or activity sectors are split (and diluted) between categories. But such a comprehensive analysis would face a lack of available LCA data.

- Environmental Impacts Generated in the EU

Most of the environmental impacts linked to resources consumption and air emissions are generated by two main categories, for which the use stage is predominant:

- transport (goods transport and private transport of passengers by car),
- building occupancy (mainly due to the energy used to heat domestic and commercial buildings).

“Food products” production generates most of the water emissions contributing to eutrophication (mainly from “vegetables” due to the use of fertilisers) and photochemical oxidation (mainly from “food from animals”[4] due to enteric fermentation and manure management).

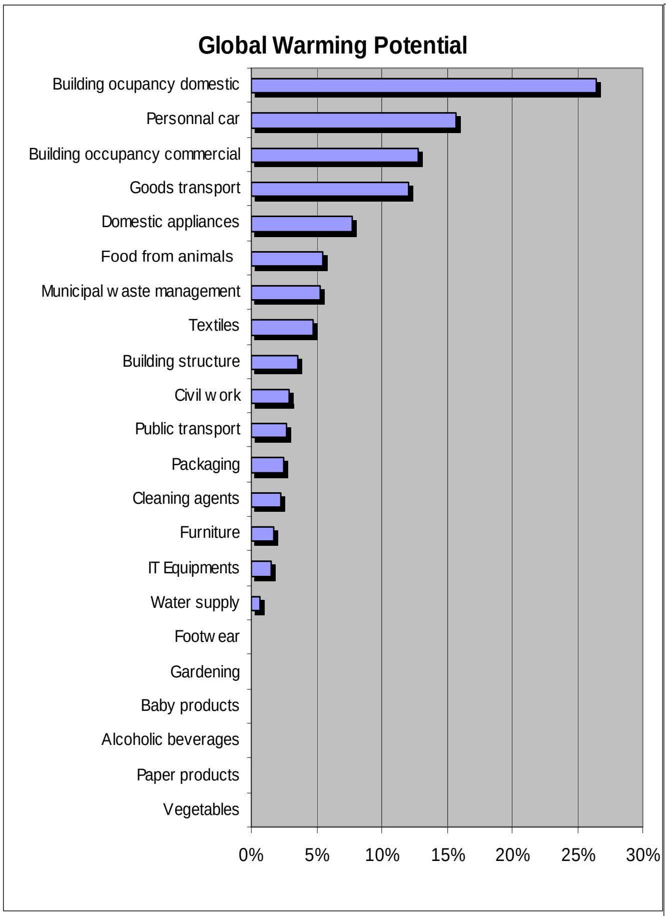
As for toxicity and ecotoxicity risks as well as solid waste, LCA data being of relatively poor quality and heterogeneous according to products, results are less robust. However, one can mention that the main categories contributing toxicity and ecotoxicity risks are different according to the type of toxicity considered and, from data available, appear to be the following for human toxicity risk:

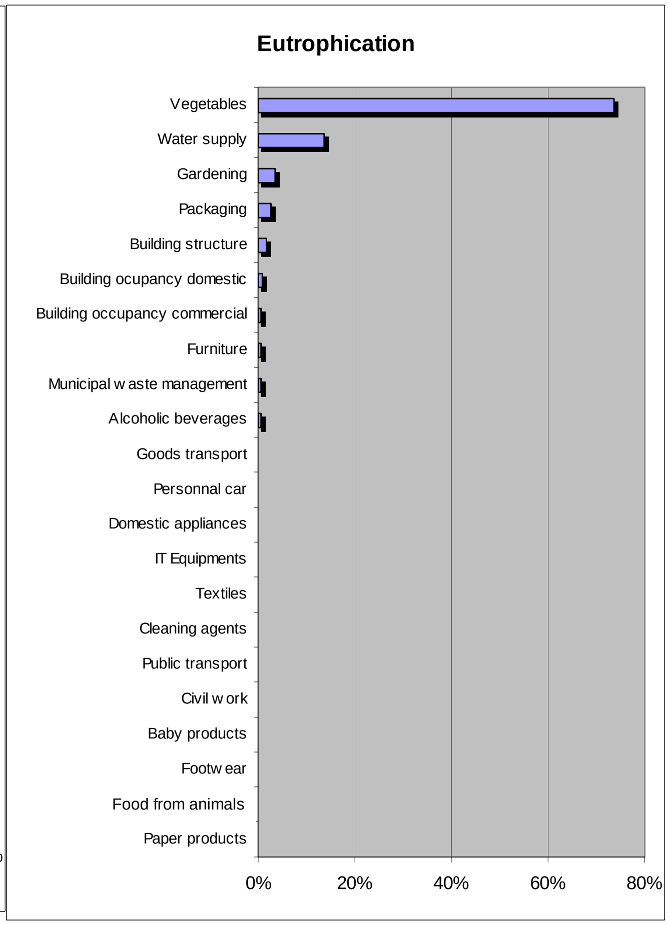
- “Water supply” explains toxicity risks on human health (mainly due to the AOX content of sewage sludge (end of life step) associated with “waste water treatment”),
- As for the “years of life lost” indicator, the main burden comes from “transport” and “building occupancy” (due to several air emissions: dusts, NOx, SOx, VOC).

4 Meat and dairy products.

Contribution of the Different Categories to Environmental Impacts at the EU Level

	Total EU impacts (all the categories together) = 100%			
	10-20%	***20-40%***	***60-80%***	***40-60%***
A/ Environmental Impacts				
Depletion of non renewable resources	EEE	**Building occupancy** Transport		
Greenhouse effect				
Air acidification				
Ozone Depletion		Building occupancy		**Transport**
Photochemical oxidation	Building occupancy	**Transports** Food products		
Eutrophication	Water supply		**Food products**	
Human Toxicity	Packaging		**Water supply**	
Years of Life Lost	EEE	Building occupancy		**Transport**
B/ Other Environmental Indicators				
Primary energy		**Transport** Building occupancy		
Dusts	EEE Transport	**Building occupancy**		
Metals into air				**Building occupancy**
Metals into water		EEE		
Metals into soil		Transports Water supply		**MSW management**





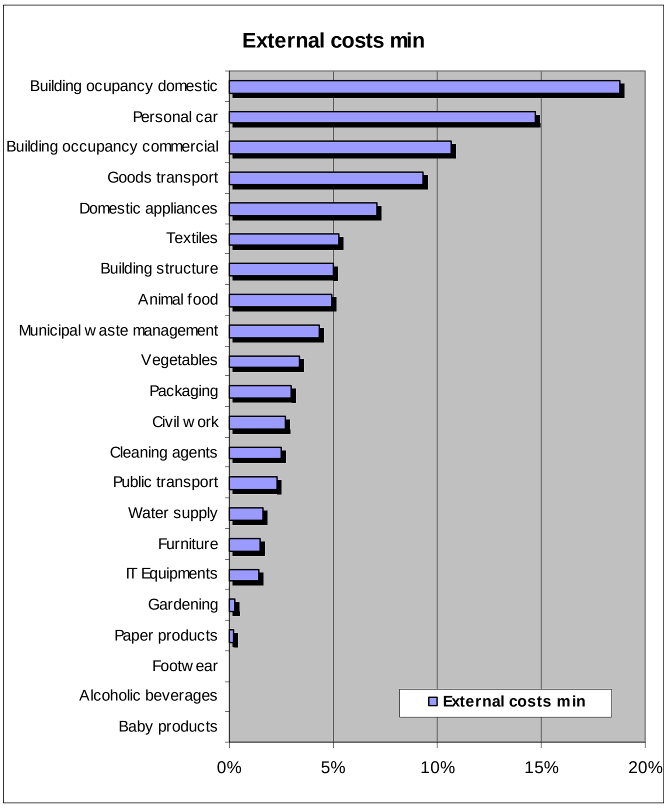
NB: more graphics are presented in the report

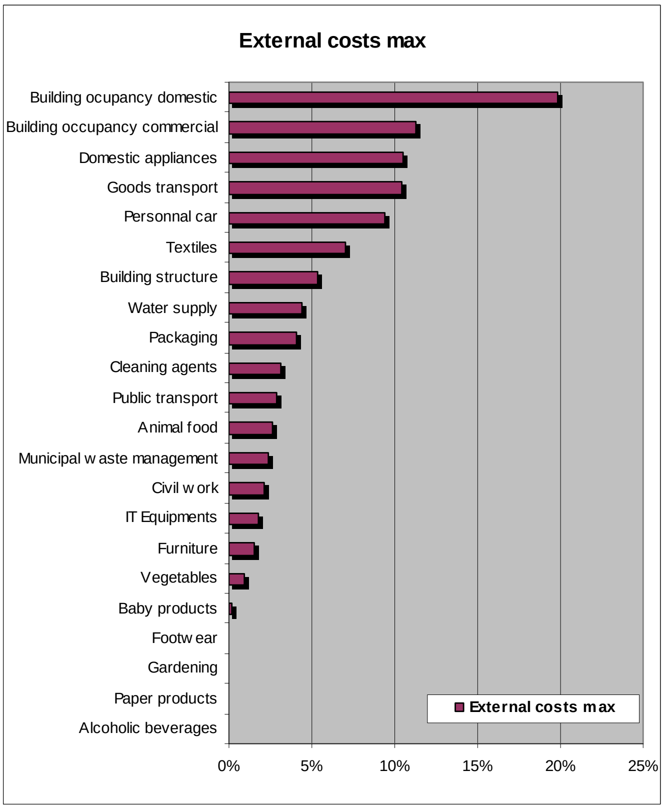
External Cost of the Environmental Impacts Generated in the EU

Considering the current state of the art of environmental impacts monetarisation applied to LCA, the range in which the external cost varies is large: the minimum is likely to be near 220 and the maximum is higher than 960 Euros / capita per yr (higher because several environmental impacts are not monetarised).

More than 50% can be allocated to greenhouse effect and another significant proportion to human health effects caused by dusts. The use stage of the products / services consumed in the EU is likely to be at the origin of more than 60% of the overall external cost: transport (goods transport and personal cars) and building occupancy (mainly space heating of domestic and commercial building) are the main contributing categories.

Contribution of the Different Categories to the Overall External Cost at the EU Level
(in % of the total generated by all the categories studied)





■ Internalisation of Environmental External Costs

In order to assess the level of internalisation, two types of data are useful:

- life cycle price: the overall life cycle price (all categories altogether) assessed in this study amounts approximately to 5 920 Euros / capita / year.
- environmental taxes: the total amount of environmental taxes linked to the product categories considered is assessed to be somewhere in a large range, between about 1 550 and 4 800 Euros / capita / year[5], very probably closer to the low value of the range (because of exemptions and subsidies, in particular concerning energy). The highest environmental tax revenue is that from energy related taxes and the second highest is linked to water effluents related taxes.

  When compared to the life cycle price, environmental taxes represent a significant proportion, which is somewhere between 25% and 80% of the life cycle price[6] (probably closer to the low value of the range than to the high value).

  Remark: much of the revenue of so-called "environmental taxes" is not used for environmental purposes. This should be seen as a limitation to classify the taxes as environmental.

The precise quantification of the six indicators about internalisation was not very conclusive at that stage.

Overall, the level of "environmental taxes" often exceed calculated environmental externalities. This statement should however be taken with much care as "environmental taxes" are often not used for environmental purposes. Furthermore, the identified levels of taxes tend to be maximum levels, as exemptions and subsidies are not fully taken into account whereas the calculated levels of environmental externalities tend to be minimum values due to the omission of factors for which there are insufficient data to allow monetarisation.

However, it was possible to draw preliminary conclusions about the relative positioning of the categories, according to some of these indicators.

The study identified categories for which the level of externalities relative to environmental taxes seemed to be the lowest compared to other categories.

(D-indicator) Current Level of Internalisation of the External Cost
Possible Relative Position of the Categories

-		+
Vegetables MSW management	Goods transport Personal cars Passengers public transport Civil work Building occupancy – Domestic sector Building occupancy – Commercial sector Cleaning agents – Textile detergent Cleaning agents – Personal care EEE – IT EEE – Domestic appliances Food from animals Baby products	Water supply Building structure Furniture Textiles Beverage Gardening Packaging Paper products Footwear

5 At least in Denmark and France, which are representative of European countries with a quite developed environmental taxation system.

6 It is assessed to represent "only" between 5 and 40% in Poland.

The study also identified categories for which the share of environmental externalities compared to overall life cycle price seemed to be the lowest compared to other categories.

(F-Indicator) Importance of Environmental Externalities Compared to Life Cycle Price

- → **+**

At least 1%	***At least 5%***	***At least 5 to 15%***	***At least 5 to 25%***	***Not Been Assessed***[7]
Beverage Paper products Footwear Building structure	Furniture Cleaning agents Vegetables Food from animals	Personal cars EEE – IT Textiles	EEE – Domestic appliances Building occupancy – Domestic sector Water supply Passengers public transport	Goods transport Baby products Gardening MSW management Civil work Packaging Building occupancy – Commercial sector

These conclusions should be considered as a first attempt to compare categories rather than as definitive prioritisation.

[7] No data available to approximate the life cycle price.

6. Key Results of the Case Studies

■ **Significant differences between options exist at a micro-economic level** (higher than 20% and up to more than a 100 factor for the case studies performed), if not for all of the main environmental impacts considered (renewable resources, global warming, air acidification, photochemical oxidation, human toxicity), at least for some of them.

Repartition of the Case Studies according to the Level of the Differences between Options

	Factor between the option having the lowest environmental impact and the option having the highest environmental impact[8]			
	1.2 to 2[9]	2.1 to 10	11 to 100	101 to 1000
	- **Improvement potential** +			
Case Studies	▪ Personal computers*	▪ Screen computers ▪ Lamps* ▪ Floor coverings* ▪ Liquid packaging systems ▪ Car pooling ▪ Tablecloths ▪ Flushing systems	▪ Fuels for vehicles ▪ Road paint* ▪ Insulation ▪ Goods transport ▪ Passengers transport ▪ Agriculture ▪ Plates	▪ Space heating ▪ Meeting

■ **The choice between various options corresponding to a given function can make a significant difference at the European level** (i.e. can provide significant environmental benefits in the order of magnitude of several percentage points) **for mainly two categories**:

- **goods and passengers transport** (in particular transportation means and type of fuels),
- **building occupancy** (in particular type of energy consumed and energy efficiency).

■ **For the other categories**, options exist which provide significant environmental benefits at a micro-economic level, i.e. for a given functional unit.

However, **these benefits are less significant for the whole European economy** as a result of the smaller share of these categories on the overall environmental impacts. **Nevertheless, this does not prevent these choices between options from being important because when adding all these relatively minor environmental benefits, the decrease of environmental burdens becomes significant at the European level**, with an order of magnitude which can be, for certain environmental impacts, comparable to those of transport and building occupancy.

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[8] the highest factor reached for at least one environmental impact

[9] i.e. the “worst” option has an impact 20% to 200% higher than the “best” option

6. FURTHER RESEARCH WORK

Further research work will be necessary in the future:

- a standardisation work to classify products and services consumed in the EU within a life cycle perspective,
- a concerted European effort to establish a whole easily accessible LCA database of good quality,
- the development of a database of external cost factors applicable to LCI data (inputs and outputs occurring all along the life cycle of products and services),
- the elaboration of a catalogue of environmental taxes in a format compatible with LCA and the design of a method to better take into account, at a macro-economic level, specific exemptions and subsidies applying to only some categories and flows,
- an in-depth work to define more precisely relevant IPP indicators in order to satisfy decision-makers expectations and in the same time take into account the uncertainties which are still important for several basis data,
- further thought given to the prospective dimension which is necessary to be included when elaborating a policy (in particular IPP).

CONTENT

1 PART 1 - METHODOLOGICAL FRAMEWORK

1.1 OBJECTIVES AND CONTENT OF THE STUDY

1.1.1 Background of the Study

In the past decade, environmental policymakers around the world have increasingly been looking at ways to improve the environmental performance of products across their life cycle. In February 2001, the European Commission published its thinking on these issues by means of the Green Paper on Integrated Product Policy[10], which states that:

"*The environmental performance of products can best be optimised by the market once all prices reflect the true environmental costs of products throughout their life cycle. However, this is not always the case and there are market failures ("external costs"). In order to provide an evaluation of these external costs, it is essential that objective criteria are established to assess the environmental performance of products.*

On the basis of these criteria, the Commission intends to investigate the main price elements which are not in conformity with the polluter pays principle and which prevent that environmental efforts made by companies are properly rewarded in product prices. The associated external cost shall be quantified as far as possible. These investigations should assist in identifying the main stages of the life cycle of products, including transport, where external costs occur and in conceiving measures to better take into account these external costs in the price of new products and/or elements related to their use".

In that context, the European Commission, DG Environment, has commissioned the present study on external environmental effects related to the life cycle of products and services.

1.1.2 Objectives of the study

The purpose of the study is to give a good overview of the environmental impacts (both physical impacts and monetary quantification as far as possible) related to the various product groups which together make our economy.

The study also gives an overview of the distribution of these impacts across the various stages of the life cycle of these product groups and includes case studies on specific products and/or product-service systems.

The results are intended to provide comparisons of the various product groups on the basis of the following ratio: external effects / market prices (do market prices reflect the true environmental costs of products throughout their life cycle ?).

The results are reported in the most informative way as possible in order to provide support for decision making in the prioritisation of targets in the field of IPP.

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[10] COM(2001) 68 final, 07.02.2001

1.1.3 Content of the Study

The project was performed according to three phases:

- **Phase one (life cycle assessment : LCA)**: to give a thorough overview of the different environmental impacts related to the life cycle of the various categories of products and services consumed in the European Union and candidate countries; then to show the distribution of impacts across the life cycle stages of main product and service categories.
- **Phase two (monetary evaluation)**: to evaluate (as far as possible) these environmental impacts in monetary terms, and estimate to what degree these impacts are covered by current prices and which share would be external effects.
- **Phase three (case studies)**: to show the difference in environmental impacts and externalities related to the life cycle of various options to satisfy the same consumer demand (case studies).

A workshop with key experts in this field was organised during the project to discuss about key methodological issues.

1.2 Product or Service Categories Covered by this Study

1.2.1 Classification Elaborated

■ According to the terms of reference, 20 to 30 categories of final products and services had to be selected in order to cover the entire economy, be broadly representative and allow most products and services to be allocated to an individual category with representative environmental impacts.

Remark: the term 'final products' designates products which need no additional transformation prior to their use.

In the domain of environmental policy, there is no standard approach to classify products and services consumed in the EU within a life cycle perspective (life cycle assessment is a tool which has been generally applied at a microeconomic level).

Our starting point was to investigate the existing official classifications (see Appendix 1). But they present several drawbacks regarding the purpose of the study that did not allow us to use them directly, even the statistical classification of products by activity (CPA).

Some Existing Classifications

Classification	Main characteristics	Drawbacks in the scope of this study
NACE Rev. 1 (Nomenclature générale des Activités économiques dans les Communautés Européennes)	Set up in 1970 in order to harmonise the national economic activities classification. Basis for statistics on production, production factors…. Revised version compulsory since 1993. Organised on four levels: section (A to Q), division (01 to 99), group (additional digit) and class (additional digit).	Activity oriented, not product oriented
CPA (Classification of Products by Activity)	Covers products generated by each activity, based on the NACE Rev.1 classification. The code is made of 6 digits, the first four being from the NACE classification and the last two being used for products.	Not life cycle oriented: products are classified according to their industrial origin. 1st consequence: intermediary products are classified, which can then have different life cycles according to their use. 2nd consequence: for a given final product (e.g. electrical equipment), its life cycle may cover different CPA categories (the production of the equipment itself, the production of the energy consumed during its use, the maintenance service during its use…)
PRODCOM	Details the C, D, and E sections of NACE Rev.1 by splitting them in products. Used to present production data by activity.	

■ A new classification of products and services had then to be established. Priority were put on five criteria:

- exhaustiveness: according to the terms of reference, the categories had to cover the entire European economy,
- representativeness: according to the terms of reference, the categories had also to allow most products and services to be allocated to an individual category with representative environmental impacts,
- relevance with the LCA approach: the chosen categories had to allow to take into account the different stages of the life cycle, including the use and the end of life steps,

- limitation of double-counting (for instance for intermediate products, to consider them separately as product categories and to include them in the life cycle of final products where they are consumed could generate double-counting),
- relevance with the IPP, in particular coherence with existing European classifications: the aim was to facilitate in the future the implementation of policies focusing on categories recognised by Member states[11].

Two complementary classifications were eventually elaborated.

Two Complementary Classifications

	Purpose	Principles and characteristics
"Final Products" Classification	To cover the entire European economy, taking into account the LCA approach constraint and limiting double counting	**27 categories of final <u>products or services</u> split into 7 families** 7 **families** corresponding to 7 major **consumption expenditures** in the European economy: - Food and beverages - Clothing and footwear - Housing - Healthcare and body care - Transport - Communication, recreation and culture - Other products and services In each family, 2 to 7 **categories** which are **more life-cycle oriented** (e.g. 3 categories in "Food & Beverage" family: "Vegetables", "Food from animals"[12], "Alcoholic beverages"): they gather products or services with significant similarities either at their production stage (similar components) or at their use step
"Transversal products" Classification	To focus on activity sectors or intermediate products / services common to most of the final products / services and for which environmental legislation already exists	**14 categories split into 6 families** (out of the 14 categories, 7 are new compared to the "Final products" classification) - Electric and electronic products and equipment - Construction work - Building occupancy - Packaging - Textile - Transport Each family is split into categories corresponding to the main sectors or intermediate products / services where final products / services are used. E.g. packaging into food and non food, EEE into domestic appliances and information technology equipment.…

[11] Being able to refer to existing European classifications also allowed us to gather macroeconomic data (such as consumption at the European level) used in the impact assessment phase (see $1.3.2.2).

[12] Meat and dairy products.

Remark: the "Transversal products" classification aggregates two types of data:

- products or activities not covered by the "Final products" classification[13],
- some data which are parts of some categories from the "Final products" classification[14].

For that reason, the two classifications are complementary, without generating significant double-counting (the double-counting are estimated to be less than 10% for the main environmental impacts - see section 2.1.1.3 for details).

- *Remark about consumption by enterprises*

Any consumption by enterprises is regarded as intermediate consumption – intermediate in the sense that it is an input into the production of goods and services. Theoretically, they are thus included in the Life Cycle Inventory of final products.

But because they are of interest for policy makers (they represent a significant part of the European Gross Domestic Product GDP and they can be subject to regulation), some of them are also explicitly covered by the study, in the two classifications (energy, transport, construction…).

Although theoretically taken into account in the LCI of final products, it could have been of interest for policy makers to have results for other categories of products and services specifically consumed by enterprises (such as machinery, equipment and apparatus), which represent a significant part of the European GDP. However, no LCI data are available or easily useable concerning these types of products or services. For that reason, it would not have been possible to include them in the present study, which does not prevent from integrating them at a later stage, when data are available.

Remark: regarding "machinery, equipment and apparatus" category, in default of having LCI data for that category, it is interesting to mention at that stage that the environmental impacts generated by the production of these equipments are usually not included in the life cycle inventory of final products. Sensitivity analyses made by LCA experts have shown that it is of minor impact on the overall LCA results of final products.

- **Thus the specificity of the classification used in this study includes the following:**

- **based on final products and services (not intermediary products) in the "Final products" classification and focusing on major transversal activities / products / services in the "Transversal products" classification,**
- **split into 13 families and 34 different categories covering most of the entire EU economy,**
- **few double counting.**

- Available LCI data allowed us to eventually study 27 categories out of the 34 different categories distinguished, through 18 different fact sheets.

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[13] packaging, transport, at least those which are not already included in the ready-for-use LCI of the upstream inputs

[14] Ex: electricity consumed during the use of EEE is both:

- in the EEE category of the "Transversal products" Classification, where their whole life cycle is taken into account,

- and part of the Housing family in the "Final Products" Classification, where the electricity consumed during the use of domestic appliances is taken into account in the "Domestic appliances" category.

- *Remark about services*

Services are included in the scope of the categories studied at different levels:

- several categories studied are focusing on services: "Water supply and waste water treatment", 3 types of "Transport", "Municipal waste management",
- although no specific fact sheets were elaborated for them, **other services** such as banking and financial services, hospitals, education services, public authorities functioning… **are partly integrated in several of the studied product-oriented categories**[15]**, through their consumption of specific products**: "Building occupancy – commercial sector", "Paper products", "Building structure – commercial sector", "Textile – industrial and non domestic use", "Footwear", "Packaging", "Food and beverages".

The following tables present the detailed classification used in this study, as well as the categories eventually studied ("1" in the first column) and the 19 fact sheets elaborated (cf appendix report).

They also indicate the corresponding sections of the CPA classification. Most of our categories refer to several CPA categories. As indicated above, products being classified in the CPA according to their industrial origin, the life cycle of a final product (e.g. electrical equipment) often covers different CPA categories (the production of the equipment itself, the production of the energy consumed during its use, the maintenance service during its use…).

It should be noted that this exercise was necessary in the framework of this study but it is not the end of the discussion on this issue. We had to find a compromise between being exhaustive and life-cycle oriented. But the categorisation used in this study still presents some weaknesses (e.g. products or services consumed by businesses and administration not well covered) which will not be overcome without a standardisation work.

[15] These categories cover not only households' consumption but the entire European consumption.

Product and Service Categories Classification Used in this Study

Factsheet in the study	**Family** (1) / Categories (2)	**Main relationships with the CPA classification**																											
		A	B	CA	CB	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM	DN	E	F	G	H	I	J	K	L	M	N	O
	Food and beverages																													
1	Vegetables	X				X																								
1	Food from animals	X				X																								
1	Alcoholic beverages					X																								
	Clothing and footwear																													
(5)	Textile (apparels and non domestic textiles)						X																							
1	Footwear (leather)							X																						
	Housing																													
(6)	Building structure (residential)				X				X			X	X	X	X						X									
(3)	Domestic appliances																X									X				
(7)	Building occupancy (residential sector) (heating, hot water, ventilation, domestic appliances, lighting)			X							X									X										
1	Water (supply and waste water treatment)																			X										
1	MSW management (recycling, incineration, landfill)																													X
1	Furniture																		X											
1	Cleaning agents											X																		
	Healthcare and body care																													
	Personal care products									X		X																		
1	Baby products									X		X																		
	Medecines and pharmaceuticals											X																		
	Transport																													
(4)	Public transport (road, rail, water, air)																	X						X						
(4)	Personal cars																	X						X						
	Communication, recreation and culture																													
(3)	Information technology equipment															X	X									X				
1	Paper products									X																				
	Games & toys																		X											
1	Gardening											X																		
	Jewelry																		X											
	Restaurants & hotels																						X							
(8)	Other services																													X
	Other products and services																													
	Machinery, equipment & apparatus															X	X													
	Other products																		X											
(8)	Other services																								X	X	X	X	X	

(1) Families correspond to major consumption expenditures in the European Union

(2) Categories are more life-cycle oriented (gather products or services with significant similarities either at their production stage (similar components) or at their use step)

(3) Included in Electric and Electronic Equipments factsheet (cf below)

(4) Included in Transport factsheet (cf below)

(5) Included in Textile factsheet (cf below)

(6) Included in Building Structure factsheet (cf below)

(7) Included in Building Occupancy factsheet (cf below)

(8) Banking, insurance… services are partially taken into account in other categories: 'Paper products' category above and 'Building structure (commercial sector)' and 'Building occupancy (commercial sector)' categories below

Product and Service Categories Classification Used in this Study (Contd)

'Transversal products' Classification (activity sectors or intermediate products or services common to most of the final products)

Factsheet in the study	Family / Categories	Main relationships with the CPA classification: A	B	CA	CB	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM	DN	E	F	G	H	I	J	K	L	M	N	O
1	**Electric and electronic products and equipment**															X	X									X				
	Domestic appliances																													
	Information technology equipment																													
	Construction work				X				X			X	X	X	X						X									
1	Building structure (commercial and residential)																													
1	Civil work (roads and other infrastructures)																													
1	**Building occupancy**			X							X									X										
	Residential sector (gas, fuel, electricity, biomass)																													
	Commercial sector (gas, fuel, electricity, biomass)																													
1	**Packaging**								X	X			X	X	X															
	Food (glass, paper, plastics, metals…)																													
	Non food (glass, paper, plastics, metals…)																													
1	**Textile**						X																							
	Apparel																													
	Home furnishing																													
	Industrial and non domestic uses																													
1	**Transport**																	X						X						
	Public transport (road, rail, water, air)																													
	Personal cars																													
	Goods transport (road, rail, water)																													

18	**factsheets presented in the study**

1.2.2 "Economic Representativeness" of the Product or Service Categories Considered

■ Two types of indicators are used in this report to assess the representativeness of the results of this study:

- "economic representativeness": this indicator aims at assessing the representiveness of the studied categories compared to the whole economy that is supposed to be covered.

  This indicator is described in this chapter.
- "environmental representativeness": the objective is to assess the representativeness of the environmental impacts quantified in this study with a bottom-up approach (see §1.3.2.1) compared to the total impacts generated at the European level assessed through top-down approaches.

  This indicator is described in section 2.1.1.

■ Assessing the economic weight that the studied categories compared to the whole economy present difficulties, linked to several points:

- Our categories are life-cycle-oriented, i.e. encapsulate various activity sectors or types of consumers, whereas available macro-economic data refer either to activity sectors or types of consumers (enterprises, individuals, non-profit institutions serving households and government).
- No homogeneous macro-economic data regarding the consumption of these types of consumers are available.

■ Considering the available macro-economic data, it was quite easy to quantify the "economic representativeness" of the categories considered for one type of consumers: individuals. For the other types of consumers, only a qualitative assessment can be made at that stage.

■ **The study reaches a good "economic representativeness" regarding the consumption of individuals, probably somewhere between 60 and 75%.**

Because it is not easy to assess the representativeness of the services which are only partially studied through some of the main products / services they consume, a range was assessed first considering that 0% of such services are studied and secondly than 100% of them are studied.

A detailed calculation is presented in the table next page.

■ **The study reaches a medium level of "economic representativeness" regarding the consumption of the other consumers (enterprises, non-profit institutions serving households and government), which can not be quantified.**

Because data related to consumption patterns of enterprises, public procurement and non-profit institutions are not available with the same detail as those of individuals, it is not easy to quantify the "economic representativeness" of the study regarding this portion of the economy.

But only few product or service categories specifically consumed by government or enterprises are not covered by the two classifications used of the study, such as: maintenance of specific material such as defence equipment, aeronautics…

“Economic Representativeness” Regarding the Consumption of Individuals

		Purchasing Power Standard - PPS in the EU				Corresponding category in the study
		Per household	Per capita	% T1/T3	% T2/T3	
		Average nb of persons / household	*2,54*			
Studied						
Hair care + Skin care			59,19 €	1%	1%	Cleaning agents
Toileteries			31,71 €	1%	0%	Cleaning agents
Clothing		1 204,39 €	474,17 €	8%	6%	Textiles (for apparel)
Footwear		291,53 €	114,78 €	2%	2%	Footwear
Household textiles		153,07 €	60,26 €	1%	1%	Textiles (for home furnishing)
Furniture & furnishing, carpets		651,93 €	256,67 €	4%	3%	Furniture (domestic)
Tools & equip for house and garden		125,66 €	49,47 €	1%	1%	Furniture (garden)
Rentals for housing - Maintenance, repair of the dwelling		5 174,88 €	2 037,35 €	34%	27%	Building structure
Electricty, gas, others fuels		972,53 €	382,89 €	6%	5%	Building occupancy
Motor car		1 568,53 €	617,53 €	10%	8%	Transports
Railway		84,91 €	33,43 €	1%	0%	Transports
Road		114,38 €	45,03 €	1%	1%	Transports
Air		58,07 €	22,86 €	0%	0%	Transports
Fuels and lubricants		857,46 €	337,58 €	6%	5%	Oils & lubricants
Telephone+fax equipments		39,28 €	15,46 €	0%	0%	EEE (IT equipment)
Household appliance		234,66 €	92,39 €	2%	1%	EEE (Domestic appliances)
Audio-visual equipments		127,00 €	50,00 €	1%	1%	EEE (IT equipment)
Information processing equipments		119,00 €	46,85 €	1%	1%	EEE (IT equipment)
Recording media		101,70 €	40,04 €	1%	1%	EEE (IT equipment)
Telephone and fax services		495,14 €	194,94 €	3%	3%	EEE (IT equipment)
Books		126,35 €	49,74 €	1%	1%	Paper products
News papers & periodicals		207,07 €	81,52 €	1%	1%	Paper products
Miscellanous printed paper		30,92 €	12,17 €	0%	0%	Paper products
Meat		898,69 €	353,81 €	6%	5%	Animal food
Milk, cheese and eggs		500,38 €	197,00 €	3%	3%	Animal food
Alcoholic beverage (wine)		179,23 €	70,56 €	1%	1%	Alocoholic beverage
Vegetables		360,23 €	141,82 €	2%	2%	Vegetables
Fruits		260,38 €	102,51 €	2%	1%	Vegetables
Water supply		367,80 €	144,80 €	2%	2%	Water supply and waste water treatment
Sub-total products & services studied, "partialy studied services" excluded	t1	**14 937,37 €**	**5 971,76 €**			
Insurance and financial services		963,00 €	379,13 €			
Recreational and cultural services		593,00 €	233,46 €			
Package holidays, rest. & hotels		2 153,00 €	847,64 €			
Sub-total of some of the "services partialy studied"	t2	**3 709,00 €**	**1 460,24 €**			
TOTAL domestic expenditures studied, "partialy studied services" excluded	T1=t1	**14 937,37 €**	**5 971,76 €**	**61%**		
TOTAL domestic expenditures studied, "partialy studied services" included	T2= t1+t2	**18 646,37 €**	**7 431,99 €**		**76%**	
Not studied						
Other food		1 625,78 €	640,07 €			
Non alcoholic beverages		301,53 €	118,71 €			
Other alcoholic beverages		258,41 €	101,74 €			
Other products and services		4 034,91 €	1 588,55 €			
Sub-total not studied	t3	**6 220,63 €**	**2 449,07 €**			
TOTAL domestic expenditures	T3= t1+t2 +t3	**24 867,00 €**	**9 790,16 €**			

■ Other checking were also made for specific flows quantified in this study, which show the good representativeness of the study:

Flow	***EU data***	***Total of all the categories covered by this study***
Consumption of primary energy for domestic use	382 Euros / capita / yr	average European price for electricity, fuels and gas x total electricity, fuels and gas consumption = 363 Euros / capita / yr
Consumption of detergent for household textiles	12 kg / capita / yr	12 kg / capita / yr

1.3 Methodology Elaborated to Assess Environmental Impacts and Externalities of Products or Services Life Cycle at a Macroeconomic Level

1.3.1 Overall Description of the Four-Step Methodology

■ The specificity of the methodology developed in this study is that it aims at **integrating, for the first time** and based on the current state of the scientific knowledge, **four dimensions of the Integrated Product Policy**:

- all the major potential **environmental impacts** associated to products and services.

  The potential environmental impacts that are traditionally studied include those linked to resources consumption (non renewable resources depletion), air emissions (global warming, air acidification, photochemical oxidation…), water releases (eutrophication). They encompass human health and ecotoxicological aspects.

- the **external costs** of these environmental impacts.

  Externalities are the costs imposed on society and the environment that are not accounted for by the producers and consumers, i.e. that are not included in market prices. They include damage to the natural and built environment, such as effects of air pollution on health, buildings, crops, forests and global warming; occupational disease and accidents; and reduced amenity from visual intrusion of plant or emissions of noise.

- the different stages constituting the **life cycle** of products and services.

  The interest of a life cycle-oriented approach in the framework of the IPP is justified by the fact that product and service categories present contrasted life cycle patterns. For instance, as the study shows (see section 2), the use stage is predominant for "transport" category, the production stage for "food" and the end of life stage for "building structure".

- the main product and service categories constituting the **entire European economy**.

  The large coverage of the study will help policy-makers in their prioritisation process to identify product or service categories for future policy development or implementation.

■ LCA[16] is an important tool to support IPP work, alongside other key methodologies such as material flow analysis. LCA is however the most comprehensive approach to assess environmental impacts[17] of products/services in quantitative terms throughout their lifecycle. That is why DG Environment required that this study was based on LCA. It had to be adapted to the specificities of the study, in particular its macroeconomic dimension, as it will be explained in the next sections of the report.

As for the evaluation of external costs, numerous projects have been launched during the last ten or twenty years and major research works are still on-going. But none of the existing monetary valuation methods have been developed in a full LCA-based context[18]. It was not the purpose of this project to

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[16] The term LCA is used as defined in ISO 14040: "*compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its lifecycle*".

[17] Or "burdens".

[18] Several have been carried out on a life cycle basis, such as ExternE studies, but focusing on specific flows or aspects from life cycle, such as energy.

undertake such a work but only to derive cost factors from existing literature. The way how this part of the project was handled, as well as the difficulties encountered, are detailed in chapter 1.3.3.

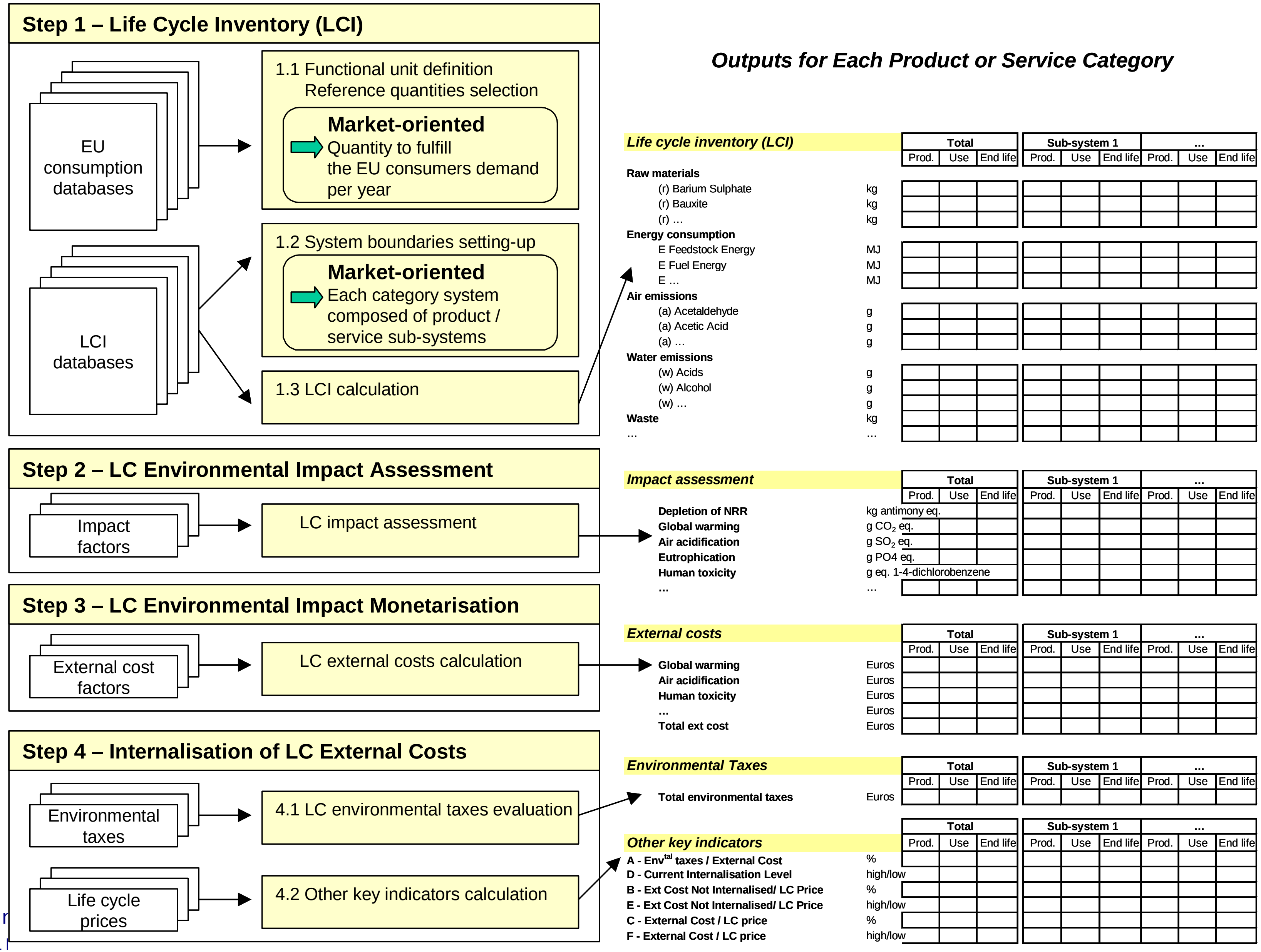
- The elaborated methodology is constituted of four steps:

1. **Life Cycle Inventory (LCI) step**, to inventory and quantity all the inputs from nature and outputs to nature occurring along the life cycle of products and services,
2. **Environmental Impacts Assessment step**, to assess the environmental impacts generated by the inputs and outputs quantified,
3. **Monetarisation step,** to assess the external costs of the studied life cycles,
4. **Internalisation step,** to estimate the part of external costs already internalised into prices.

This is a **bottom-up approach**, first looking at the product or service life cycles individually, then transposing them to the European macroeconomic level.

Remark: Given that the results of the Environmental Impacts Assessment step are multi-criteria (the environmental impacts quantified are expressed in different units which prevents them from being aggregated on an objective basis), the monetarisation step may be seen as a way to obtain a global score for the life cycles analysed, which may facilitate the decision-making process for policy makers.

Four-Step Methodology to Assess Environmental Impacts and Externalities of Products and Services Life Cycle at the Macro-Economic Level



1.3.2 Methodological Framework for the Assessment of the Environmental Impacts

In this LCA methodological part, we will successively discuss:

- Market-oriented LCA, as LCA adapted to the macroeconomic dimension of the study,
- Key methodological aspects of LCI and LCA: functional unit, system boundaries, inventories, environmental impacts assessment,
- Limitations and Uncertainties Linked to the LCI & LCA steps.

1.3.2.1 Market-Oriented LCA

■ Life cycle assessment (LCA) is a decision support tool supplying information on the environmental effects of products. It provides information on the environmental effects and potential impacts of all the stages of product life cycle (from “cradle to grave”), by :

- compiling an inventory of relevant inputs and outputs of a product system throughout its entire lifecycle,
- assessing the potential environmental impacts associated with those inputs and outputs,
- interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.

LCA is a product-oriented environmental assessment method which has been generally used at a micro-economic level (process-oriented LCA, product-oriented LCA, waste-oriented LCA). A product system is the part of the economy that produces a certain amount of service that is called "functional unit" in LCA.

In this study, an attempt is made to derive a simplified Life Cycle Assessment addressing product systems on a **macro-economic level** (i.e. integrating consumption patterns in the European Union), which can be called “**market-oriented LCA”**. Such a method is particularly relevant for the reduction of the environmental burden caused by a wide range of products satisfying different consumer demands.

■ The definition of LCA with the most authority nowadays is the ISO 14040 definition (ISO 14040, 1997).

In this ISO “code of practice”, LCA is divided into four main steps:

- Step 1 - Goal definition and scope

  The products to be assessed are defined, a functional basis for comparison is chosen and the required level of detail is described.

- Step 2 - Inventory analysis

  The inputs - energy and raw materials used - and outputs - emissions to the atmosphere, water and land - are quantified for each process and then combined in the process flow chart (life cycle inventory, LCI).

- Step 3 - Impact assessment

  The effects of the resources used and emissions generated are grouped and quantified into a limited number of impact categories which may then be weighted for importance.

- Step 4 - Improvement assessment

The results are reported in the most informative way as possible and the need and opportunities to reduce the impact of the product(s) on the environment are systematically evaluated.

Key methodological issues related to steps 2 and 3 are described hereafter (the goals of the study being described in section 1.1.2 Objectives of the study, the scope in section 1.2 Product or Service Categories Covered by this Study and the "improvement assessment" step 4 being not part of the study).

1.3.2.2 Functional Units

■ A functional unit is a measure of the performance of the functional outputs of the product system under study. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results.

The ISO 14040 defines the functional unit as "a quantified performance of a product system for use as a reference unit in a life cycle assessment study".

■ The study dealing with about 30 categories of products representative of our economy at a macro-economic level and having to be compared, we had to chose a common functional unit relevant for all of them.

The chosen functional unit, consistent with the goal of the study, is:

quantity Q of products needed to fulfil the demand of European consumers per year.

with:

- **Time reference: 1999**
- **Geographic reference: European Union**
- **Scope reference: consumption (importation of goods are thus part of the system boundaries but not exportation).**

The quantity Q of commodities needed to satisfy the end-use consumption in the EU during a year may be expressed in various units, depending on each product group:

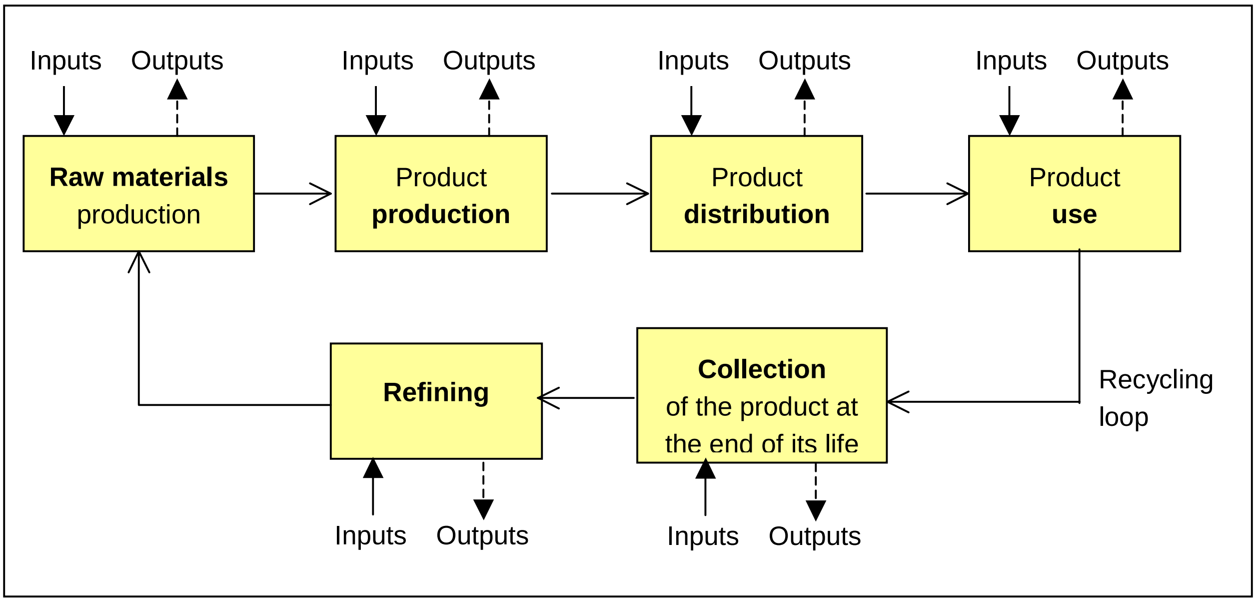
- t or m^3 of products (most of products),
- m or m^2 of products (carpet, roads, some construction products …),
- Dimensionless number of sale units (pairs of shoes, …),
- Specific units such as pkm (passenger x km) or (tkm) tonne x km for transport services of passengers or goods.

1.3.2.3 System Boundaries

■ LCA is a tool for the assessment of the potential environmental impacts of a product system. Not only potential impacts due to the usage of a product, but also production, transportation, maintenance, and waste disposal are considered (i.e. its entire life cycle).

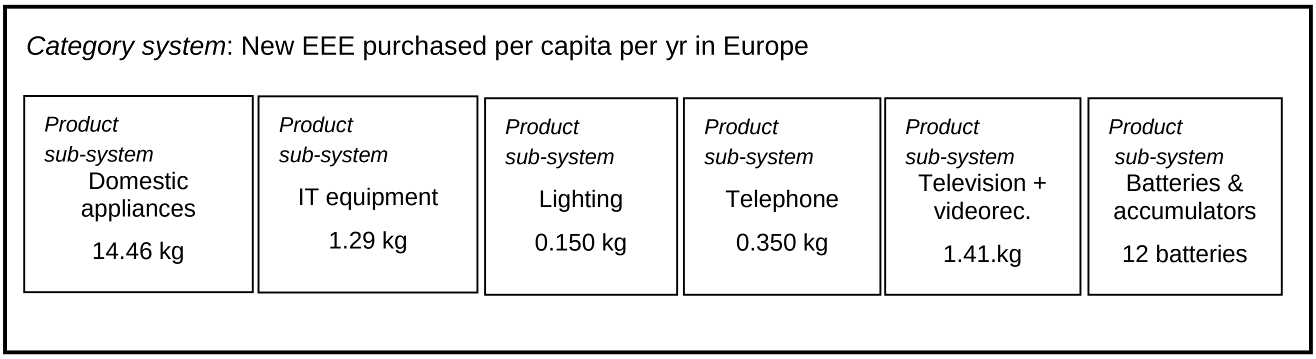
A product system can be represented graphically as follows.

Boundaries of a Product System



■ In the scope of the study, LCA results are presented at the level of categories, each of them including different types of products thus life cycles with different patterns. An LCA system referring to a given category is thus composed of various product sub-systems.

Boundaries of a Category System
Example - Electric and Electronic Equipment Category



1.3.2.4 Life Cycle Inventory

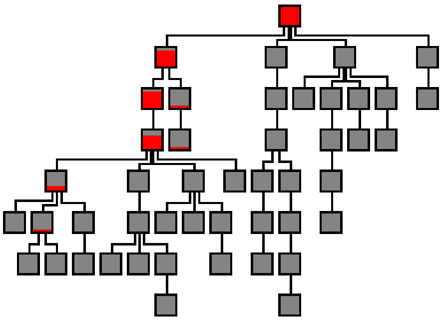
Overview

As stated below, the basis of an LCA study is an inventory of all the inputs and outputs of industrial processes that occur during the life cycle of a product. This includes the production phase as well as the distribution, use and final disposal of the product.

The life cycle can be presented as a process tree.

Example of a process tree

Each box represents a process which forms part of the life cycle. Every process has defined inputs and outputs.



Process inputs can be divided into two categories:

- inputs of raw materials and energy resources (environmental inputs),
- inputs of products, semi-finished products or energy, which are outputs from other processes (economic inputs).

Similarly, there are two kinds of outputs:

- outputs of emissions (environmental outputs),
- output of a product, a semi-finished product or energy (economic outputs).

With information about each process and a process tree of the life cycle, it is possible to draw up a life cycle inventory of all the environmental inputs and outputs associated to the product. The result is called *impacts table*. Each impact is expressed as a particular quantity of a substance.

In this study, the impacts table related to each product system under study has about 300 rows (each row represents an elementary flow).

Inventory process in greater detail

The inventory process seems simple enough in principle. In practice, it is subject to a number of practical and methodological problems, including:

- System boundaries

  In breaking the life cycle down into processes, it is not always clear how far one should go in including processes belonging to the product concerned. In the production of polyethylene, for example, oil has to be extracted; this oil is transported in a tanker; steel is needed to construct the tanker, and the raw materials needed to produce this steel also have to be extracted. For practical reasons a line must be drawn. For example, the production of capital goods is usually excluded.

- Processes that generate more than one product

  For example the electrolysis of salt produces chlorine. The environmental effects of the electrolysis process cannot be ascribed entirely to chlorine alone, as caustic soda and hydrogen are also produced. A suitable allocation rule is needed here, for instance allocation on mass basis or economic value of the products. In this study, we have generally used dataset based on **allocation on mass basis**.

- Avoided impacts

  When a disposal process generates a profitable output, such as energy generation at a municipal waste incineration plant, it not only causes impacts. It also saves impacts as it is no longer necessary to produce the energy or the material in a normal way.

  To allow for this, *avoided impacts* are introduced. These are equivalent to the impacts that would have occurred in actual production of the material or energy. The avoided impacts of a process are deducted from the impacts caused by other processes. In this study both the attribution of impacts concept and the avoided emissions concept have been used for the category "**municipal waste management**".

- Geographical variations

  An electrolysis plant in Sweden uses much less environmentally detrimental electricity than an identical plant in Holland, as hydroelectric power is abundantly used in Sweden. In this study, we have generally used **average data at the European level** (for instance, the electricity mix is an average of the European mixes).

- Data quality

  Publications on environmental process data are often incomplete or inaccurate. Moreover, the data are subject to obsolescence; there are many cases where processing industries have cut emissions by 90% during the last ten years. The use of obsolete data can therefore cause distortions.

- Choice of technology

  A distinction can be made between *worst, average,* and *best* (or *modern*) technology. Before starting to collect data it is important to be aware of which type of technology you are interested in. In this study we have collected **average technology as far as possible**.

Despite these problems, it is often quite feasible to carry out an impact inventory. It is unreasonable, however, to treat the results as an absolute truth. Factors such as the choice of technology and system boundaries, data quality etc. have to be taken into account when interpreting them. This is why it often seems to be disagreement among experts about the environmental soundness of a product.

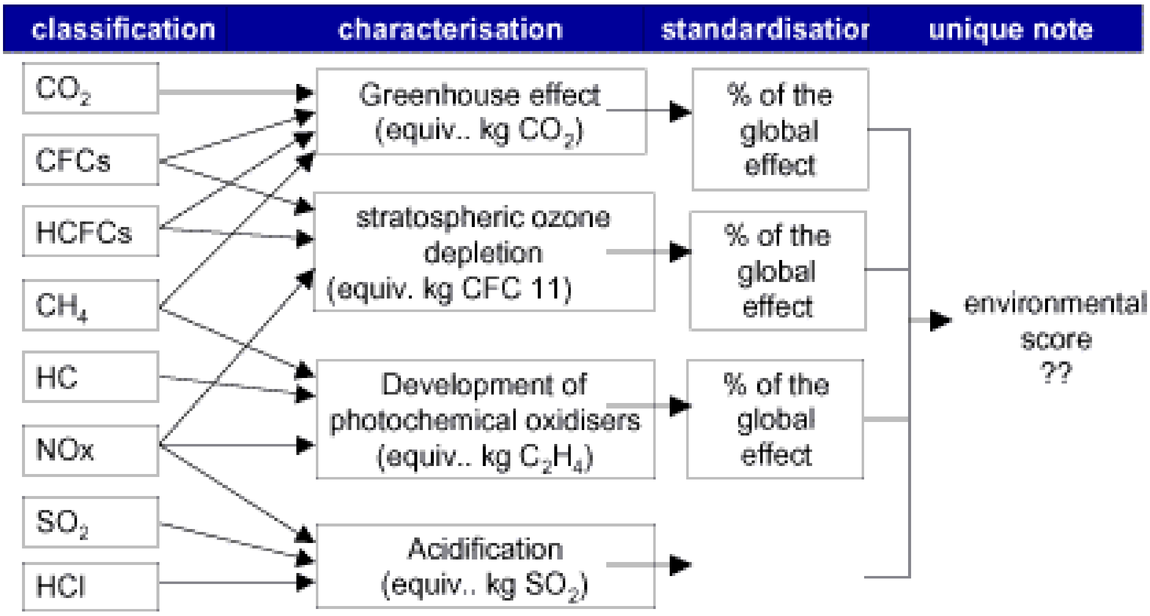
1.3.2.5 Environmental Impacts Assessment

■ The inventory table is the most objective result of a LCA study. However, a list of substances is difficult to interpret. To make this task easier, life cycle impact assessment (LCIA) is used to evaluate the environmental impacts.

Two problems exist regarding environmental impact assessment:

- Data are not sufficient to calculate the damage caused by a given impact to ecosystems.
- There is no generally accepted way to quantify quantifiable damage caused to ecosystems.

■ A general approach to calculate potential environmental impacts is described hereafter with consistency to ISO standards related to LCA (ISO 14042, 14043).



Classification and characterisation

In the classification step, all substances are sorted into classes according to the effect they have on the environment. For example, substances that contribute to the greenhouse effect or that contribute to ozone layer depletion are divided into two classes. Certain substances are included in more than one class. For example, NOx is found to be toxic, acidifying and causing eutrophication.

The substances are aggregated within each class to produce an *effect score*. It is not sufficient just to add up the quantities of substances involved without applying weightings. Some substances may have a more intense effect than others. This problem is dealt with by applying weighting factors (so called characterisation factors) to the different substances. This step is referred to as the characterisation step.

Example of Characterisation Step for a Small Inventory Table

Emissions are multiplied by the corresponding weighting factor before being summed per class. The results are the effect scores.

Emission	Quantity (kg)	Greenhouse	Ozone layer depletion	Human toxicity	Acidification
CO2	1.792	**x 1**	-	-	-
CO	0.000670	-	-	**x 0.012**	-
NOx	0.001091	-	-	**x 0.78**	**x 0.7**
SO2	0.000987	-	-	**x 1.2**	**x 1**
Effect scores:		1.792	0	0.00204	0.0017

The interpretation of these scores may be less confusing than interpretation of a substance list, but is by no means without problems. If all the scores for one product are higher than those for another, it is easy enough to conclude which is the more environmentally friendly. But if one has a higher score for acidification, while the other has a higher score for the greenhouse effect it becomes difficult to justify such a conclusion.

Interpretation depends on two factors:

- The relative size of the effect compared to the size of the other effects. In this example it is important to see whether the ecotoxicity score of 100% refers to a very high or an extremely low effect level. This is normalisation.
- The relative importance attached to the various environmental effects. This is evaluation.

Normalisation (or standardisation)

In order to gain a better understanding of the relative size of an effect, a normalisation step is required. Each effect calculated for the life cycle of a product is benchmarked against the known total effect for this class. However, this step is still debatable and this study does not propose any standardisation approach.

Evaluation of the normalised effect scores

Normalisation considerably improves our insight into the results. However, no final judgment can be made as not all effects are considered to be of equal importance. In the evaluation phase the normalized effect scores are multiplied by a weighting factor representing the relative importance of the effect. However, this step requires accurate, complicated and… debatable system constructions; therefore, this study does not propose any unique note in order to aggregate heterogeneous environmental scores.

■ It should be reminded that LCAs assess **potential impacts and not actual impacts**. The term "potential" covers three characteristics of LCAs:

- The assessment of LC environmental impacts is dependent on the current **scientific knowledge** and existing models, which is intrinsically **limited**.
- Environmental impacts are assessed and aggregated from **inputs and outputs** occurring at different life cycle stages which means **with different space and time location**.

  When the environmental impact studied is global (e.g. global warming or non renewable resources depletion) and the inputs or outputs are cumulative (e.g. greenhouse gases or non renewable resources), this does not make any difference.

  But this is when the environmental impact is local (e.g. air acidification) or the inputs / outputs are not cumulative (e.g. noise) that the aggregation of inputs / outputs contribution to the studied environmental impact results in potential impacts. For instance, adding up local impacts as noise and odour does not make a lot of sense because they are not global and cumulative impacts but rather dependent on the location of the "emissions".

  Thus LCAs assess **maximum potential environmental impacts** as if all the inputs and outputs occur at a same location in space and time.
- For a given physical phenomenon (e.g. air acidity), LCAs do not quantify "endpoint" impacts (such as in monetarisation methods: respiratory diseases caused by an increase of air acidity…) ; rarely "midpoint" impacts (e.g. photochemical ozone creation potential) but generally **"start point" impacts,** i.e. the influence that pollutants emitted can have on the state of the environment (air acidity in that example). It gives a scale to assess the contribution to the environmental impact but not a quantification of the environmental impact itself (the higher the impact value quantified in LCA, the higher the environmental impact, without quantifying it directly).

Start, Mid and End Point Environmental Impacts
E.g. for air acidification

Type of impact	***Scope***	***Unit***	***Where it is quantified***
Start point impact	Quantity of air emissions which influence air acidity	g SO2 equivalent	LCAs
Mid point impact	Air acidification (i.e. increase of air acidity) due to pollutants emitted	Proton concentration in the air (acidity quantity) $g\ H^+ / m^3$	Impact studies
End point impact	Social impacts of air acidification on human and ecosystems (such as respiratory diseases)	e.g. Number of years of life lost	External cost analyses

Remark: this specificity of LCA addressing potential and not actual impacts concerns only the environment impacts assessment step. This does not concern the LCI step where inputs and outputs are quantified for each stage individually[19]. This is important when considering monetarisation, because existing methods of monetarisation are site-specific (see section 1.3.3).

[19] It is only when one adds the different step that the "potentiality" issue occurs.

- The following impact categories are considered in this study for the impact assessment step.

Environmental Impacts Considered

Environmental Impacts

Linked to resources consumption	
Depletion of non renewable resources	kg antimony eq.
Linked to air emissions	
Greenhouse effect (direct, 100 yrs)	g CO_2 eq.
Stratospheric Ozone Depletion	g CFC-11 eq.
Air acidification	g SO_2 eq.
Photochemical oxidation	g ethylene eq.
Linked to water effluents	
Eutrophication	g PO4 eq.
Linked to human health	
Human Toxicity	g eq. 1-4-dichlorobenzene
Years of Life Lost	year
Linked to ecotoxicological risk	
Aquatic Ecotoxicity	g eq. 1-4-dichlorobenzene
Sediment Ecotoxicity	g eq. 1-4-dichlorobenzene
Terrestrial Ecotoxicity	g eq. 1-4-dichlorobenzene

Other Flows Not Taken Into Account in the Environmental Impacts Above

Primary energy	MJ
Dusts	g
Dioxins	g
Metals into air	g
Metals into water	g
Metals into soil	g
Municipal and industrial waste	kg
Hazardous waste	kg
Inert waste	kg

These categories are consistent with the use of existing European LCA inventory databases, except YOLL (Years of Life Lost), which has been added because it is commonly monetarised.

Some other impact categories of interest (e.g. noise, odor, biodiversity, risk of accidents… – see next chapter) have not been included in the scope of this study because of data gaps in most of available LCI databases.

Remark: the term « dusts » used all along the report is taken as an equivalent to “particulate matter”.

1.3.2.6 Limitations and Uncertainties Linked to the LCI & LCA step

- **Uncertainties linked to system boundaries setting up**

Although theoretically similar from a product or service category to another, system boundaries are very dependent on available LCI data. For instance, transformation or use steps as well as production steps of some product components or consumables can not systematically be integrated due to a lack of LCI data (see section 1.4.1.2).

- **Uncertainties linked to the composition of the product or service categories**

As described in section 1.3.2.3, most of the product and service categories selected are composed of numerous sub-systems (e.g. the "vegetable food products" category theoretically contains all sorts of vegetables and fruits) whose LCI may differ more or less significantly.

But only those sub-systems for which LCI data were available were able to be integrated. Eventually, the composition of the categories was adjusted according to available LCI data (see section 1.4.1.2). Practically, extrapolation were made: sub-systems with no available LCI are considered having the same LCI as others, if possible as those presenting close life-cycle patterns.

- **Uncertainties linked to LCI calculation and environmental impacts assessment**

Two basic kinds of uncertainty have to be distinguished:

- the first one is linked to the level of reliability and accuracy of the inventory datasets,
- the other concerns the calculation modelling used to describe the physical phenomena linked to the environmental impacts.

The soundness of every environmental impact indicators is scored ('++++' high reliability to '+' = very low reliability) in the table below.

The scores for the confidence in the inventory data reflect the today's state of the art for the inventory stage within the LCA framework.

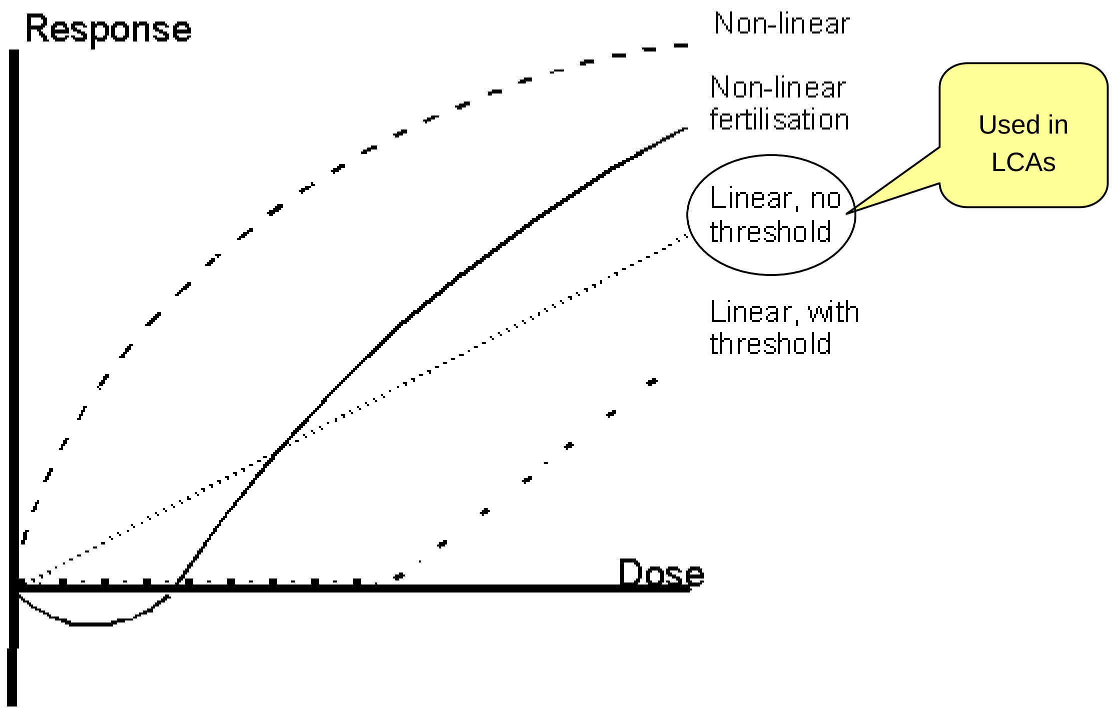
Although the availability of LCI data has improved immensely over the last years, the proliferation of LCI data on the information market has lead to problems with data quality, comprehensiveness, comparability and equal distribution of LCI data. In particular, environmental data do not exist for all products or services, for all life cycle stages and for all inputs or outputs contributing to environmental impacts. Several quality parameters can be set up as:

- time representativeness: are the data only specific to the time period when the inventories were carried out? do they fit to describe prospective situations?
- geographical representativeness: are the data specific to a given location (country, region...) or representative of an average European situation?
- technological representativeness: are the data specific to a given technology or do they cover the diversity of possible technologies?
- environmental representativeness: are the inventories focusing only on some inputs/orputs or is the level of comprehensiveness good?

The scores for the reliability of the calculation methods are representative of the today's state of the art for environmental impact assessment within the LCA framework; additional works are in progress to improve the indicators related to human health and ecosystems.

In particular, it should be noted that linear models with no threshold are used today to assess the environmental impacts. Response and thresholds effects are neglected. That means that nor the adaptation capacity of humans and ecosystems neither their specific response are taken into consideration. This is likely to constitute a huge approximation.

Linear Models as Basis of LCA



As for toxicity, although the level of uncertainty is not easy to quantify, it is likely to be high:

- first, it is difficult to predict and quantify which toxic substances could potentially be released during the manufacturing, use or disposal of products. Thus most of available LCI databases are of poor quality when considering toxic substances inventoried.
- secondly, controversy still exists among the scientific community regarding the characterisation impact factors to assess the contribution of each toxic substances to the different types of toxicity (human toxicity, aquatic ecotoxicity, sediment ecotoxicity and terrestrial ecotoxicity).

It should be noted that a method is being developed as part of the 5th framework project OMNIITOX (www.omniitox.net), which may help to improve the way toxicity is taken into account in LCA in the future.

Level of Confidence of LCAs

Area of protection	Impact category	Scientific unit for the indicator	Confidence in the inventory data	Reliability of the calculation methods
Consumption of resources	Fossils fuels	kg eq. crude oil	+++	+++
		MJ		
	Total energy	MJ	+++	+++
	Water	kg	+++	+++
Air pollution	Global warming potential	kg eq. CO2	+++	+++
	Acidification potential	kg eq. SO2	++	++
	Photochemical pollution	kg eq ethylene	+	++
Water pollution	Eutrophication potential	kg eq. PO4	++	++
Waste	Solid waste	kg	+++	++++
Human health and Ecosystems	Human toxicity	kg eq. 1-4 dichlorobenzen	+	+
	Aquatic ecotoxicity	kg eq. 1-4 dichlorobenzen	+	+
	Terrestrial ecotoxicity	kg eq. 1-4 dichlorobenzen	+	+

- **Limitation of environmental impacts captured**

The notion of Environment is vague. The goal of Life Cycle Assessment is not to cover the entire environmental issue: only what is quantitative (measurable) and extensive (which can be added throughout an entire lifecycle) is taken into account. We talk about environmental accountancy.

Some impact categories are not or not well captured by LCA because of two main reasons:

- either they are not compatible with the LCA methodology, such as:
  - noise,
  - odor,
  - nature conservation (biodiversity, etc.),
  - land disturbance[20],
  - disamenity,
  - risk of accidents (nuclear, oil slicks, transport…).

  As mentioned above, one of the reasons is that adding local impacts as noise and odour does not make a lot of sense because they are not global and cumulative impacts but rather dependent on the location of the "emissions".
- or they are not well / comprehensively assessed in available LCA databases, such as sometimes:
  - nuclear waste,
  - toxicity of products,
  - land use.

As a consequence, the study will only focus on the environmental impacts generally assessed in LCAs.

20 i.e. effects of land use (by human activities) on ecosystems structure and functioning.

1.3.3 Methodological Framework for the Monetary Valuation of Environmental Impacts

This chapter successively examines:

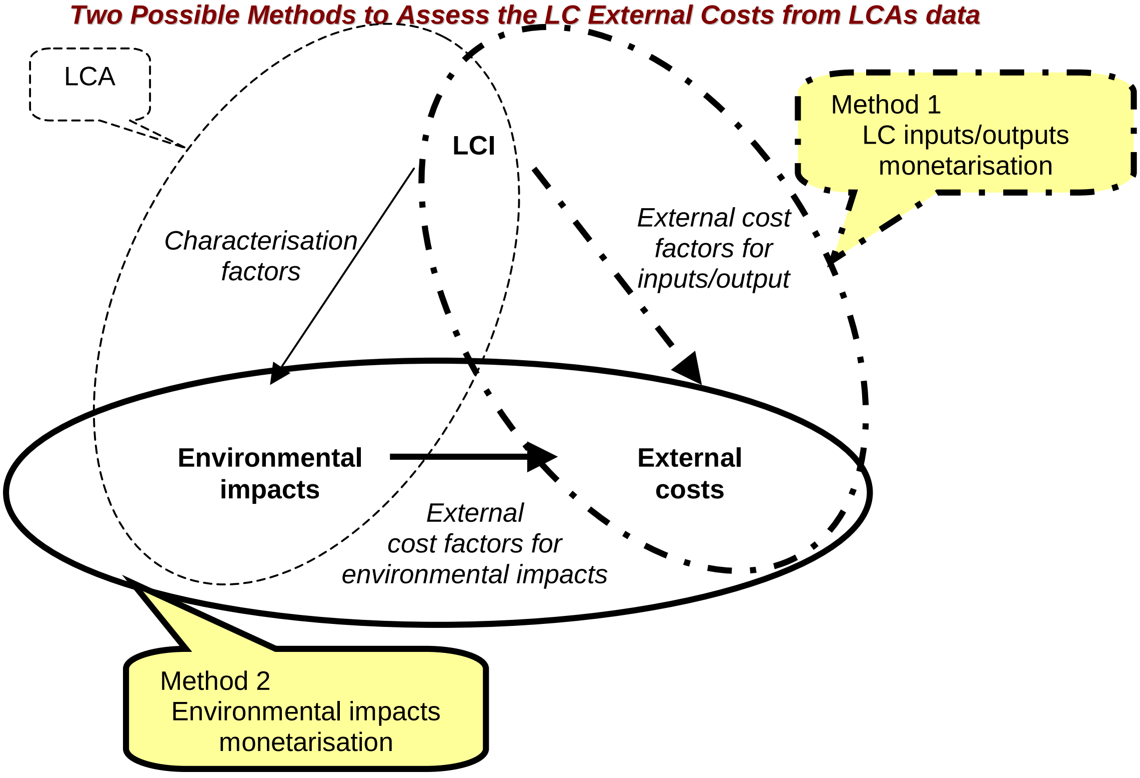
- how external cost factors can be used in such a macro-economic and LCA-based study,
- what are the cost factors data the most appropriate to this study (more precisely, what is the existing monetarisation method which gives the most appropriate cost factors),
- the difficulties linked to this monetarisation step combined with LCAs.

1.3.3.1 Use of External Cost Factors in an LCA-Based Study

■ Theoretically, two methods are possible to assess the external costs of products of services life cycle starting from LCA results:

- Method 1: to monetarise the inputs and outputs quantified on the LC inventory and then to add them to obtain the total external cost associated to the LC,
- Method 2: to monetarise the environmental impacts assessed and then to add those to obtain the total external cost associated to the LC.

Two Possible Methods to Assess the LC External Costs from LCAs data



Method 1: LC inputs/outputs monetarisation

For each input or output, the following calculation method consists in:

IO x ECFi = ECio

Where IO = quantification of the input or output under consideration (e.g. X g SO_2)

ECFio = external cost factor related to the input or output IO under consideration (e.g. Y Euros / g SO_2)

ECio = external cost obtained for the input or output (in Euros)

The total external cost EC is then the sum of the ECio of all the inputs and outputs of the LCI.

Method 2: Environmental impacts monetarisation

For each environmental impact, the calculation method consists in:

EI x ECFei = ECei

Where EI = quantification of the environmental impact under consideration (e.g. for air acidification, X g SO_2 equivalent)

ECFei = external cost factor related to the environmental impact EI under consideration (e.g. for air acidification, Y Euros / g SO_2 equivalent)

ECei = external cost obtained for the environmental impact (in Euros)

The total external cost EC is then the sum of the ECei of all the environmental impacts assessed.

- Theoretically, the two preceding methods should converge and the total external costs EC should be the same[21].

Given that the calculation of the environmental impacts generates another level of uncertainties as described above (see §1.3.2.6) in addition to those inherent to the LCI step, M*ethod 1 - LC inputs/outputs monetarisation* could be preferred.

However, because external cost factors do no exist for all the inputs / outputs contributing to the environmental impacts quantified in an LCA, Method 2 was more easy to implement in this study (see section 1.4.2.2 where it is explained how external factors eventually used in this study for environmental impacts were derived from existing data).

[21] At least when using external costs factors established with an impact pathway method (which monetarises physical impacts – see below §1.3.3.2),

1.3.3.2 Existing Monetarisation Methods Which Establish Cost Factors

■ Once having decided how to use the cost factors in this study (Method 2 as described above, i.e. to apply them to the environmental impacts and not the inventory inputs and outputs), the next step was to select (or build) these cost factors.

For that purpose, we examined existing monetarisation methods (which produce cost factors) to identify which one(s) could fit the most with an LCA framework.

■ Monetarisation methods have been developed for years (and until quite recently, independently from LCAs). This is not the purpose of this work to discuss them in detail. Very brief background information are given in appendix 2.

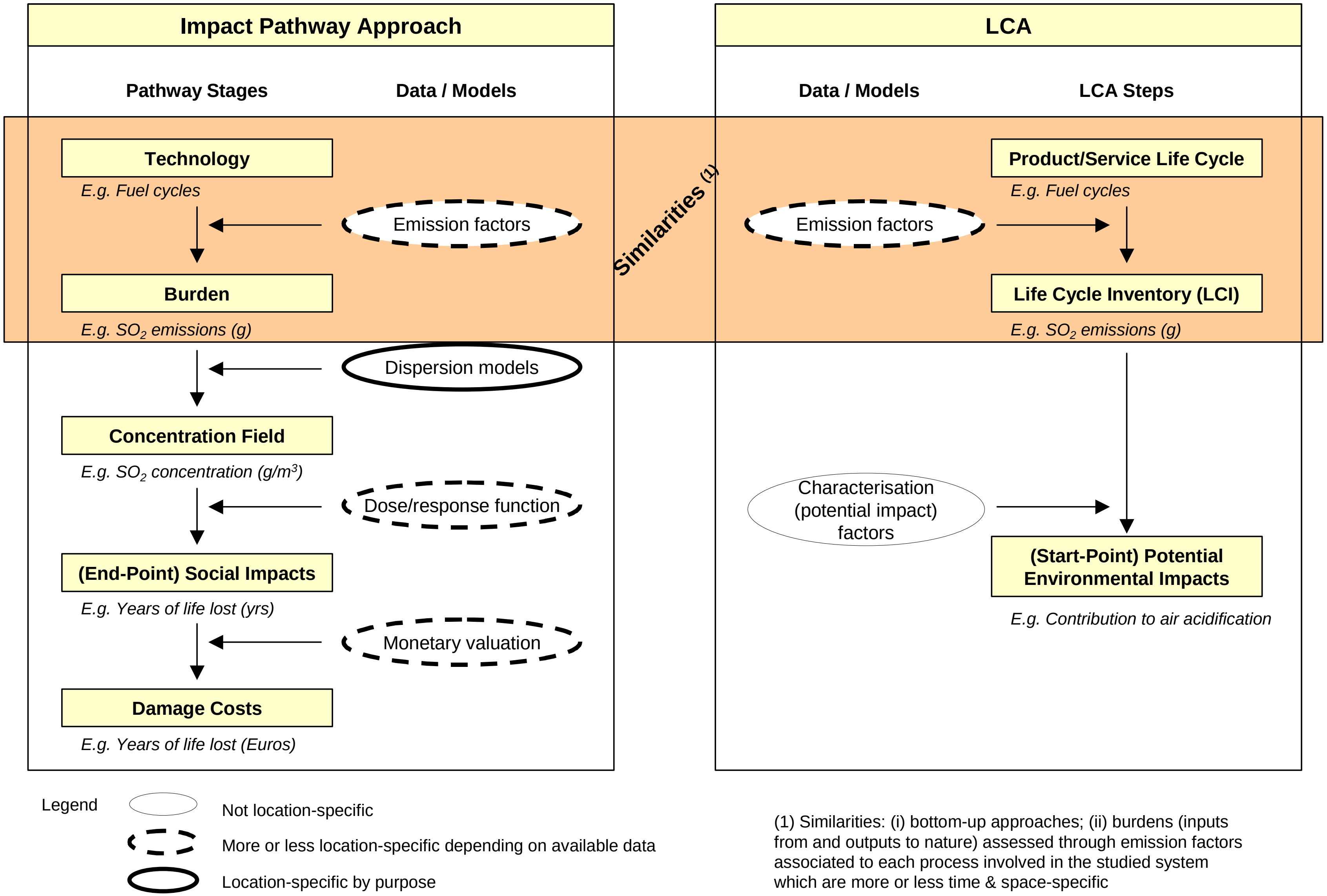
■ An intermediate experts workshop was held in June 2002 to look at the monetarisation issues of the study.

Following the advice given by the experts and the choices made by the project leaders from the European Commission, it was concluded that to build cost factors for the purpose of this study, one should give preference to the impact pathway approach which presents similarities with the LCA methodology (as described in the figure next page) and focus on studies carried out for the European Commission, especially resulting from the ExternE project, largely accepted in the community working in the domain of monetarisation.

The Impact pathway approach (also called Dose-response or Damage costs approach) sits between life cycle assessment and valuation. It is based on the use of a damage functions to link an environmental alteration to its consequences (e.g. on health) and then the imputation of the costs of these consequences to the environmental damage. In particular contingent valuation, preventive and restorative expenditures provide the data that are used for valuation in the impact pathway approach (see appendix 2 for a little bit more information).

These sources of information have then been used in priority to establish the cost factors eventually used in this study (see section 1.4.2).

Characteristics of Impact Pathway Approach and LCA



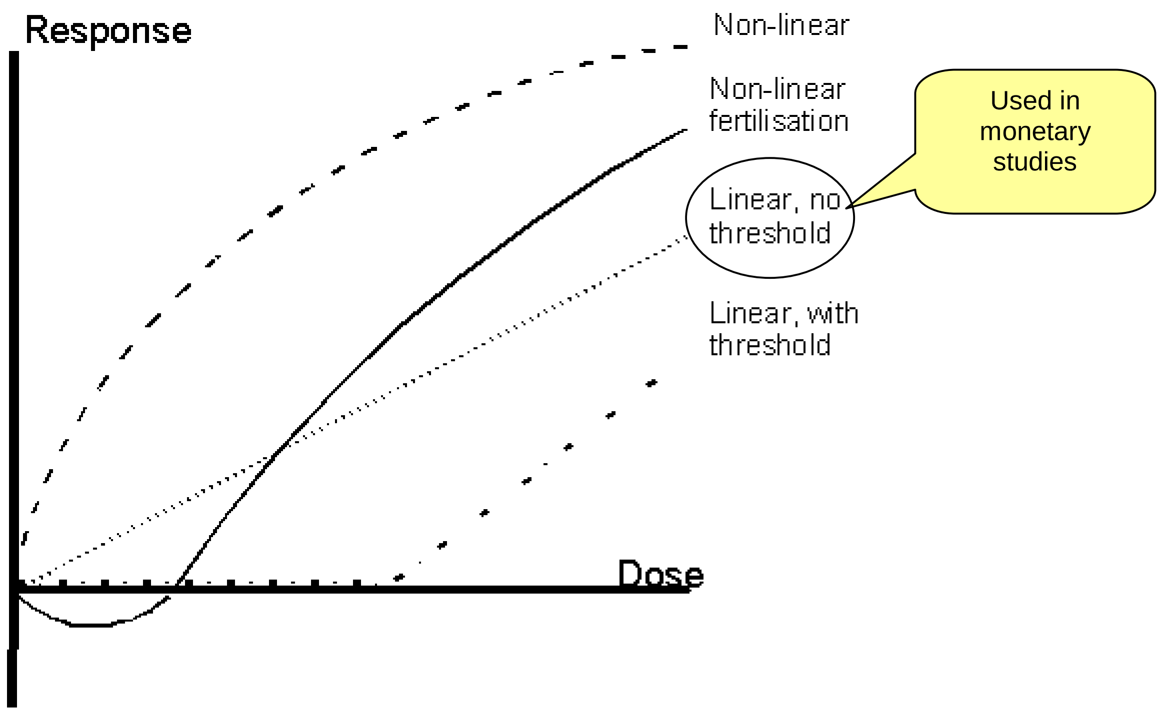
(1) Similarities: (i) bottom-up approaches; (ii) burdens (inputs from and outputs to nature) assessed through emission factors associated to each process involved in the studied system which are more or less time & space-specific

1.3.3.3 Difficulties Linked to Applying Monetarisation to Life Cycle Studies and Uncertainties

■ First of all, it is important to mention that some uncertainties are directly linked to the monetarisation methods themselves, because these methods are often based on simplifying assumptions. Each method has its own logic and hypotheses which lead to specific complexities when interpreting the results (see Appendix 2).

In addition, as for LCAs, it should be noted that linear models with no threshold are often used today to assess external costs, which may lead, in certain cases, to neglect some important response and thresholds effects. That means that the adaptation capacity of humans and ecosystems and their specific response are not always taken into consideration. This is likely to constitute a huge approximation in some cases at least.

Linear Models as Basis of Monetary Studies



■ Apart from these general uncertainties, specific problems occur when combining results from monetarisation studies and LCA linked to the specificities of each type of approaches.

A first difficulty is related to the fact that many substances can contribute to more than one type of environmental impact. For instance, NOx emissions have an effect on eutrophication, acidification, and photochemical oxidation as well as on human health. However, while LCA quantifies the different categories of environmental impacts, the economic valuations are generally estimations for distinct pollutant emissions, including all its different impacts. Sometimes it is not possible to differentiate the impacts involved in the calculation.

Another difficulty concerns the fact that units of data are not always the same and are sometimes incompatible. For example, outputs of LCA for human toxicity are expressed in 1,4-dichlorobenzene equivalent, whereas carcinogenic effects are mainly evaluated in the literature for heavy metals emissions.

The last difficulty, but not the least, is simply that some impacts, which are quantified in LCA, are not monetarised, neither studied, in environmental economics literature, as for example water consumption.

■ A limit of the overall approach is linked to the fact that it combines potential global impacts (LCA) with actual location and source-specific external cost factors (monetarisation).

On one hand, the environmental impacts quantified through an LCA approach are both potential and global:

- potential because the actual fate of the impact factors (emissions) in the environment and the exposure of natural systems (humans and other living systems) to these impact factors are not considered in the computational models used in LCA approach,
- global because emissions which occur in different locations at different times are simply summed throughout a product system lifecycle. This method is valid for emissions which contribute to an environmental impact in a cumulative manner (greenhouse gases or ozone depleting substances). But for others impact categories (human health, ecotoxicology, eutrophication…), this method conducts to an overstatement of actual effects.

On the other hand, monetarisation methods aim at addressing the location and source-specific nature of impacts associated with emissions to air, water, land. For instance, the implications of emissions from a 50 m stack are very different to those at ground level.

■ The goal of this part of the project was to integrate a financial axis in the life cycle assessment of product groups, and thus to allow policy makers to get a picture of the approximate financial implications of environmental impacts linked to product life cycles.

However, the task was not an easy one to define the convenient methodology, identify the existing studies giving the appropriate numbers, and then calculate and interpret the overall results for all covered product groups. **It is thus important to underline that the results of this work are rather to be seen as a first step in developing a suitable methodology for future work, than as a definitive basis for policy decision making**.

Another important point is the following: this economic part of the study was carried out from April to August 2002. The more recent existing studies in the field of monetarising external effects were thus not taken into account. However, we tried to at least mention them, in order to simplify future work on this field.

1.3.4 Methodological Framework for the Internalisation of External Costs

1.3.4.1 Role of Environmental Taxes in the Internalisation of External Costs

Taxes and charges are currently the most common (though not necessarily widely used) attempt to internalise external effects, ideally aiming at prices to reflect the environmental impacts of products.

In order to study the degree of internalisation of environmental external effects of different product categories, the analysis of environmental taxes is a first proxy. For that, the total amount of taxes and charges related to the life cycle of a product has to be compared to the monetary valuation of the different external effects.

1.3.4.2 Methodology Used to Assess the Level of Internalisation of the External Costs and Key Indicators

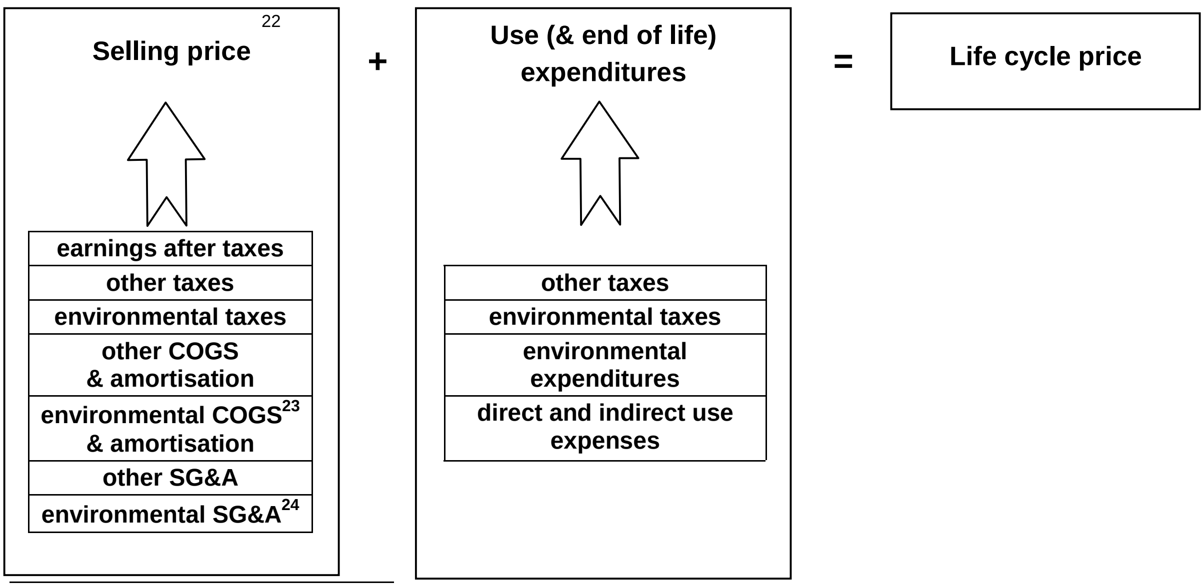
After having assessed the external costs generated during the whole life cycle of the marketed products or services, the study aims at evaluating the level of internalisation into the prices already reached for external costs.

1.3.4.2.1 Life Cycle Price

- Definition of "life cycle price"

Given that we take into account the whole life cycle of products, the price we consider has to correspond to the whole life cycle as well i.e. has to include the expenditures during the use and the end of life of goods. This price can be called '**life cycle price**'.

Definition of Life Cycle Price



[22] Corresponding to the 'purchasing price' by consumers or the 'market price'.

[23] Costs Of Good Sold.

[24] Selling, General and Administrative expenses.

- Quantification of life cycle prices

In order to assess the life cycle price of a given product or service category, two types of methods are possible:

- a bottom-up approach, assessing first the life cycle price of each main product or service constituting the category by adding their selling price and the expenditures linked to their use. Then the life cycle price of the category can be deduced by adding these individual life cycle prices.
- a top-down approach, based on global European data split between the different categories studied.

Because macroeconomic data are already available in that field (contrary to the LCA field), we whose **a top-down approach, consisting into approximating the life cycle prices with the average European households expenditures**.

1.3.4.2.2 Life Cycle Environmental Taxes

To calculate the overall environmental taxes for the whole life cycle of a given product or service, we multiplied each environmental tax applying to a given LC inventory flow (inputs or outputs) with the flow quantified in the LCI.

1.3.4.2.3 Key Indicators about Internalisation

Six key indicators have been defined to analyse the internalisation of external costs into prices.

Intermediary Indicators *Indicators **quantified** from data calculated in the study*	**Decision-Making Oriented Indicators** *Indicators derived from intermediary indicators and expressed with **semi-quantitative scale to compare categories***
A-Indicator = % of environmental taxes compared to external cost By calculating the percentage that the environmental taxes represent compared to the external cost, it gives information on the **current level of internalisation reached**[25]: - A-indicator **> or = 100%**: this means that the environmental taxes are higher than the external cost and thus, that external cost can be considered being **already totally internalised**, - A-indicator **< 100%**: this means that **only a part** of the external cost can be considered being **already internalised**.	**D-Indicator = current level of internalisation reached** D-Indicator is directly dependant on A-indicator value: - D-Indicator = relatively high if A-Indicator > or = 100%, - D-Indicator = relatively medium for intermediary values of A-indicator, - D-Indicator = relatively low if A-Indicator << 100%.
B-Indicator = % of external cost not yet internalised compared to life cycle price The external cost not yet internalised is taken equal to: - 0 if 100% of external cost is already internalised (i.e. if A-indicator > or = 100%). - External cost minus environmental taxes if less than 100% of external cost is already internalised (i.e. if A-indicator < 100%; in that case, environmental taxes are lower than external cost).	**E-Indicator = importance of externalities not yet internalised compared to the overall life cycle price** E-Indicator is directly dependant on B-indicator value: - E-indicator = relatively high for the highest values of B-indicator, - E-indicator = relatively medium for intermediary values of B-indicator, - E-indicator = relatively low for the lowest values of B-indicator.
C-Indicator = % of external cost compared to life cycle price The comparison of the orders of magnitude of both external cost and life cycle allows to check if the external cost is higher or lower than the life cycle price and if their difference is important or not. - C-Indicator > 100% means that external cost is higher than LC price, - C-Indicator < 100% means that external cost is lower than LC price.	**F-Indicator = importance of externalities compared to the overall life cycle price** F-Indicator is directly dependant on C-indicator value: - F-indicator = relatively high for the highest values of C-indicator, - F-indicator = relatively medium for intermediary values of C-indicator, - F-indicator = relatively low for the lowest values of C-indicator.

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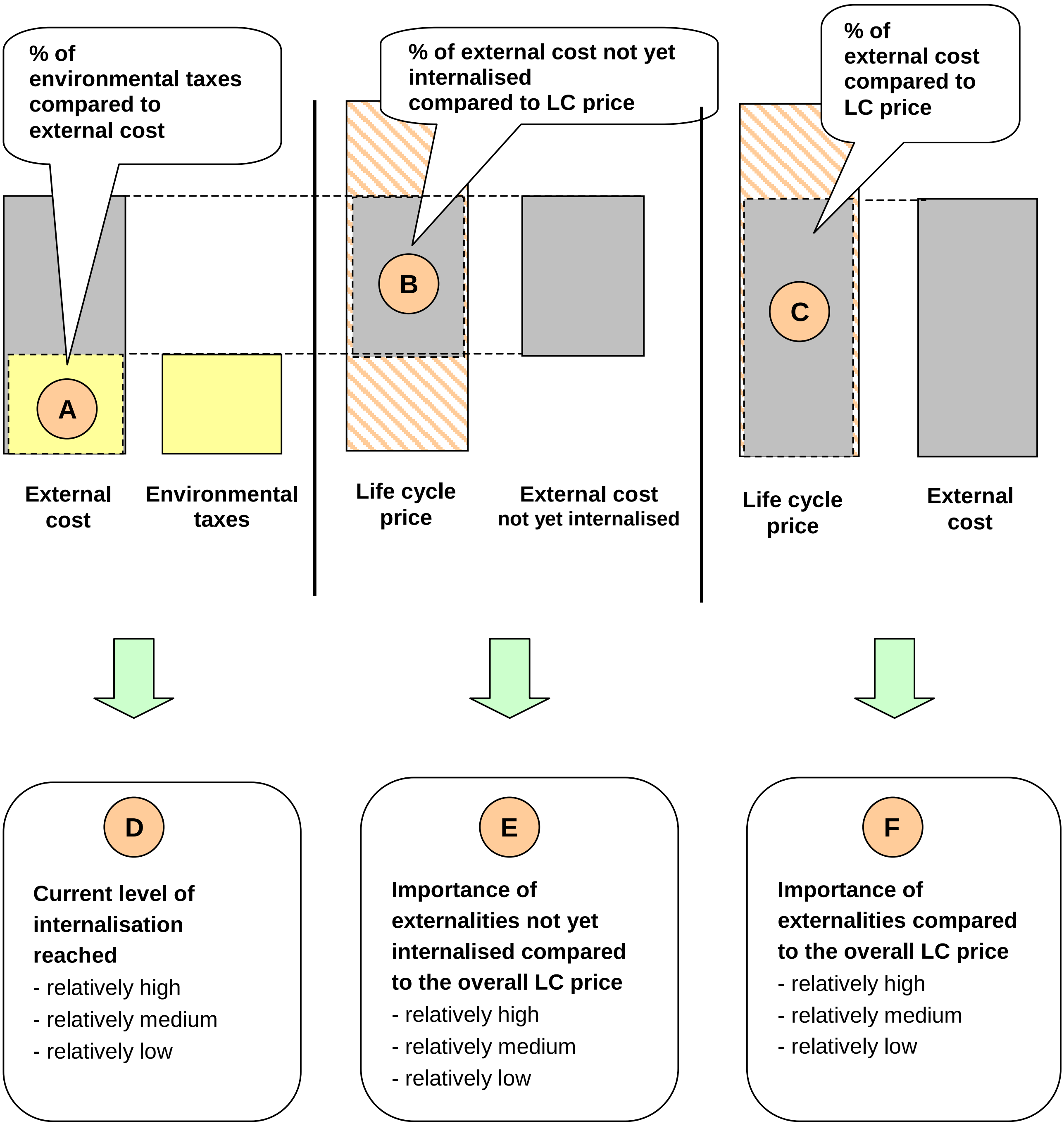
[25] The hypothesis being indeed that the environmental taxes are the means to internalise external cost.

Six Key Indicators about External Cost Internalisation



1.3.4.3 Difficulties of Using Tax Data in a Study on Life Cycle Assessment and Uncertainties

■ Using tax data in a study on LCA presents many difficulties. **Databases on taxes are not classified in a way directly compatible with LCA**. The way implying the least difficulties was to classify environmental taxes by domain (taxes on energy, taxes on transport, taxes on water consumption, taxes on waste water, …). This classification permits to estimate the total amount of environmental taxes and fees related to the life cycle of a category of products, by adding the taxes paid at every step of the life cycle. For taxes on air pollution, or water consumption, this is quite easy because the units are the same as in LCA. But taxes on specific products are more difficult to connect with LCA data because the units are not always the same.

■ Many simplifications were made in this part of the study. Some simplifications aimed at reducing the volume of data. For example, taxes on cars in Denmark are differentiated according to fuel consumption, but this differentiation is not clearly kept in the database used. The solution we chose was to consider an **interval, covering all the existing tax rates**.

■ Another simplification concerns exemptions and subsidies.

All countries have numerous exemptions and rebates, in particular concerning energy and fuel taxes, or subsidise environmentally harmful energy sources (for example, coal) and economic activities (for example, heating of greenhouses in the Netherlands and Sweden).

These provisions are not easy to take into account in such a life-cycle oriented and macro-economic study because:

- no database is currently available giving a general overview, and it would have needed a very long time to collect all the information to make such a database,
- the products or activities to which exemptions or subsidies applied are either the final product or service for which the LCI is calculated or intermediary products or services consumed during the life of the final product or service studied. Especially the second case presents problems, when intermediate products or services are part of an aggregated LCI, without knowing the quantities involved.

For practical reason, when applying the environmental taxes to the LC inventory flows quantified, two main approximations were made:

- existing **subsidies** were **not integrated**,
- many **exemptions** apply to particular products or activities and different tax rates exist for certain products which can not be easily taken into account when considering such a macro-economic life-cycle oriented approach. The solution we chosed was to consider data ranges:
  - for the taxes where exemptions apply (e.g. taxes related to energy): **a min value and a max value corresponding to the minimum and maximum taxes existing in the country**,
  - where different tax rates exist: an **interval covering the diversity of rates**.

1.3.5 Summary of the Difficulties and Uncertainties to Implement the Methodology

Step generating uncertainties	Description of the uncertainties	Attempt to qualify the uncertainty level	Origin of the uncertainties and next		
			Specific to the methodology	Pragmatical choices (limited resources)	Could be improved with research works
Market-Oriented LCI and Impact Assessment Steps					
Macroeconomic dimension	***Limited representativeness of the categories considered*** The product and service categories selected were expected to cover the entire European economies. But due to a lack of LCI data and in order to limit double-counting, pragmatic choices were made. As a result, some of European economic sectors are less represented than other (e.g. services, food products).	++		X	X
Setting up of system boundaries	***Some steps not taken into account*** Transformation or use steps as well as production steps of some product components or consumables can not systematically be integrated due to a lack of LCI data.	++		X	X
Composition of the product or service categories	***Heterogeneity of the studied categories and lack of LCI data*** Only those sub-systems for which LCI data were available were able to be integrated. Practically, it means that sub-systems with no available LCI are considered having the same LCI as others, if possible as those presenting close life-cycle patterns.	+++		X	X
Choice of reference quantities	***Uncertainties of existing consumption datasets***	+		X	X
Choice of LCI datasets	***Uncertainties of existing LCI datasets*** Although the availability of LCI data has improved immensely over the last years, the proliferation of LCI data on the information market has lead to problems with data quality, comprehensiveness, comparability and equal distribution of LCI data. In particular, environmental data do not exist for all products or services, for all life cycle stages and for all inputs or outputs contributing to environmental impacts.	++		X	X
Choice of impact factors	***Limitation of environmental impacts captured*** Some impact categories are not or not well captured by LCA because either they are not compatible with the LCA methodology (noise, odour, nature conservation (biodiversity, etc.), land use and land disturbance, risk of nuclear accidents) or they are not always assessed in available LCA databases (nuclear waste, toxic emissions, ...).	+	X	X	X
	Uncertainties of existing impact factors databases Such as global warming, toxicity on human and ecosystem in particular.	+		X	X

Step generating uncertainties	Description of the uncertainties	Attempt to qualify the uncertainty level	Origin of the uncertainties and next		
			Specific to the methodology	Pragmatical choices (limited resources)	Could be improved with research works
Monetarisation Step					
Methodological incompatibiltities	***Combination of potential global impacts (LCA) with actual location and source-specific external cost factors (monetarisation)*** On one hand, the environmental impacts quantified though an LCA approach are both potential and global. On the other hand, moneratisation methods aim to address the location and source-specific nature of impacts associated with emissions to air, water, land.	+++	X		X
Choice of the external cost factors	***Huge variation ranges between existing sources of information*** In particular due to the fact that local conditions vary significantly from one study to another	+++		X	X
	Lack of comprehensiveness of the external costs assessed External costs studies are more focused on air emissions than other sources of impacts, even if some studies address impacts generated by water emissions or waste. In particular, impacts specific to non renewable resources other than those linked to air emissions are not well analysed yet. They are not included in the study.	+++		X	X
	Lack of consistency between the external costs assessed Not necessarily the same effects monetarised in the available literature	+		X	X
Internalisation Step					
Choice of environmental taxes	***Difficulties to take into account exemptions and subsidies*** Areas of application and exemptions difficult to take into account properly. Hence, the degree to which internalisation of impacts occurs is lijely to be over-stated.	++	?	X	X
	Large scope of environmental taxes Difficult to consider only the taxes corresponding to the environmental impacts actually monetarised	+	?	X	X

1.4 Data and Hypotheses

After having presented the general methodology elaborated for the specific purposes of the study, this section presents all the data and hypotheses used for each main part of the methodology.

We successively look at data and hypotheses related to:

- environmental impacts,
- external costs,
- Internalisation of external costs.

1.4.1 Environmental Impacts

1.4.1.1 Reference Quantities Related to Functional Units

- The following table gives the reference quantity for each of the categories considered, based on "Consumers in Europe – Facts and figures" (Eurostat, 2001), which is the most relevant and useful information source in the domain of consumer policy. The aim of this publication is to present, for the first time, a comprehensive collection of the most important data available from different sources on consumption patterns, including expenditure and prices. It examines the realities of the European economy and the European single market from the consumer's viewpoint.

Functional Units and Reference Quantities Considered

Functional Units & Reference Quantities

Functional Unit: Final consumption in the European Union per yr	**Reference Quantities**				
	Total European Union		**Per capita**		**Scope**
	Qty	Unit	Qty	Unit	
'Final products' Classification					
Food and beverages					
Vegetable food products	184	Mt	491	kg	UE 15, 1999
Non vegetable food products	36	Mt	97	kg	UE 15, 1999
Beverages (alcohol)	1.28E+07	m3	34	l	UE 15, 1999
Clothing and footwear					
Textile (apparels and non domestic textiles)	5.4	Mt	14	kg	UE 15, 1999
Footwear (leather)	1.6	Billions pairs of shoes	4	pairs of shoes	UE 15, 1999
Housing					
Building occupancy domestic sector					
Space heating	6.8E+12	MJ	1.8E+04	MJ	UE 15, 1999
Water heating	1.5E+12	MJ	4.0E+03	MJ	UE 15, 2000
Cooking	5.2E+11	MJ	1.4E+03	MJ	UE 15, 2001
Electrical appliances and lighting	1.1E+12	MJ	2.9E+03	MJ	UE 15, 2002
Building occupancy commercial sector					
Space heating	2.3E+12	MJ	6.1E+03	MJ	UE 15, 1999
Water heating	3.9E+11	MJ	1.0E+03	MJ	UE 15, 2000
Cooking	2.2E+11	MJ	5.8E+02	MJ	UE 15, 2001
Electrical appliances and lighting	1.5E+12	MJ	4.0E+03	MJ	UE 15, 2002
Water (supply and waste water treatment)					
Drinkable water supply	2.2E+10	m3	59.2	m3	UE 15, 1999
Sewage sludge (Dry matter)	7	Mt	18.7	kg	UE 15, 1999
MSW management	215.6	Mt	575	kg	UE 15, 1999
Furnishing					
Domestic	14.8	Mt	39	kg	UE 15, 1999
Garden	0.5	Mt	1	kg	UE 15, 1999
Office	2.0	Mt	5	kg	UE 15, 1999
Healthcare and bodycare					
Personal care products (soap and toitries)	1.9	Mt	5	kg	UE 15, 2002
Baby products	2.7E+10	Diapers	71	Diapers	UE 15, 1999
Communication, recreation and culture					
Information technology equipment	134.6	M units	0.36	units	UE 15, 1999
Graphical and sanitary paper products					
Newsprint	9.8	Mt	26	kg	UE 15, 1999
Woody uncoated	4.1	Mt	11	kg	UE 15, 1999
Woody coated	6.2	Mt	16	kg	UE 15, 1999
Uncoated woodfree	8.9	Mt	24	kg	UE 15, 1999
Coated woodfree	8.7	Mt	23	kg	UE 15, 1999
Case materials	18.2	Mt	48	kg	UE 15, 1999
Folding boxboards	8.7	Mt	23	kg	UE 15, 1999
Wrapping	2.9	Mt	8	kg	UE 15, 1999
Gardening	1.24	Mt	3.3	kg	UE 15, 1999

Functional Units and Reference Quantities Considered (contd.)

Functional Unit: Final consumption in the European Union per yr	Reference Quantities				
	Total European Union		Per capita		Scope
	Qty	Unit	Qty	Unit	
'Transversal products' Classification					
Electric and electronic products and equipment					
Electric lamps and lighting	323	M units	0.86	Units	UE 15, 1998
Domestic appliances	60	M units	0.16	Units	UE 15, 1999
Information technlogy equipment	134.6	M units	0.36	Units	UE 15, 1999
Construction work					
Building structure	711	Mt	1911	kg	UE 15, 1999
Civil work (roads and other infrastructures)	269	Mt	719	kg	UE 15, 1999
Building occupancy (energy supply)					
Electricity	4.1E+06	TJ	1.1E+01	GJ	UE 15, 1999
Thermal energy - fuels	3.8E+06	TJ	1.0E+01	GJ	UE 15, 1999
Thermal energy - natural gas	5.6E+08	TJ	1.5E+03	GJ	UE 15, 1999
Thermal energy - coal and others	1.0E+05	TJ	2.7E-01	GJ	UE 15, 1999
Packaging					
Food	18.4	Mt	49	kg	UE 15, 1999
Non food	39	Mt	106	kg	UE 15, 1999
Textile					UE 15, 1999
Apparel	2.5	Mt	6	kg	UE 15, 1999
Home furnishing	1.7	Mt	4	kg	UE 15, 1999
Industrial and non domestic uses	1.1	Mt	3	kg	UE 15, 1999
Transport					
Public transportation for passengers (transport services)	1.00E+06	M pkm	2 678	pkm	UE 15, 1999
Personal cars	4.79E+06 14.7	M pkm M cars	1 0073 47	pkm kg	UE 15, 1999
Freight transportation (road, rail, water, air)	2.96E+06	M tkm	7970	tkm	UE 15, 1999

bn: billion; M: million; pkm: passenger x km; tkm: tonne x km

1.4.1.2 System Boundaries

■ Considering the wide scope of each category under consideration and the lack of LCI data for certain sub-systems or life cycle stages included in these categories, pragmatic choices had to be made.

Thus it is necessary to describe with transparency the sub-systems and data which were eventually taken into account in the studied systems.

For that purpose, a detailed fact sheet per category was elaborated which presents all the hypotheses and sources of information and LCI data used (it also includes the detailed results obtained: physical and monetarised environmental impacts, taxes, lie cycle prices…) (see the appendix report).

The following tables summarise most of the system boundaries.

System Boundaries

'Final products' Classification	Content of the category: Main products / services included	Content of the category: Main products / services not included (no LCA data available)	Life cycle steps taken into account: Components production from raw material extraction	Product production	Distribution	Use	End of life
Food and beverages							
Vegetable food products	The overall quantity of vegetable consumed in the EU are considered having an LCI equivalent to the average LCI of potatoes and tomatoes		X	X	In Transport category	Energy to cook in Domestic Appliances Category	Packaging in Packging category
Non vegetable food products	The quantity of beef and milk consumed in EU	Fish food products and other meats	X	X			
Beverages	Wine	Other alcoholic products and Non-alcoholic products	X	X			
Clothing and footwear							
Textile (apparels and non domestic textiles)	Cotton, wool, polyester…	Fine leather goods (gloves, bags…)	X	X		X (except dry cleaning)	X
Footwear	Leather shoes, synthetic shoes and slippers	Specific shoes for industrial or professional uses	X	X			X
Housing							
Building structure	Building materials (concrete, bricks, wood, steel, plastics, …)	Building installation, equipments (boilers, sanitary equipment, …).	X			X	X
Domestic appliances	Computers, TV, telephone, lamps, batteries	Small appliances (shaves, hair dryers, …), fax, micro-wave owen	X			X	X
Building occupancy	Energy for space heating, hot water, domestic appliances, lighting	Space cooling, ventilation	X	X		X	X
Water supply and waste water treatment	Water supply, distribution by pipes, waste water treatment, and spreading of sewage sludge		X	X	X (pipes)	X	X
Municipal Solid Waste management	Recycling, incineration, composting, landfilling	Collection	X	X	In Transport category	X	X
Furniture	Wood and non wood interior & exterior furniture, textiles	Sanitary equipments	X			X	X
Cleaning agents	Domestic and professional detergent products	Flagrances, perfumes	X			X	X
Healthcare and bodycare							
Personal care products	Toiletries, soap	Cosmetics, perfumes	X			X	X
Baby products	Diapers	Cream, talc…	X	X		X	X
Transport							
Personal cars	Automotives and fuels	Motorcycles, Bicycles…	X	X		X	X
Public transport (road, rail, water, air)	Vehicles and fuels for road, rail, air, sea		X	X		X except repair	X
Communication, recreation and culture							
Information technology equipment	Computers, telephones, video and media recorder	Telephone and Internet infrastructures	X			X	X
Paper products	Graphic and sanitary paper: newsprint ,other graphic, woody uncoated, woody coated, uncoated woodfree, coated woodfree, case materials, folding boxboards, wrapping		X	X		X	X
Gardening (tools, fertilisers)	Furniture, fertilisers and pesticides	Tools, flowers, seeds…	X	X (except for furniture)		X	X

System Boundaries (contd)

'Transversal products' Classification	Content of the category: Main products / services included	Content of the category: Main products / services not included (no LCA data available)	Life cycle steps taken into account: Components production	Product production	Distribution	Use	End of life
Electric and electronic products and equipment							
Domestic appliances	See above						
Information technlogy equipment							
Construction work							
Building structure (commercial and residential)	See above						
Civil work (roads and other infrastructures)	Concrete, asphalt, bitumen	metallic constructions	X		In transport category	X	X
Building occupancy							
Residential sector (gas, fuel, electricity, biomass)	See above						
Commercial sector (gas, fuel, electricity, biomass)	Energy for space heating, hot water, domestic appliances, lighting	Space cooling, ventilation	X	X		X	X
Packaging							
Food Non food	Packaging materials (plastics,metals, paper, glass…)	Expanded polystyrene	X	X		X	X
Textile							
Apparel Industrial and non domestic uses	Textiles fibres (polyamide, wool, cotton…)		X	X		X (except dry cleaning)	X
Home furnishing	Textiles fibres (polyamide, wool, cotton…)		X	X			X
Transport							
Goods transport (road, rail, water)	Vehicles and fuels for road, rail, air, sea		X	X (except vehicles)		X (except repair)	X

1.4.1.3 Sources of LCI Data

■ In this study, life cycle inventory (LCI) of each product system was obtained by using the "cradle to gate" or "gate-to-gate" LCI directly available in three LCI databases:

- Simapro version 4.0 (2001),
- Boustead version 4.1 (2000),
- Wisard & Team (version 1999).

However, these databases do not cover all the unit processes of interest. For instance, with respect to the textile products, no ecoprofile is available regarding both the fabric production and the clothing manufacturing.

When possible in such cases, bibliographic data were derived from reference documents on Best Available Techniques which is available for many types of manufacturing industry (downloadable documents from the EU, DG Joint Research Centre, Seville – Bureau of Integrated Pollution Prevention and Control). However, the selected data are not always representative of the BAT; they correspond to an average technology in the EU.

■ Some simplifications were necessary.

- Origin of energy and materials.

  Energy, especially electric energy is obtained from national networks. It is produced by different power stations, e.g. natural gas, hard coal, nuclear and hydro power. The corresponding resources and emissions depend on the mix of power stations, e.g. the German electricity mix is quite different from the French mix. For instance, the CO_2 mass emission per unit of electric energy can differ by a 2 factor.

  In this study, the LCI of 1 kWh of electric power is based on the average electricity mix at the EU level (data computable from DG Transport & Energy).

  In LCI of the main materials, like plastics, steel, aluminium, paper products, etc. data are as far as possible representative of a EU mix of international suppliers (the main ecoprofiles are published by professional organisations: data from APME-PWM for plastic materials, IISI for steel, EAA for aluminium, etc.).

1.4.1.4 Classification and characterisation

■ To assess the environmental impacts, the characterisation factors used in this study are those published by Centre of Environmental Science (CML, university of Leiden, NL) - Section Substances and Products (SSP).

These data are not specific to the Dutch situation. They are valid whatever the geographical scope and context.

They are downloadable from http://www.leidenuniv.nl/interfac/cml/lca2/ .

■ The following tables summarise the inputs and outputs contributing to the environmental impacts considered (details about characterisation factors are given in appendix 3).

Environmental Impacts and Environmental Flows Concerned (Classification Step)

NB: the term « dusts » used all along the report is taken as an equivalent to “particulate matter”

Environmental Impacts		**Inputs or Outputs Concerned**
Linked to resources consumption		
Depletion of non renewable resources	kg antimony eq.	Oil (in ground), Natural Gas (in ground), Coal (in ground), Bauxite (Al2O3, ore), Copper (Cu, in ore), Iron (Fe, in ore), Iron (Fe, ore), Lead (Pb, in ore), Manganese (Mn, in ore), Nickel (Ni, in ore), Phosphate Rock (in ground), Potassium Chloride (KCl, as K2O, in ground), Silver (Ag, in ore), Uranium (U, in ore), Uranium (U, ore), Zinc (Zn, in ore), Lignite (in ground), Barium Sulphate (BaSO4, in ground), Chromium (Cr, in ore), Ilmenite (FeO.TiO2, ore), Sulphur (S, in ground), Silver (Ag, in ore)
Linked to air emissions		
Greenhouse effect (direct, 100 yrs)	g CO_2 eq.	Carbon Dioxide (CO2, fossil), Methane (CH4), Nitrous Oxide (N2O), CFC 11 (CFCl3), CFC 12 (CCl2F2), CFC 13 (CF3Cl), CFC 114 (CF2ClCF2Cl), HCFC 22 (CHF2Cl), Halon 1301 (CF3Br), Carbon Tetrafluoride (CF4)
Stratospheric Ozone Depletion	g CFC-11 eq.	CFC 11 (CFCl3), CFC 12 (CCl2F2), CFC 114 (CF2ClCF2Cl), HCFC 22 (CHF2Cl), Halon 1301 (CF3Br)
Air acidification	g SO_2 eq.	Sulphur Oxides (SOx as SO2), Nitrogen Oxides (NOx as NO2), Ammonia (NH3)
Photochemical oxidation	g ethylene eq.	Acetaldehyde (CH3CHO), Acetic Acid (CH3COOH), Acetone (CH3COCH3), Acetylene (C2H2), Alcohol (unspecified), Aldehyde (unspecified), Alkane (unspecified), Alkene (unspecified), Aromatic Hydrocarbons (unspecified), Benzene (C6H6), Butane (n-C4H10), Butene (1-CH3CH2CHCH2), Carbon Monoxide (CO), Ethane (C2H6), Ethanol (C2H5OH), Ethyl Benzene (C6H5C2H5), Ethylene (C2H4), Formaldehyde (CH2O), Halogenated Hydrocarbons (unspecified), Heptane (C7H16), Hexane (C6H14), Hydrocarbons (except methane), Hydrocarbons (unspecified), Methane (CH4), Methanol (CH3OH), Nitrogen Oxides (NOx as NO2), Pentane (C5H12), Polycyclic Aromatic Hydrocarbons (PAH, unspecified), Propane (C3H8), Propionaldehyde (CH3CH2CHO), Sulphur Oxides (SOx as SO2), Toluene (C6H5CH3), VOC (Volatile Organic Compounds), Xylene (C6H4(CH3)2)
Linked to water effluents		
Eutrophication	g PO4 eq.	Ammonia (NH4+, NH3, as N), Phosphorus (P), COD (Chemical Oxygen Demand), Nitrogenous Matter (Kjeldahl, as N), Nitrate (NO3-), Nitrogenous Matter (unspecified, as N), Nitrite (NO2-), Phosphates (PO4 3-, HPO4--, H2PO4-, H3PO4, as P), Phosphorus Pentoxide (P2O5)

Remark: when choices where made at the beginning of the study regarding data and hypotheses, characterisation factors available did not include deposition from air contribution to eutrophication. Any update of the study could take than phenomenon into consideration, characterisation factors being now available.

Environmental Impacts and Environmental Flows Concerned (Contd.)

Linked to human health and ecotoxical risk

Human Toxicity	g eq. 1-4-dichlorobenzene	(a) Antimony (Sb), (a) Arsenic (As), (a) Barium (Ba), (a) Beryllium (Be), (a) Cadmium (Cd), (a) Cobalt (Co), (a) Copper (Cu), (a) Lead (Pb), (a) Mercury (Hg), (a) Molybdenum (Mo), (a) Nickel (Ni), (a) Selenium (Se), (a) Thallium (Tl), (a) Tin (Sn), (a) Vanadium (V), (a) Zinc (Zn), (a) Ammonia (NH3), (a) Hydrogen Sulphide (H2S), (a) Hydrogen Chloride (HCl), (a) Ethylene (C2H4), (a) Formaldehyde (CH2O), (a) Benzene (C6H6), (a) Toluene (C6H5CH3), (a) Phenol (C6H5OH), (a) Ethyl Benzene (C6H5C2H5), (w) Arsenic (As3+, As5+), (w) Barium (Ba++), (w) Cadmium (Cd++), (w) Chromium (Cr III), (w) Chromium (Cr VI), (w) Chromium (Cr III, Cr VI), (w) Cobalt (Co I, Co II, Co III), (w) Copper (Cu+, Cu++), (w) Lead (Pb++, Pb4+), (w) Mercury (Hg+, Hg++), (w) Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI), (w) Nickel (Ni++, Ni3+), (w) Selenium (Se II, Se IV, Se VI) , (w) Tin (Sn++, Sn4+), (w) Vanadium (V3+, V5+), (w) Zinc (Zn++), (w) Formaldehyde (CH2O), (w) Benzene (C6H6), (w) Toluene (C6H5CH3), (w) Phenol (C6H5OH), (w) Ethyl Benzene (C6H5C2H5), (w) Methylene Chloride (CH2Cl2, HC-130), (w) chloroform (CHCl3, HC-20), (w) trichloroethane (1,1,1-CH3CCl3), (w) Trichloroethylene (CCl2CHCl), (w) tetrachloroethylene (C2Cl (s) Cobalt (Co), (s) Copper (Cu), (s) Lead (Pb), (s) Mercury (Hg), (s) Nickel (Ni), (s) Zinc (Zn).
Years of Life Lost	year	(a) Dust, (a) Hydrocarbons (except methane), (a) Hydrocarbons (unspecified), (a) Nitrogen Oxides (NOx as NO2), (a) Particulates (unspecified), (a) Sulphur Oxides (SOx as SO2), (a) VOC (Volatile Organic Compounds)
Aquatic Ecotoxicity	g eq. 1-4-dichlorobenzene	(a) Antimony (Sb), (a) Arsenic (As), (a) Barium (Ba), (a) Beryllium (Be), (a) Cadmium (Cd), (a) Cobalt (Co), (a) Copper (Cu), (a) Lead (Pb), (a) Mercury (Hg), (a) Molybdenum (Mo), (a) Nickel (Ni), (a) Selenium (Se), (a) Thallium (Tl), (a) Tin (Sn), (a) Vanadium (V), (a) Zinc (Zn), (a) Ethylene (C2H4), (a) Formaldehyde (CH2O), (a) Benzene (C6H6), (a) Toluene (C6H5CH3), (a) Phenol (C6H5OH), (a) Ethyl Benzene (C6H5C2H5), (a) Benzo(a)pyrene (C20H12), (w) Arsenic (As3+, As5+), (w) Barium (Ba++), (w) Cadmium (Cd++), (w) Chromium (Cr III), (w) Chromium (Cr III, Cr VI), (w) Chromium (Cr VI), (w) Cobalt (Co I, Co II, Co III), (w) Copper (Cu+, Cu++), (w) Lead (Pb++, Pb4+), (w) Mercury (Hg+, Hg++), (w) Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI), (w) Nickel (Ni++, Ni3+), (w) Selenium (Se II, Se IV, Se VI), (w) Tin (Sn++, Sn4+), (w) Vanadium (V3+, V5+), (w) Zinc (Zn++), (w) Formaldehyde (CH2O), (w) Benzene (C6H6), (w) Toluene (C6H5CH3), (w) Phenol (C6H5OH), (w) Ethyl Benzene (C6H5C2H5), (w) Methylene Chloride (CH2Cl2, HC-130), (w) Chloroform (CHCl3, HC-20), (w) Trichloroethane (1,1,1-CH3CCl3), (w) Trichloroethylene (CCl2CHCl), (w) Tetrachloroethylene (C2Cl4), (s) Arsenic (As), (s) Cadmium (Cd), ((s) Nickel (Ni), (s) Zinc (Zn)
Sediment Ecotoxicity	g eq. 1-4-dichlorobenzene	(a) Antimony (Sb), (a) Arsenic (As), (a) Barium (Ba), (a) Beryllium (Be), (a) Cadmium (Cd), (a) Cobalt (Co), (a) Copper (Cu), (a) Lead (Pb), (a) Mercury (Hg), (a) Molybdenum (Mo), (a) Nickel (Ni), (a) Selenium (Se), (a) Thallium (Tl), (a) Tin (Sn), (a) Vanadium (V), (a) Zinc (Zn), (a) Ethylene (C2H4), (a) Formaldehyde (CH2O), (a) Benzene (C6H6), (a) Toluene (C6H5CH3), (a) Phenol (C6H5OH), (a) Ethyl Benzene (C6H5C2H5), (a) Benzo(a)pyrene (C20H12), (w) Arsenic (As3+, As5+), (w) Barium (Ba++), (w) Cadmium (Cd++), (w) Chromium (Cr III), (w) Chromium (Cr VI), (w) Chromium (Cr III, Cr VI), (w) Cobalt (Co I, Co II, Co III), (w) Copper (Cu+, Cu++), (w) Lead (Pb++, Pb4+), (w) Mercury (Hg+, Hg++), (w) Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI), (w) Nickel (Ni++, Ni3+), (w) Selenium (Se II, Se IV, Se VI), (w) Tin (Sn++, Sn4+), (w) Vanadium (V3+, V5+), (w) Zinc (Zn++), (w) Formaldehyde (CH2O), (w) Benzene (C6H6), (w) Toluene (C6H5CH3), (w) Phenol (C6H5OH), (w) Ethyl Benzene (C6H5C2H5), (w) Methylene Chloride (CH2Cl2, HC-130), (w) Chloroform (CHCl3, HC-20), (w) Trichloroethane (1,1,1-CH3CCl3), (w) Trichloroethylene (CCl2CHCl), (w) Tetrachloroethylene (C2Cl4), (s) Arsenic (As), (s) Cadmium (Cd), (
Terrestrial Ecotoxicity	g eq. 1-4-dichlorobenzene	(a) Antimony (Sb), (a) Arsenic (As), (a) Barium (Ba), (a) Beryllium (Be), (a) Cadmium (Cd), (a) Cobalt (Co), (a) Copper (Cu), (a) Lead (Pb), (a) Mercury (Hg), (a) Molybdenum (Mo), (a) Nickel (Ni), (a) Selenium (Se), (a) Thallium (Tl), (a) Tin (Sn), (a) Vanadium (V), (a) Zinc (Zn), (a) Ethylene (C2H4), (a) Formaldehyde (CH2O), (a) Benzene (C6H6), (a) Toluene (C6H5CH3), (a) Phenol (C6H5OH), (a) Ethyl Benzene (C6H5C2H5), (a) Benzo(a)pyrene (C20H12), (w) Arsenic (As3+, As5+), (w) Barium (Ba++), (w) Cadmium (Cd++), (w) Chromium (Cr III), (w) Chromium (Cr VI), (w) Chromium (Cr III, Cr VI), (w) Cobalt (Co I, Co II, Co III), (w) Copper (Cu+, Cu++), (w) Lead (Pb++, Pb4+), (w) Mercury (Hg+, Hg++), (w) Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI), (w) Nickel (Ni++, Ni3+), (w) Selenium (Se II, Se IV, Se VI), (w) Tin (Sn++, Sn4+), (w) Vanadium (V3+, V5+), (w) Zinc (Zn++), (w) Formaldehyde (CH2O), (w) Benzene (C6H6), (w) Toluene (C6H5CH3), (w) Phenol (C6H5OH), (w) Ethyl Benzene (C6H5C2H5), (w) Methylene Chloride (CH2Cl2, HC-130), (w) Chloroform (CHCl3, HC-20), (w) Trichloroethane (1,1,1-CH3CCl3), (w) Trichloroethylene (CCl2CHCl), (w) Tetrachloroethylene (C2Cl4), (s) Arsenic (As), (s) Cadmium (Cd), (

Environmental Impacts and Environmental Flows Concerned (Contd.)

Other Flows		Inputs or Outputs Concerned
Primary energy	MJ	Feedstock Energy, Fuel Energy
Dusts	g	Dust, Particulates (unspecified)
Dioxins	g	Dioxins
Metals into air	g	Aluminium (Al), Antimony (Sb), Cadmium (Cd), Cobalt (Co), Copper (Cu), Chromium (Cr III, Cr VI), Iron (Fe), Lanthanum (La), Lead (Pb), Manganese (Mn), Mercury (Hg), Metals (unspecified), Molybdenum (Mo), Nickel (Ni), Scandium (Sc), Thallium (Tl), Thorium (Th), Tin (Sn), Titanium (Ti), Uranium (U), Vanadium (V), Zinc (Zn), Zirconium (Zr)
Metals into water	g	Aluminium (Al3+), Aluminium Hydroxide (Al(OH)3), Arsenic (As3+, As5+), Cadmium (Cd++), Cerium (Ce++), Chromate (CrO4--), Chromium (Cr III), Chromium (Cr III, Cr VI), Chromium (Cr VI), Cobalt (Co I, Co II, Co III), Copper (Cu+, Cu++), Iron (Fe++, Fe3+), Lead (Pb++, Pb4+), Manganese (Mn II, Mn IV, Mn VII), Mercury (Hg+, Hg++), Metals (unspecified), Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI), Nickel (Ni++, Ni3+), Rubidium (Rb+), Silver (Ag+), Tin (Sn++, Sn4+), Titanium (Ti3+, Ti4+), Vanadium (V3+, V5+), Zinc (Zn++)
Metals into soil	g	Aluminium (Al), Cadmium (Cd), Chromium (Cr III, Cr VI), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Zinc (Zn)
Municipal and industrial waste	kg	Municipal and industrial waste
Hazardous waste	kg	Hazardous waste
Inert waste	kg	Inert waste

1.4.2 External Costs

1.4.2.1 Brief Overview of Literature Selected for this Study

■ In accordance with the objectives of the study and its limited resources, the external cost factors used in this study are based on data extracted from literature. Available external cost factors compatible with such a LCA-based study were selected in priority. For some impacts (e.g. for acidification potential), it was necessary to build new estimates, by adapting existing monetary values to LCA outputs. The way to obtain them is explained in detail in appendix 4.

A large literature exists about the monetarisation of environmental impacts (see Appendix 5 §5.4), especially for air emissions. It was decided to make a selection of studies, selected among others according to several criteria:

- the methodology used in the study and the assumptions made,
- the degree of compatibility of the results with LCA,
- the date when the study was carried out (recent studies were preferred),
- its context (official contexts; for example, studies for the European Commission were preferred),
- and its scale (studies concerning the European context were preferred).

Next to this, we focused our attention on studies using the **impact pathway approach**. This has been largely used for conventional air emissions and is therefore generally accepted for this area of externalities. However, it has not been used for water emissions, mainly due to the lack of scientific knowledge, but also due to the site-specific character of the emissions and impacts. For each result used in this study, the method applied by the authors is presented, with its assumptions and uncertainties.

Remark: In an intermediate experts workshop in June 2002, we proposed a set of data extracted from a large number of studies. The main idea of this approach was to include an extensive overview of different studies that come to very varying results for the same environmental impacts (due to different methodologies applied and to different settings and hypotheses in which the studies were carried out. The idea of this approach was to show to policy makers that financial impacts of external effects can be of great importance and variety. In this case, results from monetarisation essentially have a didactic meaning for policy makers.

However, at the outcome of the experts workshop and following the advice given and the choices made by the project leaders from the European Commission, it was concluded to focus the choice of data developed in the framework of European Commission financed studies, especially resulting from the ExternE project. The reason was that these studies are based on methodologies largely accepted in the community working in the domain of monetarisation.

■ The values proposed are thus deduced, directly or indirectly, from three main studies:

- ExternE

  A project to evaluate the externalities of energy, sponsored by the European Commission between 1995 and 1998 and carried out in all countries of the European Union. The evaluation of externalities is based on a common methodology, the impact pathway method. A specific European model was developed for this project (ECOSENSE: model for the dispersion of pollutants). Each country estimated the impacts of pollutants emitted by energy production based on this model.

- Spadaro & Rabl (1999)

  A study that proposed simple impact indices for LCA, based on the impact pathway method. Results are given for the principal air pollutants. The authors had previously worked on the French national implementation of the ExternE program.

- RDC-Environment & Pira International (2001)

  A study for the European Commission that aimed at evaluating the achievement of reuse and recycling targets for different packaging materials. For that, economic valuations of environmental impacts were derived, based as far as possible on the impact pathway method.

These studies are briefly presented in appendix 4.

1.4.2.2 External Cost Factors Considered in this Study

- They covered the impacts on the environment and on human health generated by:
- air emissions,
- water emissions (only partially for eutrophicant emissions, but other emissions into water are not taken into account)
- solid waste.

As far as the non renewable resources depletion impact is concerned, it seemed, from the review of the available literature (in particular the ExternE study for that specific issue), that the impacts monetarised for air emissions are also integrated in the monetarisation of non renewable resources use (e.g. the monetarisation of non renewable resources consumption takes into account the air emissions released during their use). In order to prevent double counting of impacts, it was decided not to take into account external cost factors for resources existing in available literature.

- *Remark*: it is not easy to assess the level of underestimation of the overall external cost due to this decision. Impacts specific to non renewable resources other than those linked to air emissions (e.g. resource depletion, damage on landscapes, …) are indeed not included in this study. However, without pretending covering the entire issue, it should be noted that the scarcity of non renewable materials, which constitutes one of the major source of external costs, is more or less integrated in the selling prices of the products.

- As for air emissions, data from literature are not ready for use in an LCA context.

As described in section 1.3.3.1, external cost factors have to be selected for each substance corresponding to the unit in which an environmental impact is expressed (SO_2 for air acidification, CO_2 for greenhouse effect…).

Among the environmental impacts, two types are to be distinguished according to available external cost factors:

- those for which an external cost factor is available for the substance in which the impact is expressed (e.g CO_2 for greenhouse effect),
- those for which no external cost factor is available for the substance in which the impact is expressed (e.g ethylene for photo-oxidation).

For the latest, an external cost factor was derived from data existing for another substance contributing to the same impact. For instance, the external cost factor for ethylene was derived from the one for NOx contributing to photo-oxidation.

■ The following table sums up the cost factors considered in the study. Appendix 5 describes, for each of them, how these values were selected or built.

External Cost Factors Considered to Monetarise Environmental Impacts

Data sources
(1) ExternE
(2) RDC-Environment & Pira Internl (2001)
(3) Spadaro & Rabl (1999)
(4) CML 2002
(5) Goedkoop & al. (1999 - Ecoindicator 99)
(6) COWI (2000)
(7) J.V. Spadaro & Ari Rabl, Int J.LCA 4 (4) 229-243 (1999).

AIR EMISSION IMPACTS	Cost factors (Euros/g)			Impact factors	
	Min	Max	Data source	Value	Data source
	a			b	
Stratospheric Ozone Depletion (g CFC11 eq.)	0.00068	0.00068	(2) & (3)		
Air Acidification (g SO2 eq.)	0.00009	0.00438	a_{SO2}/b_{SO2}		
(a) Sulphur Oxides (SOx as SO2)	0.00011	0.00525	(2) & (3)	1.2	(4)
Greenhouse effect (direct, 100 years) (g CO2 eq.)	0.000019	0.000048	(1)		
Photochemical oxidation (g ethylene eq.)	0.0007	0.0009	(1) & (7)		
(a) Nitrogen Oxides (NOx as NO2)	0.0008	0.0031	(1) & (3)	0.028	(4)
Human Toxicity (g 1-4-dichlorobenzene eq.)					
(a) Cadmium (Cd)	0.021	0.021	(3)		
(a) Chromium (Cr III, Cr VI)	0.140	0.140	(3)		
(a) Nickel (Ni)	0.003	0.003	(3)		
(a) Arsenic (As)	0.171	0.171	(3)		
Human health effects caused by dusts (g)	0.0014	0.0593	(1)		
Human health effects caused by dioxins (g)	12950	27750	(1)		

WATER EMISSION IMPACTS	Cost factors (Euros/g)			Impact factors	
	Min	Max	Data source	Value	Data source
	a			b	
Eutrophication (g eq. $P0_4$)	0.0015	0.0015	a_{PO4}/b_{PO4}		
(w) Phosphorus (P)	0.0047	0.0047	(1)	3.06	(4)

SOLID WASTE IMPACTS	Cost factors (Euros/kg)		
	Min	Max	Data source
Disaminity caused by incineration (kg of waste)	0.004	0.014	(6)
Disaminity caused by landfilling (kg of waste)	0.006	0.019	(6)

The following table presents the effects that are monetarised for each environmental impact considered in the study.

Effect (or Endpoint Impact) Monetarised for each (Startpoint) Environmental Impact

	Effects Monetarised						
	Human health			Ecosystems	Material & building	Disamenity [26]	Forests & crops
	Mortality	Morbidity (chronic disease)	Morbidity (acute disease)				
Greenhouse effect	✓			✓	✓		✓
Stratospheric ozone depletion				✓			
Air acidification				✓	✓		✓
Photochemical oxidation				✓			
Dusts	✓			✓	✓		✓
Dioxins	✓						
Eutrophication				✓[27]			
Incineration						✓	
Landfilling						✓	
Human toxicity related to carcinogen metals	✓						

[26] Local nuisance impacts including odour, noise, dust, litter….

[27] Abatement costs at sewage or industrial plants to reduce emissions contributing to eutrophication

1.4.3 External Costs Internalised

1.4.3.1 Brief Overview of Environmental Taxes in the European Union

The OECD defines a tax as a compulsory, unrequited payment to general government. Taxes are unrequited in the sense that benefits provided by governments to taxpayers are not normally in proportion to their payments. The term “environmentally related taxes” (sometimes also called “green taxes”) is used by the OECD to describe any tax levied on tax-bases deemed to be of particular environmental relevance (Barde & al., 2002).

In Europe, environmental taxes represent about 7% of total taxes. 90% of their benefits come from energy and transport sectors.

The following table gives an overview of environmental taxes in the European Union in 2000.

Overview of Environmental Taxes in the European Union in 2000

Instruments	**A**	**B**	**DK**	**FI**	**FR**	**GE**	**GR**	**IR**	**IT**	**L**	**NL**	**P**	**E**	**S**	**UK**
NOx charges					**X**				**X**				**X**	**X**	
agricultural inputs															
pesticides		**X**	**X**	**X**										**X**	
fertilisers	**X**		**X**	**X**							**X**			**X**	
other goods – ecotaxes															
batteries	**TBS**	**X**	**X**			**TBS**			**X**					**X**	
plastic carrier bags			**X**						**X**						
disposable containers	**DRS**	**X**	**X**	**X**							**DRS**			**X**	
tyres			**X**	**X**										**X**	
CFCs and/or halons			**X**												
disposable cameras		**X**													
lubricant oil charge			**X**	**X**					**X**				**X**	**X**	
oil pollution charge				**X**	**X**										
others	**DRS**	**X**	**X**		**X**				**X**		**X**		**X**	**X**	
waste															
user charge	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
waste tax (landfill)	**X**	**X**	**X**	**X**	**X**	**X**			**X**		**X**			**X**	**X**
hazardous waste tax		**X**	**X**	**X**	**X**	**X**									
others			**X**	**X**	**X**						**X**				
water															
user charge	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
water (abstraction) tax			**X**												
waste water tax		**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**		**X**	**X**	**X**
others		**X**	**X**	**X**	**X**	**X**			**X**		**X**		**X**		**X**
aggregates tax		**X**	**X**											**X**	**X**
air transport															
noise charge/others		**X**	**X**		**X**	**X**		**X**	**X**		**X**	**X**		**X**	**X**

X: Economic instrument such as tax or charge *Source: ECOTEC (2001)*

DRS: Deposit refund scheme

TBS: Take back scheme

Another interesting table has been proposed by the EEA, illustrating the environmental effects of environmental taxes in the European Union. It helps to underline the effects of internalisation of external costs.

Environmental Effects of Green Taxes

Tax on	***Where?***	***Efficiency***
Motor fuels	All European countries	Positive effect on vehicles consumption (eg GB). Substitution observed in case of differentiated taxation.
Other energy use	Many European countries	Improvement of energy efficiency and substitution of fuels in countries with the higher tax rates (Denmark, Finland, Sweden)
Vehicles sales registration	Many European countries	Tendency in decreasing in vehicle sales. More effect when differentiated taxation.
Motor vehicles property	Many European countries	More effect when differentiated taxation.
Motor vehicles use	Many European countries	Efficiency not yet proved.
Industrial emissions to air and water	Many European countries	Positive effect, better when benefits are changed in environmental investments.
Agricultural inputs	Belgium, Denmark, Norway, Sweden	Direct effect limited.
Packaging	Norway, Poland, Belgium, Estonia, Denmark…	Positive effect in Estonia of deposit system.
Chemical substances	Denmark, Switzerland, Island, Hungary…	In Denmark, contributed to reduce use of CFC.
Batteries	Sweden, Hungary, Denmark…	Serves essentially as instrument to stimulate used batteries recovery.
Tyres	Denmark, Hungary…	Benefits are used to finance used tyres treatment.
Water resources	Many European countries	A decrease in industrial use of groundwater has been noticed in the Netherlands after introducing this tax.
Waste	Denmark, Finland, Great-Britain, Italy, Norway…	Efficient for tax on waste, for reducing waste, passing from landfill to incineration or recycling.

Source: European Environment Agency

1.4.3.2 Introduction to Environmental Taxes in the Three Countries Selected in this Study

In order to simplify the study, three countries were chosen to be analysed according to their environmental taxes: Denmark, representing a high level of environmental taxation, France, representing a medium level of environmental taxation, and Poland, representing one of the future member countries.

Most of the data used in this study come from two main sources:

- The database built by the OECD (available on http://www.oecd.org/EN/document/0,,EN-document-471-14-no-1-3016-471,00.html). However, it does not accurately represent the current and most recent situation, as taxes change rapidly, especially in this domain.
- The Eco-tax Database, elaborated by Stefan Speck for of Forum of the Future in 2001/2002. This database was used for France and Denmark, with the taxes for 2000.

In addition, for France, the picture was completed by another available database, established in 2001 by the '*Centre d'Information pour les Entreprises et Partenaires'* (CIEPE), information centre for firms and partners. For some taxes, other databases were available that seemed more relevant, and we used them, e.g. for taxes on energy products (provided by the European Environmental Agency).

1.4.3.2.1 Denmark

Denmark is a country with a high level of environmental taxes. The oldest ones are taxes on petrol that have been existing since 1917, and taxes on energy since 1977. Between 1985 and 1992, taxes on lead in petrol, waste, packaging, CFC and resources (gravel) were settled within the framework of an environmental tax reform. Between 1992 and 2001, new taxes on waste, PVC, packaging, piped water, pesticides, organic solvents, HFC, PFC and SF6 were adopted. This tax system has a substantial environmental effect (all emissions decreased), although numerous exemptions and complicated structure might reduce effectiveness.

1.4.3.2.2 France

France is a country with a medium level of environmental taxes compared to the European average. A general tax on polluting activities (TGAP) has been implemented recently. The first text preparing it, in 1997, was based on a set of five existing ecotaxes (treatment and storage of special industrial waste, air pollution, oils, noise nuisances, domestic waste). TGAP was extended to new areas in 2000 (detergents, gravel, pesticides, industrial classified facilities, …).

1.4.3.2.3 Poland

Poland is a country with a relatively low level of environmental taxes. A complete system of fees on air pollution has been implemented, with a relatively high level. In January 2002, environmental taxes on water extraction, waste, gas, dust emissions and waste disposal, were increased. However, there has been no substantial environmental tax reform. It is currently not part of the public debate, nor a political party project.

1.4.3.3 Environmental Taxes Considered in this Study

The environmental taxes used in the study are summarised hereafter and related to each concerned flow inventoried in LCIs.

As described in §1.3.4, two main types of difficulties had to be dealt with:

- several exemptions or subsidies exist which apply to intermediary products or services consumed during the life of the final product or service studied,
- different tax rates exist for a given product, e.g. cars according to fuel consumption.

The solution we chose was to consider **data ranges**:

- **for the taxes where exemptions apply** (e.g. taxes related to energy): a **min value 0** (as if the exemption were total) and a **max value corresponding to the maximum tax existing in the country**,
- **where different tax rates exist**: **an interval covering the diversity of rates**.

A detailed presentation of how the environmental taxes used in the study were derived from literature data and existing database is included in appendix 6.

A quantification of total environmental taxes and their split between the different components (energy, water…) is presented in the Results chapter (§2.1.4.2). It shows that taxes related to energy and water effluents are the most important.

Environmental Taxes Considered for the 3 Countries

Flow	*Units*	Denmark		France		Poland	
		Min	Max	Min	Max	Min	Max
(r) Gravel (unspecified)	Euros/kg	1,12E-03	1,12E-03	9,00E-05	9,00E-05		
Water Used (total)	Euros/litre	1,14E-03	1,14E-03	9,00E-05	5,20E-04	1,70E-05	1,87E-04
(a) Aromatic Hydrocarbons (unspecified)	Euros/g			3,81E-05	3,81E-05		
(a) Arsenic (As)	Euros/g					6,95E-02	6,95E-02
(a) Benzene (C6H6)	Euros/g					1,59E-03	1,59E-03
(a) Cadmium (Cd)	Euros/g					3,47E-02	3,47E-02
(a) Carbon Dioxide (CO2, fossil)	Euros/g	6,70E-06	1,34E-05			5,00E-08	5,00E-08
(a) Carbon Monoxide (CO)	Euros/g					2,73E-05	2,73E-05
(a) CFC 11 (CFCl3)	Euros/g	4,00E-03	4,00E-03				
(a) CFC 114 (CF2ClCF2Cl)	Euros/g	4,00E-03	4,00E-03				
(a) CFC 12 (CCl2F2)	Euros/g	4,00E-03	4,00E-03				
(a) CFC 13 (CF3Cl)	Euros/g	4,00E-03	4,00E-03				
(a) Chromium (Cr III, Cr VI)	Euros/g					9,93E-03	9,93E-03
(a) Cobalt (Co)	Euros/g					9,93E-03	9,93E-03
(a) Dioxins (unspecified)	Euros/g					6,95E-02	6,95E-02
(a) Halon 1301 (CF3Br)	Euros/g	4,00E-03	4,00E-03			3,47E-05	3,47E-05
(a) HCFC 22 (CHF2Cl)	Euros/g	4,00E-03	4,00E-03				
(a) Hydrocarbons (except methane)	Euros/g			3,81E-05	3,81E-05	2,73E-05	2,73E-05
(a) Hydrocarbons (unspecified)	Euros/g			3,81E-05	3,81E-05	2,73E-05	2,73E-05
(a) Hydrogen Chloride (HCl)	Euros/g			0,0000274	0,0000274		
(a) Lead (Pb)	Euros/g					7,90E-06	7,90E-06
(a) Magnesium (Mg)	Euros/g					4,00E-06	4,00E-06
(a) Mercury (Hg)	Euros/g					3,47E-05	3,47E-05
(a) Methane (CH4)	Euros/g					1,00E-10	1,00E-10
(a) Molybdenum (Mo)	Euros/g					2,30E-06	2,30E-06
(a) Nickel (Ni)	Euros/g					6,95E-02	6,95E-02
(a) Nitrogen Oxides (NOx as NO2)	Euros/g			0,0000381	4,57E-05	9,81E-05	9,81E-05
(a) Sulphur Oxides (SOx as SO2)	Euros/g	1,34E-03	1,34E-03	0,0000274	0,0000274	1,00E-07	1,00E-07
(a) Tin (Sn)	Euros/g					1,00E-06	1,00E-06
(a) VOC (Volatile Organic Compounds)	Euros/g			3,81E-05	3,81E-05		
(a) Zinc (Zn)	Euros/g					1,04E-03	1,04E-03
(w) Ammonia (NH4+, NH3, as N)	Euros/g	2,68E-03	2,68E-03	5,13E-02	5,13E-02	0,00E+00	0,00E+00
(w) Arsenic (As3+, As5+)	Euros/g	0,00E+00	0,00E+00	1,52E+00	1,52E+00	1,12E-02	1,12E-02
(w) BOD5 (Biochemical Oxygen Demand)	Euros/g	0	0	0,0187	0,0187	0,00022	0,00222
(w) Cadmium (Cd++)	Euros/g	0,00E+00	0,00E+00	7,60E+00	7,60E+00	1,12E-02	1,12E-02
(w) Chlorides (Cl-)	Euros/g					3,00E-05	3,00E-05
(w) Chromium (Cr III)	Euros/g	0,00E+00	0,00E+00	1,52E-01	1,52E-01	1,12E-02	1,12E-02
(w) Chromium (Cr III, Cr VI)	Euros/g	0,00E+00	0,00E+00	1,52E-01	1,52E-01	1,12E-02	1,12E-02

Environmental Taxes Considered for the 3 Countries (Contd.)

		Denmark		France		Poland	
		Min	Max	Min	Max	Min	Max
Flow	***Units***						
(w) Chromium (Cr VI)	Euros/g	0,00E+00	0,00E+00	1,52E-01	1,52E-01	1,12E-02	1,12E-02
(w) COD (Chemical Oxygen Demand)	Euros/g	0	0	0,0374	0,0374	0,0001	0,0016
(w) Dissolved Organic Carbon (DOC)	Euros/g	1,47E-03	1,47E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00
(w) Lead (Pb++, Pb4+)	Euros/g	0,00E+00	0,00E+00	1,52E+00	1,52E+00	1,12E-02	1,12E-02
(w) Mercury (Hg+, Hg++)	Euros/g	0,00E+00	0,00E+00	7,60E+00	7,60E+00	1,12E-02	1,12E-02
(w) Nickel (Ni++, Ni3+)	Euros/g	0,00E+00	0,00E+00	7,60E-01	7,60E-01	1,12E-02	1,12E-02
(w) Nitrate (NO3-)	Euros/g	2,68E-03	2,68E-03	5,13E-02	5,13E-02	0,00E+00	0,00E+00
(w) Nitrite (NO2-)	Euros/g	2,68E-03	2,68E-03	5,13E-02	5,13E-02	0,00E+00	0,00E+00
(w) Nitrogenous Matter (Kjeldahl, as N)	Euros/g	2,68E-03	2,68E-03	5,13E-02	5,13E-02	0,00E+00	0,00E+00
(w) Nitrogenous Matter (unspecified, as N)	Euros/g	2,68E-03	2,68E-03	5,13E-02	5,13E-02	0,00E+00	0,00E+00
(w) Organic Dissolved Matter (chlorinated)	Euros/g	1,47E-03	1,47E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00
(w) Organic Dissolved Matter (unspecified)	Euros/g	1,47E-03	1,47E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00
(w) Organic Matter (unspecified)	Euros/g	1,47E-03	1,47E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00
(w) Phenol (C6H5OH)	Euros/g					4,17E-03	4,17E-03
(w) Phosphates (PO4 3-, HPO4--, H2PO4-, H3PO4, as P)	Euros/g	1,47E-02	1,47E-02	1,96E-01	1,96E-01	0,00E+00	0,00E+00
(w) Phosphorus (P)	Euros/g	1,47E-02	1,47E-02	1,96E-01	1,96E-01	0,00E+00	0,00E+00
(w) Phosphorus Pentoxide (P2O5)	Euros/g	6,30E-03	6,30E-03	8,38E-02	8,38E-02	0,00E+00	0,00E+00
(w) Sulphate (SO4--)	Euros/g					3,00E-05	3,00E-05
(w) Water (unspecified)	Euros/litre	0,00157	0,00157	0,00124	0,00124	0	0
(w) Water: Chemically Polluted	Euros/litre	0,00157	0,00157	0,00124	0,00124	0	0
(w) Zinc (Zn++)	Euros/g	0,00E+00	0,00E+00	1,52E-01	1,52E-01	1,12E-02	1,12E-02
Waste (hazardous)	Euros/kg	0,335	0,335	9,10E-03	1,82E-02		
Waste (incineration)	Euros/kg	6,40E-02	8,40E-02	0,00E+00	0,00E+00		
Waste (municipal and industrial)	Euros/kg	7,00E-02	8,30E-02	1,52E-02	2,13E-02		
Waste (unspecified)	Euros/kg	7,00E-02	8,30E-02	1,52E-02	2,13E-02		
Waste (unspecified, to incineration)	Euros/kg	6,40E-02	8,40E-02	0,00E+00	0,00E+00		
Waste: Non Mineral (inert)	Euros/kg	7,00E-02	8,30E-02	1,52E-02	2,13E-02		
Waste: Non Toxic Chemicals (unspecified)	Euros/kg	7,00E-02	8,30E-02	1,52E-02	2,13E-02		
Waste: Slags and Ash (unspecified)	Euros/kg	0,335	0,335	0,0091	0,0182		
Waste landfilled	Euros/kg	7,00E-02	8,30E-02	1,52E-02	2,13E-02		
Waste incinerated	Euros/kg	6,40E-02	8,40E-02				
Waste collection	Euros/kg	0,23	0,23	0,165	0,165		
Primary energy	Euros/MJ	1.39E-03	1.95E-02	6.3E-04	2.03E-02	1.1E-03	1.38E-02

1.4.3.4 Life Cycle Prices Considered in this Study

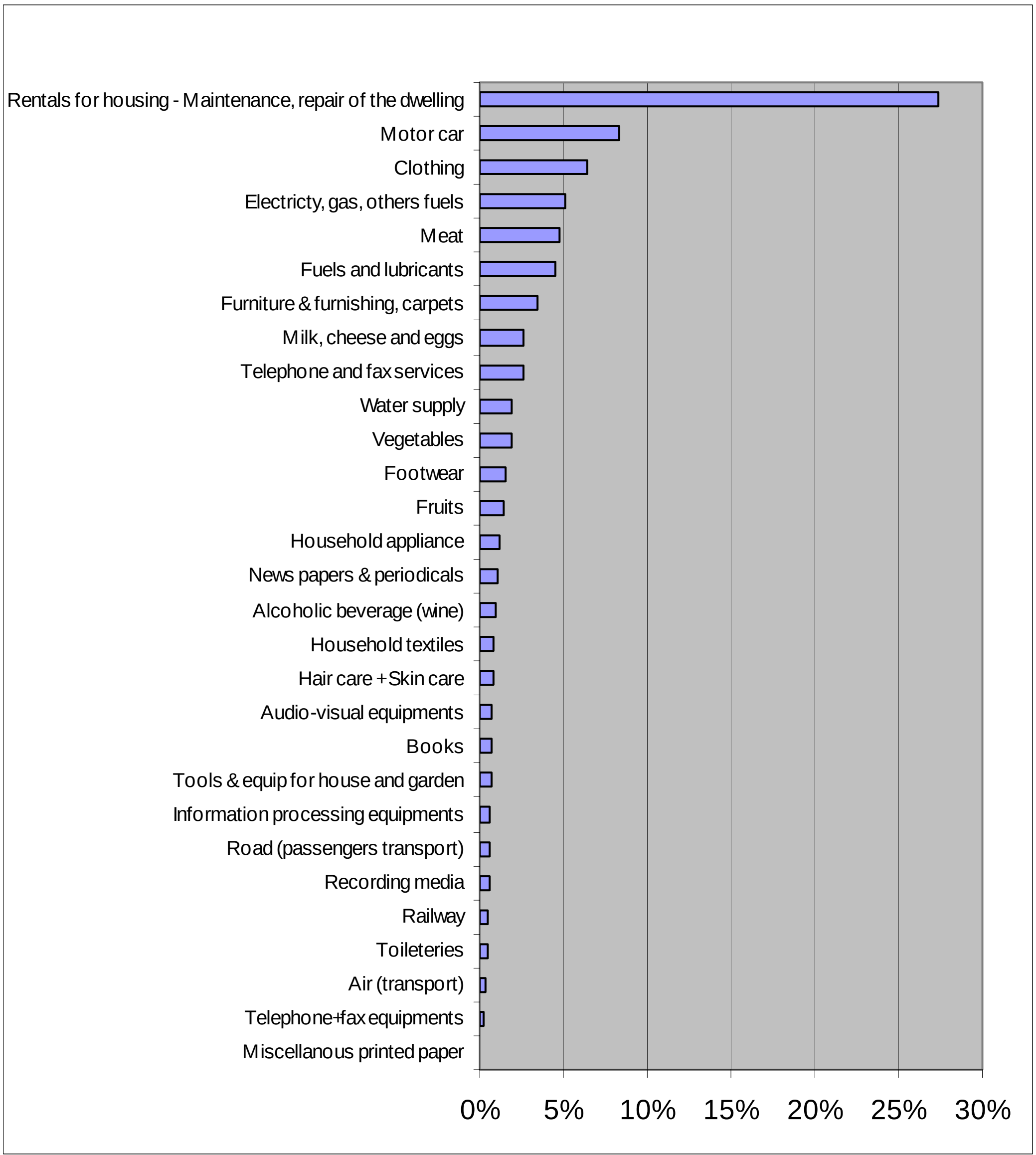
■ As indicated in section 1.3.4.2.1, a top-down methodology was used to assess the life cycle prices, based on the average European households' expenditures.

For that purpose, the "Consumers in Europe – Facts and figures" database published by Eurostat in 2001 was used. As already indicated in §1.2.2, it is the most relevant and useful information source in the domain of consumer policy. The aim of this publication is to present, for the first time, a comprehensive collection of the most important data available from different sources on consumption patterns, including expenditures and prices. It examines the realities of the European economy and the European single market from the consumer's viewpoint.

Some work (aggregation and split up) was made to allow the Eurostat data to fit with the categories classification elaborated in this study.

These data cover on the one hand goods and services associated to them (e.g. housing and repair, clothing and dry cleaning…) and on the other hand some services (water supply for instance).

Life Cycle Prices Considered
(% of the overall life cycle price obtained when adding all the categories studied)



2 PART 2 - RESULTS

2.1 RESULTS OBTAINED: PHYSICAL AND MONETARISED ENVIRONMENTAL IMPACTS OF PRODUCT OR SERVICE CATEGORIES CONSUMED IN THE EU

Given the huge amount of figures produced in this four-dimension study covering (environmental impacts, external costs, life cycles, and the entire EU economy), the presentation of the results focused on key indicators:

- indicators related to environmental impacts,
- indicators related to external costs,
- Indicators related to the internalisation of external costs: A - External costs vs. Life cycle prices, B - % of external costs internalised, C - % of life cycle prices corresponding to internalised external costs.

2.1.1 Results Reliability

In this section, we successively deal with the two types of indicators used to assess the representativeness of the study results, as mentioned in section 1.2.2:

- "economic representativeness": this indicator aims at assessing the representiveness of the selected categories compared to the whole economy that is supposed to be covered. It is thus assessed through economic data related to the consumers' expenditures.
- "environmental representativeness": the objective is to assess the representativeness of the environmental impacts quantified compared to the total impacts generated at the European level.

An attempt to assess the double-counting linked to the use of the two category classifications is also made.

2.1.1.1 "Economic Representativeness" of the Results

The "economic representativeness" of the results is quite good (see section 1.2.2 for details).

"Economic Representativeness" of the Results

Type of consumers	Level of "economic representativeness"
Individuals	**Good** between 60 and 75%, depending on what level is considered for services which are partially studied
Enterprises Government Non-profit institutions serving households	**Medium** not possible to quantify easily

2.1.1.2 “Environmental Representativeness” of the Results

An attempt to assess the “environmental representativeness” of the results is proposed by comparing:

- the sum of the environmental impacts assessed in this study for each category analysed,
- and the macro-economic data available in public databases for the same impacts, derived from key global data.

As shown in the following table, the “environmental representativeness” of the results is also good.

“Environmental Representativeness” of the Results

Environmental impacts ***Per capita per year***	**Results obtained in the study** Total of all the categories studied – see §5.1.3	**Data from Annual European Community Emission Inventory** Source: Environmental European Agency, 2002	**“Environmental Representativeness” of the results**
	a	*b*	*a/b*
Primary energy consumed (MJ)	1,6E+05	1,7E+05	**97%** **Good**
Depletion of non renewable resources (kg antimony eq.)	5,3E+01	6,8E+01	**77%** **Good**
Greenhouse effect (kg CO2 eq.)	8,9E+06	1,1E+07	**82%** **Good**
Air acidification (kg SO2 eq.)	4,7E+04	5,5E+04	**86%** **Good**

Remark: to assess the “environmental representativeness” more precisely, one should subtract double-counting as estimated next page: double-counting is indeed likely to reach between 10% and 20% for most of the environmental impacts quantified and other environmental indicators. If double-counting were subtracted from the results obtained in the study (first column of figures, a), the “environmental representativeness” will drop from 10 to 15 points (and reached, for instance for primary energy, between 82-87% instead of 97%). The “environmental representativeness” is still quite good.

2.1.1.3 Double-Counting

- Double-counting can not be avoided considering the objectives of the study: to cover the entire economy with a life-cycle approach. Many intermediary products and services are then included in several categories under consideration.

This **does not constitute a weakness of the study** given that the purpose of the study is to compare categories (even if they have sub-systems in common) in order to help establishing a prioritisation in the scope of the IPP policy.

However, it is useful to have an order of magnitude of double-counting in order to be able to judge if the environmental impacts of the categories altogether are far from the actual impacts of the entire economy.

- Double-counting appear to reach **between 10% and 20% for most of the environmental impacts** quantified and other environmental indicators (calculations are not detailed in this report).

Six main categories introduce double-counting in the results calculated for the whole EU as the sum of all the categories.

What is double-counted	**Where is it double-counted**	
	"Final products" Classification	"Transversal products" classification
Electricity consumption during the use of domestic appliances	Family "Building occupancy" / Category "Domestic appliances"	Sector "Electrical and electronic products and equipment" / Products "Domestic appliances"
Electricity consumption during the use of IT equipment	Family "Building occupancy" / Category "Domestic appliances"	Sector "Electrical and electronic products and equipment" / Products "IT Equipment"
Electricity consumption during the use of washing machines	Family "Building occupancy" / Category "Domestic appliances" Family "clothing & footwear" / Category "Textile products"	
Detergent consumption during the washing of apparel textiles	Family "clothing & footwear" / Category "Textile products"	Family "Cleaning agents" / Category "Textile cleaning agents"
Detergent consumption during the washing of industrial textiles	Family "clothing & footwear" / Category "Textile products"	Family "Cleaning agents" / Category "Textile cleaning agents"
Part of goods transport (those which may be included in upstream LCI of consumables – hypothesis : 20% of the whole "Goods transport" category)		

2.1.2 Environmental Impacts Generated in the EU

2.1.2.1 Total of all the Categories & LC Stages Contribution

Environmental Impacts Generated at the EU level
Total for all categories & LC Stages Contribution

Functional unit: Consumption per Capita per Year in Europe		**Total**	**Production stage**		**Use stage**		**End of life stage**	
A/ Environmental Impacts		**Values**	**Values**	**%**	**Values**	**%**	**Values**	**%**
Linked to resources consumption								
Depletion of non renewable resources	kg antimony eq.	52	9,0	17%	42,9	83%	0,0	0%
Linked to air emissions								
Greenhouse effect (direct, 100 yrs)	g CO2 eq.	8 736 520	1 656 095	19%	6 573 436	75%	506 989	6%
Stratospheric Ozone Depletion	g CFC-11 eq.	3	0,6	21%	2,3	79%	0,008	0%
Air acidification	g SO2 eq.	46 916	13 445	29%	33 166	71%	200	0%
Photochemical oxidation	g ethylene eq.	15 084	5 787	38%	8 484	56%	813	5%
Linked to water effluents								
Eutrophication	g PO4 eq.	6 870	5 219	76%	368	5%	1 279	19%
Linked to human health								
Human Toxicity	eq. 1-4-dichlorobenze	4 917 008 223	917 484 817	19%	105 104 461	2%	3 894 417 787	79%
Years of Life Lost	year	0,003	0,001	23%	0,002	75%	0,00005	2%
Linked to ecotoxicological risk								
Aquatic Ecotoxicity	eq. 1-4-dichlorobenze	883 620 066	78 839 920	9%	20 731 271	2%	784 048 723	89%
Sediment Ecotoxicity	eq. 1-4-dichlorobenze	2 844 196 998	253 195 311	9%	66 344 722	2%	2 524 656 575	89%
Terrestrial Ecotoxicity	eq. 1-4-dichlorobenze	323 062	85 180	26%	204 202	63%	33 680	10%
B/ Other Environmental Indic		**Values**						
Primary energy	MJ	160 060	35 028	22%	124 102	78%	695	0%
Dusts	g	7 009	1 826	26%	4 545	65%	601	9%
Dioxins	g	0,0000006	0,0000001	18%	0,0000001	18%	0,0000004	65%
Metals into air	g	858	29	3%	820	96%	9	1%
Metals into water	g	5 407	733	14%	4 446	82%	228	4%
Metals into soil	g	155	6	4%	45	29%	103,631	67%
Municipal and industrial waste	kg	1 187	176	15%	3	0%	1 008	85%
Hazardous waste	kg	17	10	57%	1	7%	6	36%
Inert waste	kg	1 290	192	15%	2	0%	1 096	85%

This table summarising the results obtained when adding all the categories analysed shows that:

- **environmental impacts linked to resources consumption and air emissions** are mostly generated during the **use stage,**
- **eutrophication** is mainly linked to the **production stage,**
- and **human toxicity, ecotoxicity risks and solid waste** are split between **use stage and end of life stages.**

Remark1: the term « dusts » used all along the report is taken as an equivalent to “particulate matter”.

Remark2: as detailed next page, the reason why the major contributing stage is not the same for the two human health indicators considered (use stage for “years of life lost” and end of life stage for “human toxicity”) has to do with the fact that they do not cover the same impacts (human toxicity is an indicator representative of the intrinsic toxicity of released substances, independently of the actual exposition of humans to these substances):

- the “human toxicity” indicator reflects the intrinsic toxicity of released substances and is directly impacted mainly by the emissions of organic micro-pollutants (AOX…), heavy metals… into air, soil and water;
- the “years of life lost” indicator reflects a risk of premature death and is directly impacted mainly by the air emissions of dusts, NOx, SOx, VOC.

Caveats: regarding the results about toxicity and ecotoxicity risks, it has to be mentioned once again that LCA data about these issues are of relatively poor quality and heterogeneous according to products. The origin of human toxicity and ecotoxicity risks (in terms of stages in the life cycle and also of categories next section) is likely to be different from what is obtained in this study and described on the previous page. For instance, as one expert mentioned, AOX is likely not to be the major overall problem for aquatic and sediment toxicity contrary to what is obtained in this study from available data, and production stages may also constitute important contributors.

Environmental Impacts Generated at the EU level
Summary of LC Stages Contribution

Main LC stage contributing to the impacts	***Main impacts & env^{tal} indicators concerned***
Use stage	Depletion of non renewable energy, including primary energy Impacts linked to air emissions: Greenhouse effect, Ozone depletion, Air acidification, Photochemical oxidation, metals, dusts Metals into water Metals into soil Years of life lost (human health) Terrestrial ecotoxicity
Production stage	Eutrophication Hazardous waste
End of life stage	Dioxins into air Human toxicity Aquatic and sediment ecotoxicity Municipal, industrial and inert waste

2.1.2.2 Relative Contribution of the Different Categories

As shown in the tables and graphs next pages and summarised below, **most of the environmental impacts linked to resources consumption and air emissions are generated by two main categories:**

- **transport (goods transport and private transport of passengers by car),**
- **building occupancy** (mainly due to the **energy used to heat** domestic and commercial buildings).

They correspond to the impacts for which the use stage is predominant (see §2.1.2.1 above).

The production of "**Food products**" generates most of the water emissions contributing to **eutrophication** (from "vegetables" mainly, due to the use of fertilisers) **and photochemical oxidation** (from "food from animals" mainly due to enteric fermentation and manure management).

As for toxicity and ecotoxicity risks generated at the EU level, the main contributing categories are different according to the type of toxicity considered and, from data available, appear to be the following:

- "**Water supply**" explains **toxicity risks on human health as well as aquatic and sediment ecosystems** (mainly due to the AOX content of sewage sludge (end of life step) associated with "waste water treatment"),
- As for the "**years of life lost**" indicator, the main burden comes from "**transport**" and "**building occupancy**" (due to several air emissions: dusts, NOx, SOx, VOC),
- « **Terrestrial ecotoxicity** » mainly originates from "**building occupancy** » and « **EEE** » (due to electricity consumption during the use stage).

Solid waste are generated from « **MSW management** » category (municipal and industrial waste) as well as « **civil work** » and « **building structure** » categories (inert waste).

Caveats 1: the fact that dioxins appear to be mostly generated by « MSW management » category results from the lack of accuracy in the way dioxins are generally accounted for in available LCIs (see §1.3.2.6). In particular, dioxins emitted by metal activities are poorly taken into account in available databases.

Caveats 2: regarding the results about toxicity and ecotoxicity risks, as reminded above, it has to be mentioned once again that LCA data about these issues are of relatively poor quality and heterogeneous according to products.

Caveats 3: the same remark should be made for solid waste. The quality of solid waste flow balances in available LCIs is low. The fact the « packaging » category appears to generate most of the hazardous waste quantified may also result from the way the category classification was made: some major other contributing industrial activities are split between studied categories and thus do not appear as such (and the hazardous waste they generate are split and then "diluted" between several categories). A third reason has to do with the fact that some major contributing categories are not studied (such as medicines and pharmaceuticals).

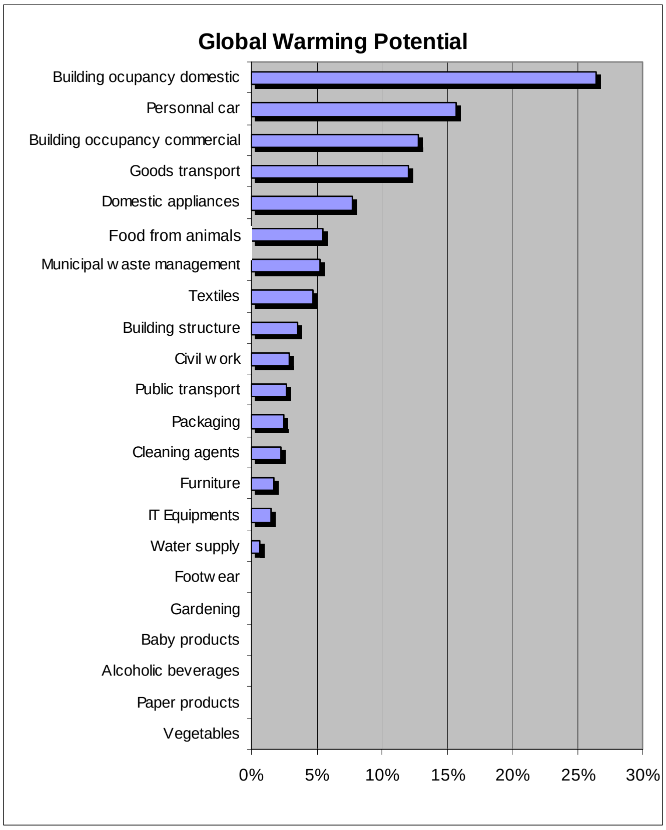
Environmental Impacts Generated at the EU level
Summary of the Contribution of the Different Categories

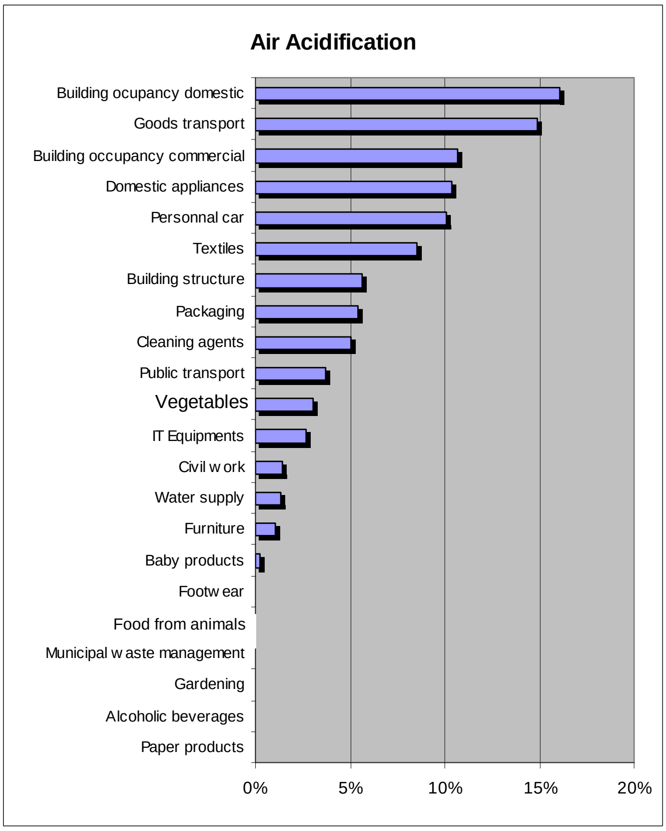
<table>
<tr><th rowspan="2"></th><th colspan="5">Contribution of the categories to total EU impacts</th></tr>
<tr><th>10-20%</th><th>20-40%</th><th>60-80%</th><th>40-60%</th><th>>80%</th></tr>
<tr><td colspan="6">A/ Environmental Impacts</td></tr>
<tr><td>Depletion of non renewable resources</td><td rowspan="3">EEE</td><td rowspan="3">Building occupancy
Transport</td><td></td><td></td><td></td></tr>
<tr><td>Greenhouse effect</td><td></td><td></td><td></td></tr>
<tr><td>Air acidification</td><td></td><td></td><td></td></tr>
<tr><td>Ozone Depletion</td><td></td><td>Building occupancy</td><td></td><td>Transport</td><td></td></tr>
<tr><td>Photochemical oxidation</td><td>Building occupancy</td><td>Transports
Food products</td><td></td><td></td><td></td></tr>
<tr><td>Eutrophication</td><td>Water supply</td><td></td><td>Food products</td><td></td><td></td></tr>
<tr><td>Human Toxicity</td><td>Packaging</td><td></td><td>Water supply</td><td></td><td></td></tr>
<tr><td>Years of Life Lost</td><td>EEE</td><td>Building occupancy</td><td></td><td>Transport</td><td></td></tr>
<tr><td>Aquatic Ecotoxicity</td><td rowspan="2">Packaging</td><td></td><td rowspan="2">Water supply</td><td></td><td></td></tr>
<tr><td>Sediment Ecotoxicity</td><td></td><td></td><td></td></tr>
<tr><td>Terrestrial Ecotoxicity</td><td></td><td>Building occupancy
EEE</td><td></td><td></td><td></td></tr>
<tr><td colspan="6">B/ Other Environmental Indicators</td></tr>
<tr><td>Primary energy</td><td></td><td>Transport
Building occupancy</td><td></td><td></td><td></td></tr>
<tr><td>Dusts</td><td>EEE
Transport</td><td>Building occupancy</td><td></td><td></td><td></td></tr>
<tr><td>Dioxins</td><td></td><td>MSW management
Packaging
Transport
EEE</td><td></td><td></td><td></td></tr>
<tr><td>Metals into air</td><td></td><td rowspan="2">EEE</td><td></td><td rowspan="2">Building occupancy</td><td></td></tr>
<tr><td>Metals into water</td><td></td><td></td><td></td></tr>
<tr><td>Metals into soil</td><td></td><td>Transports
Water supply</td><td></td><td>MSW management</td><td></td></tr>
<tr><td>Municipal and industrial waste</td><td></td><td></td><td></td><td></td><td>MSW management</td></tr>
<tr><td>Hazardous waste</td><td></td><td>MSW management</td><td></td><td>Packaging</td><td></td></tr>
<tr><td>Inert waste</td><td></td><td></td><td></td><td>Civil work
Building structure</td><td></td></tr>
</table>

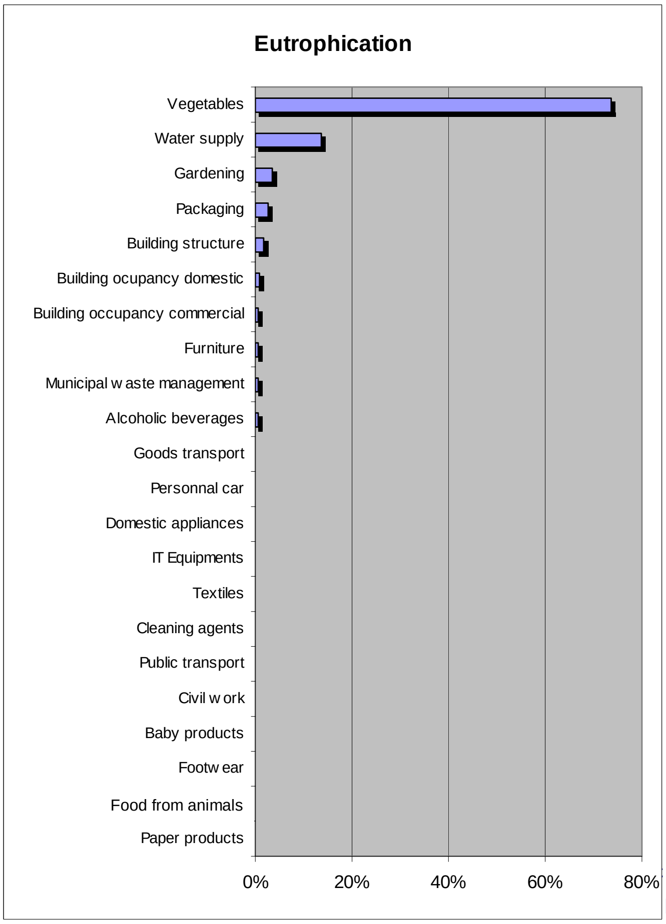
In **bold** characters, the most significant category for each impact.

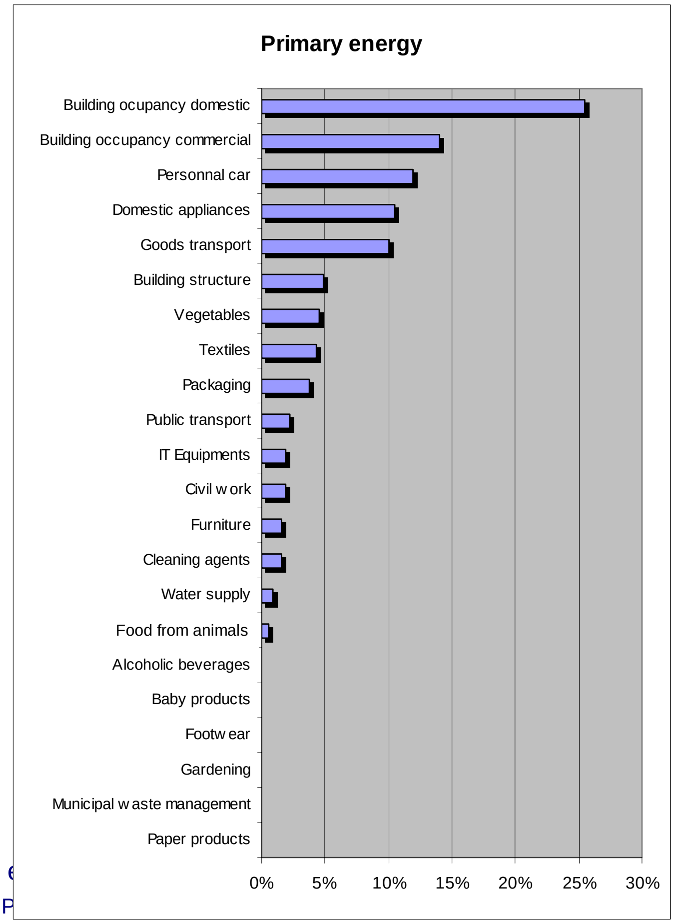
Contribution of the Different Categories to Some Environmental Impacts Generated at the EU Level

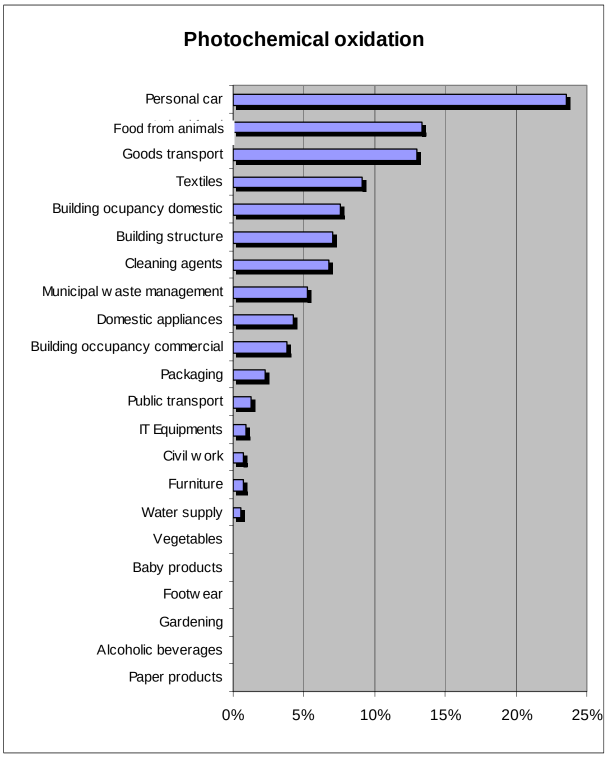
(in % of the total generated by all the categories studied)

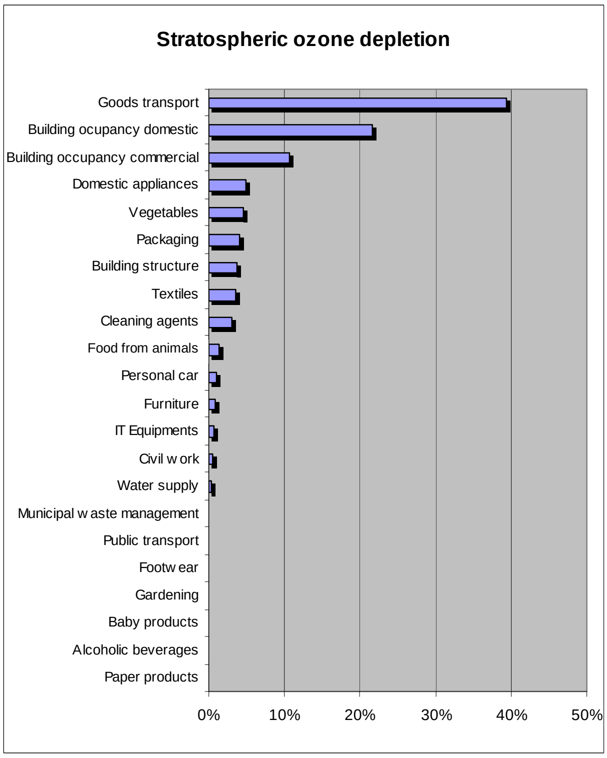


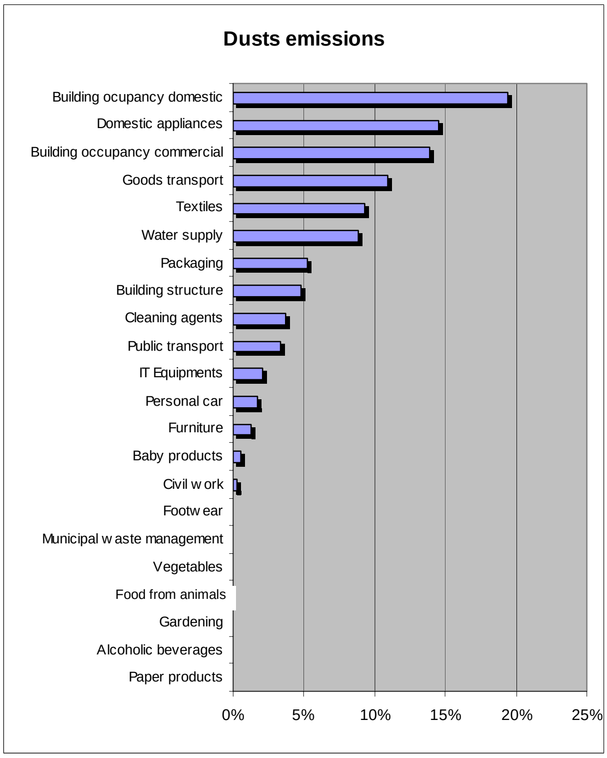


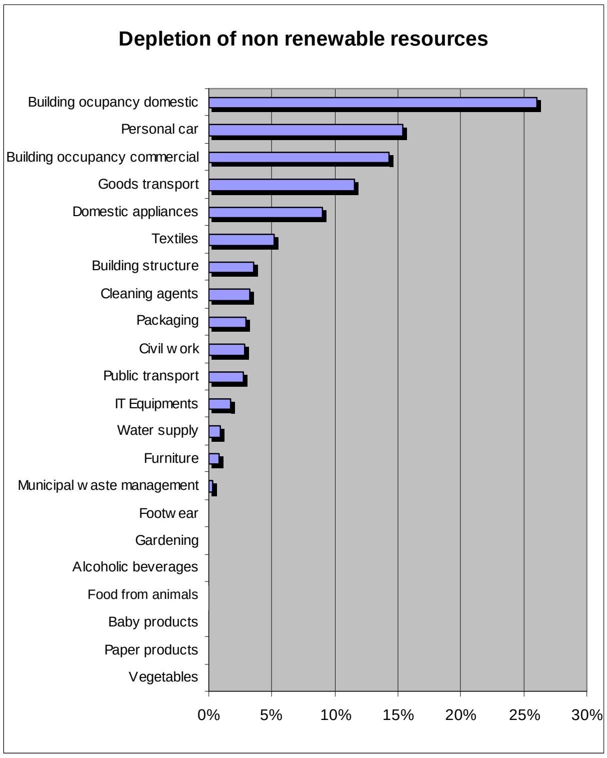





Photochemical oxidation
Personal car
Food from animals
Goods transport
Textiles
Building ocupancy domestic
Building structure
Cleaning agents
Municipal w aste management
Domestic appliances
Building occupancy commercial
Packaging
Public transport
IT Equipments
Civil w ork
Furniture
Water supply
Vegetables
Baby products
Footw ear
Gardening
Alcoholic beverages
Paper products
0%
5%
10%
15%
20%
25%


Stratospheric ozone depletion
Goods transport
Building ocupancy domestic
Building occupancy commercial
Domestic appliances
Vegetables
Packaging
Building structure
Textiles
Cleaning agents
Food from animals
Personal car
Furniture
IT Equipments
Civil w ork
Water supply
Municipal w aste management
Public transport
Footw ear
Gardening
Baby products
Alcoholic beverages
Paper products
0%
10%
20%
30%
40%
50%


Dusts emissions
Building ocupancy domestic
Domestic appliances
Building occupancy commercial
Goods transport
Textiles
Water supply
Packaging
Building structure
Cleaning agents
Public transport
IT Equipments
Personal car
Furniture
Baby products
Civil w ork
Footw ear
Municipal w aste management
Vegetables
Food from animals
Gardening
Alcoholic beverages
Paper products
0%
5%
10%
15%
20%
25%


Depletion of non renewable resources
Building ocupancy domestic
Personal car
Building occupancy commercial
Goods transport
Domestic appliances
Textiles
Building structure
Cleaning agents
Packaging
Civil w ork
Public transport
IT Equipments
Water supply
Furniture
Municipal w aste management
Footw ear
Gardening
Alcoholic beverages
Food from animals
Baby products
Paper products
Vegetables
0%
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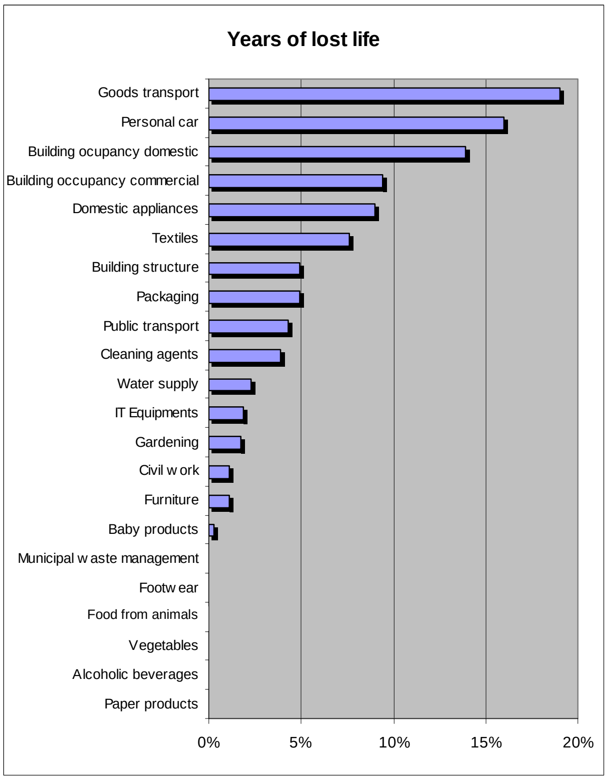
30%


Years of lost life
Goods transport
Personal car
Building ocupancy domestic
Building occupancy commercial
Domestic appliances
Textiles
Building structure
Packaging
Public transport
Cleaning agents
Water supply
IT Equipments
Gardening
Civil w ork
Furniture
Baby products
Municipal w aste management
Footw ear
Food from animals
Vegetables
Alcoholic beverages
Paper products
0%
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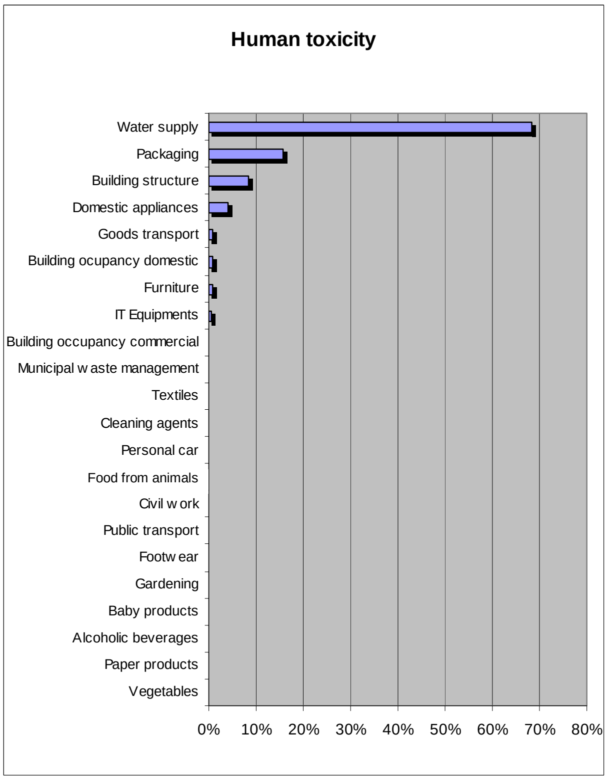
Human toxicity
Water supply
Packaging
Building structure
Domestic appliances
Goods transport
Building ocupancy domestic
Furniture
IT Equipments
Building occupancy commercial
Municipal w aste management
Textiles
Cleaning agents
Personal car
Food from animals
Civil w ork
Public transport
Footw ear
Gardening
Baby products
Alcoholic beverages
Paper products
Vegetables
0%
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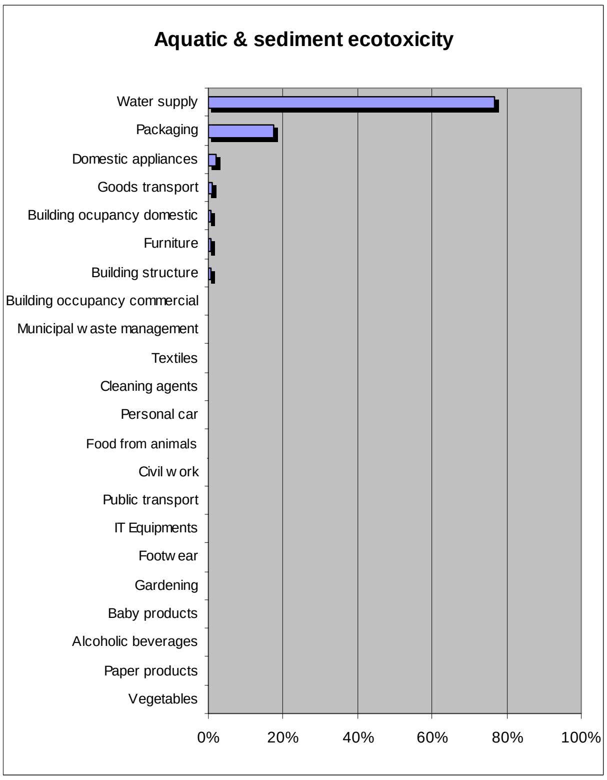
30%
40%
50%
60%
70%
80%


Aquatic & sediment ecotoxicity
Water supply
Packaging
Domestic appliances
Goods transport
Building ocupancy domestic
Furniture
Building structure
Building occupancy commercial
Municipal w aste management
Textiles
Cleaning agents
Personal car
Food from animals
Civil w ork
Public transport
IT Equipments
Footw ear
Gardening
Baby products
Alcoholic beverages
Paper products
Vegetables
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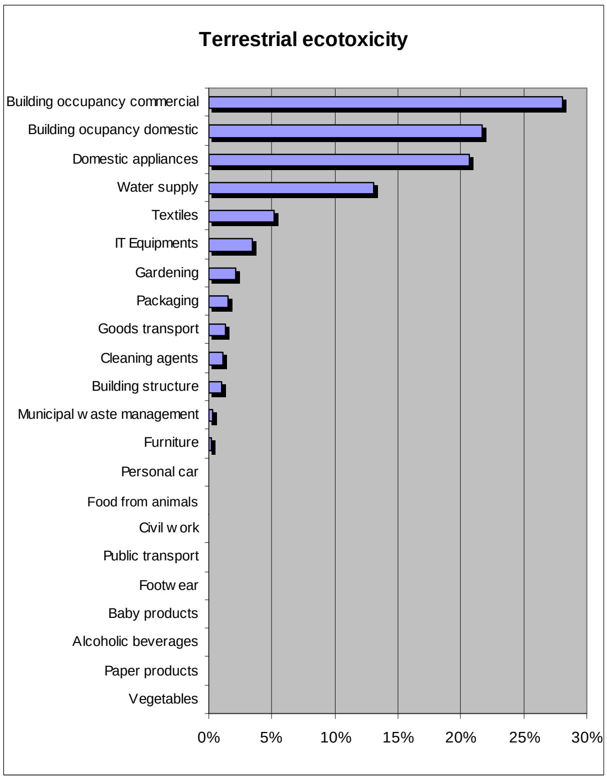
20%
40%
60%
80%
100%


Terrestrial ecotoxicity
Building occupancy commercial
Building ocupancy domestic
Domestic appliances
Water supply
Textiles
IT Equipments
Gardening
Packaging
Goods transport
Cleaning agents
Building structure
Municipal w aste management
Furniture
Personal car
Food from animals
Civil w ork
Public transport
Footw ear
Baby products
Alcoholic beverages
Paper products
Vegetables
0%
5%
10%
15%
20%
25%
30%

Environmental Impacts Generated at the EU Level – Contribution of the Different Categories (1/4)

Functional unit: Consumption per Capita per Year in Europe		**TOTAL**	**Transports**				**Civil work**	**Building structure**	**EEE**		
			Total	Goods	Personal cars	ransport service	**Total**	**Total**	**Total**	EEE IT	EEE Domestic appliances
A/ Environmental Impacts											
Linked to resources consumption			L=m+n+o	m	n	o			D=k+l	k	l
Depletion of non renewable resources	kg antimony eq.	**53**	**15.7**	6.1	8.2	1.4	**1.5**	**1.9**	**5.6**	0.9	4.8
Linked to air emissions											
Greenhouse effect (direct, 100 yrs)	g CO_2 eq.	**8 884 187**	**2622679**	881691	1509673	231315	**77185**	**283515**	**802587**	127990	674597
Stratospheric Ozone Depletion	g CFC-11 eq.	**3**	**1.2**	1.2	0.0	0.0	**0.0**	**0.1**	**0.2**	0.0	0.1
Air acidification	g SO_2 eq.	**47 089**	**13431**	6976	4735	1721	**634**	**2633**	**6140**	1283	4857
Photochemical oxidation	g ethylene eq.	**15 177**	**5713**	1956	3555	203	**103**	**1054**	**773**	140	633
Linked to water effluents											
Eutrophication	g PO4 eq.	**6 859**	**56**	30	25	0	**1**	**114**	**28**	8	20
Linked to human health											
Human Toxicity	g eq. 1-4-dichlorobenzene	**4 919 799 882**	**42 098 676**	41 949 723	45 658	103 295	**451 592**	**419 870 683**	**226 692 947**	22 658 446	204 034 502
Years of Life Lost	year	**0.003**	**0.0010**	0.0005	0.0004	0.0001	**0.0000**	**0.0001**	**0.0003**	0.0000	0.0002
Linked to ecotoxicological risk											
Aquatic Ecotoxicity	g eq. 1-4-dichlorobenzene	**884 072 296**	**8 427 639**	8 405 944	822	20 874	**90 778**	**6 079 256**	**17 874 092**	247 732	17 626 359
Sediment Ecotoxicity	g eq. 1-4-dichlorobenzene	**2 846 557 737**	**27 113 151**	27 046 164	1 897	65 091	**290 907**	**19 564 772**	**57 520 185**	790 372	56 729 814
Terrestrial Ecotoxicity	g eq. 1-4-dichlorobenzene	**252 913**	**3 701**	3 391	296	14	**89**	**2 490**	**60 935**	8 566	52 369
B/ Other Environmental Indicators		**Values**									
Primary energy	MJ	**160 516**	**38 676**	16 057	19 040	3 578	**3 005**	**7 854**	**19 926**	3 111	16 815
Fossil energy	MJ	**7 207**	**0.0**	0.0	0.0	0.0	**0.0**	**0.0**	**0.0**	0.0	0.0
Consumption of raw materials	kg	**540 897**	**0.0**	0.0	0.0	0.0	**0.0**	**0.5**	**0.0**	0.0	0.0
Dusts	g	**6 819**	**1 116**	767	117	232	**24**	**337**	**1 163**	145	1 018
Dioxins	g	**1.E-06**	**6.7E-07**	1.0E-07	5.7E-07	6.6E-10	**7.2E-09**	**4.3E-08**	**8.3E-08**	3.4E-08	4.9E-08
Metals into air	g	**863**	**46**	35	11	0	**0**	**8**	**256**	36	220
Metals into water	g	**3 568**	**185**	181	1	3	**18**	**140**	**783**	117	666
Metals into soil	g	**155**	**45**	45	0	0	**0**	**3**	**0**	0	0
Municipal and industrial waste	kg	**669**	**3**	0	0	3	**0**	**55**	**16**	5	11
Hazardous waste	kg	**17**	**1**	0	0	1	**0**	**0**	**0**	0	0
Inert waste	kg	**1 290**	**0**	0	0	0	**719**	**519**	**26**	26	1

Environmental Impacts Generated at the EU Level – Contribution of the Different Categories (2/4)

Functional unit: Consumption per Capita per Year in Europe

A/ Environmental Impacts

		TOTAL	Building occupancy										
			Total	Domestic sector					Commercial building				
			Total building occupancy	Total domestic	Space heating	Water heating	Cooking	Appliances+light	Total commercial	Space heating	Water heating	Cooking	Appliances+light
			A+B	A=a+b+c+d	a	b	c	d	B=e+f+g+h	e	f	g	h
Linked to resources consumption													
Depletion of non renewable resources	kg antimony eq.	**53**	**21.3**	**0.3**	0.2	0.0	0.0	0.0	**7.6**	0.1	0.0	0.0	0.0
Linked to air emissions													
Greenhouse effect (direct, 100 yrs)	g CO_2 eq.	**8 884 187**	**3137662**	**2028598**	1389590	306318	107516	225174	**1109063**	0	0	0	0
Stratospheric Ozone Depletion	g CFC-11 eq.	**3**	**1.0**	**0.6**	0.4	0.1	0.0	0.1	**0.3**	0.1	0.0	0.0	0.0
Air acidification	g SO_2 eq.	**47 089**	**12722**	**7531**	5159	1137	399	836	**5191**	2699	467	260	1765
Photochemical oxidation	g ethylene eq.	**15 177**	**1769**	**1145**	784	173	61	127	**624**	325	56	31	212
Linked to water effluents													
Eutrophication	g PO4 eq.	**6 859**	**91**	**64**	0	0	0	0	**26**	0	0	0	0
Linked to human health													
Human Toxicity	g eq. 1-4-dichlorobenzene	**4 919 799 882**	**54 811 356**	**36 629 218**	25 091 015	5 531 012	1 941 349	4 065 843	**18 182 138**	9 454 712	1 636 392	909 107	6 181 927
Years of Life Lost	year	**0.003**	**0.0006**	**0.0003**	0.0957	0.0211	0.0074	0.0155	**0.0002**	0.0469	0.0081	0.0045	0.0306
Linked to ecotoxicological risk													
Aquatic Ecotoxicity	g eq. 1-4-dichlorobenzene	**884 072 296**	**10 845 971**	**7 256 529**	4 970 722	1 095 736	384 596	805 475	**3 589 442**	1 866 510	323 050	179 472	1 220 410
Sediment Ecotoxicity	g eq. 1-4-dichlorobenzene	**2 846 557 737**	**34 865 972**	**23 331 420**	15 982 023	3 523 044	1 236 565	2 589 788	**11 534 553**	5 997 967	1 038 110	576 728	3 921 748
Terrestrial Ecotoxicity	g eq. 1-4-dichlorobenzene	**252 913**	**126 094**	**71 128**	48 723	10 740	3 770	7 895	**54 966**	28 582	4 947	2 748	18 688

B/ Other Environmental Indicators

		Values	Total building occupancy	Total domestic	Space heating	Water heating	Cooking	Appliances+light	Total commercial	Space heating	Water heating	Cooking	Appliances+light
Primary energy	MJ	**160 516**	**63 621**	**40 741**	27 908	6 152	2 159	4 522	**22 880**	11 898	2 059	1 144	7 779
Fossil energy	MJ	**7 207**	**0.0**	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0
Consumption of raw materials	kg	**540 897**	**0.0**	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0
Dusts	g	**6 819**	**2 143**	**1 362**	933	206	72	151	**781**	406	70	39	266
Dioxins	g	**1.E-06**	**0.0E+00**	**0.0E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Metals into air	g	**863**	**488**	**268**	184	41	14	30	**220**	114	20	11	75
Metals into water	g	**3 568**	**1547**	**866**	593	131	46	96	**681**	354	61	34	232
Metals into soil	g	**155**	**0**	**0**	0	0	0	0	**0**	0	0	0	0
Municipal and industrial waste	kg	**669**	**0**	**0**	0	0	0	0	**0**	0	0	0	0
Hazardous waste	kg	**17**	**0**	**0**	0	0	0	0	**0**	0	0	0	0
Inert waste	kg	**1 290**	**0**	**0**	0	0	0	0	**0**	0	0	0	0

Environmental Impacts Generated at the EU Level – Contribution of the Different Categories (3/4)

Functional unit: Consumption per Capita per Year in Europe

A/ Environmental Impacts

		TOTAL	Cleaning agents			Furniture	Textiles	Footwear	Packaging
			Total	detergent textile	personal care	Total	Total	Total	Total
			C=i+j	i	j				
Linked to resources consumption									
Depletion of non renewable resources	kg antimony eq.	**53**	**1.7**	0.7	0.3	**0.4**	**2.8**	**0.1**	**1.5**
Linked to air emissions									
Greenhouse effect (direct, 100 yrs)	g CO_2 eq.	**8 884 187**	**203446**	87886	35833	**151135**	**407615**	**11584**	**215789**
Stratospheric Ozone Depletion	g CFC-11 eq.	**3**	**0.1**	0.0	0.0	**0.0**	**0.1**	**0.0**	**0.1**
Air acidification	g SO_2 eq.	**47 089**	**2328**	1005	410	**478**	**3991**	**63**	**2554**
Photochemical oxidation	g ethylene eq.	**15 177**	**1023**	442	180	**107**	**1376**	**9**	**348**
Linked to water effluents									
Eutrophication	g PO4 eq.	**6 859**	**0**	0	0	**41**	**0**	**7**	**181**
Linked to human health									
Human Toxicity	g eq. 1-4-dichlorobenzene	**4 919 799 882**	**3 668 287**	1 584 646	646 100	**33 135 478**	**4 824 793**	**838**	**766 263 874**
Years of Life Lost	year	**0.003**	**0.0001**	0.0000	0.0000	**0.0000**	**0.0002**	**0.0000**	**0.0001**
Linked to ecotoxicological risk									
Aquatic Ecotoxicity	g eq. 1-4-dichlorobenzene	**884 072 296**	**734 111**	317 125	129 300	**6 670 066**	**965 009**	**75**	**154 427 829**
Sediment Ecotoxicity	g eq. 1-4-dichlorobenzene	**2 846 557 737**	**2 361 230**	1 020 017	415 887	**21 477 144**	**3 086 382**	**59**	**497 143 616**
Terrestrial Ecotoxicity	g eq. 1-4-dichlorobenzene	**252 913**	**2 803**	1 211	494	**463**	**13 073**	**44**	**3 896**

B/ Other Environmental Indicators

		Values							
Primary energy	MJ	**160 516**	**2 379**	1 028	419	**2 415**	**6 896**	**170**	**6 119**
Fossil energy	MJ	**7 207**	**0.0**	0.0	0.0	**0.0**	**0.0**	**0.0**	**0.0**
Consumption of raw materials	kg	**540 897**	**0.0**	0.0	0.0	**0.2**	**0.1**	**0.0**	**0.0**
Dusts	g	**6 819**	**256**	111	45	**92**	**653**	**8**	**361**
Dioxins	g	**1.E-06**	**4.0E-10**	1.7E-10	7.0E-11	**2.5E-08**	**1.5E-09**	**1.7E-10**	**1.2E-07**
Metals into air	g	**863**	**2**	1	0	**1**	**46**	**0**	**4**
Metals into water	g	**3 568**	**28**	12	5	**17**	**216**	**2**	**271**
Metals into soil	g	**155**	**0**	0	0	**0**	**0**	**0**	**2**
Municipal and industrial waste	kg	**669**	**0**	0	0	**21**	**9**	**5**	**175**
Hazardous waste	kg	**17**	**1**	0	0	**0**	**1**	**0**	**7**
Inert waste	kg	**1 290**	**3**	1	1	**1**	**3**	**0**	**13**

Environmental Impacts Generated at the EU Level – Contribution of the Different Categories (4/4)

Functional unit: Consumption per Capita per Year in Europe

		TOTAL	Paper products	Food products		Beverage	Baby products	Gardening	Water supply	Municipal waste management
				Animal food	Vegetables	Alcoholic beverage				
A/ Environmental Impacts										
Linked to resources consumption										
Depletion of non renewable resources	kg antimony eq.	53	0.0	0.0	0.0	0.0	0.0	0.0	0.5	-0.2
Linked to air emissions										
Greenhouse effect (direct, 100 yrs)	g CO_2 eq.	8 884 187	69	482959	-29332	3157	0	3379	51451	459309
Stratospheric Ozone Depletion	g CFC-11 eq.	3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Air acidification	g SO_2 eq.	47 089	1	0	1467	18	105	21	607	-102
Photochemical oxidation	g ethylene eq.	15 177	0	2018	0	2	27	1	76	780
Linked to water effluents										
Eutrophication	g PO4 eq.	6 859	0	0	5067	44	3	246	941	39
Linked to human health										
Human Toxicity	g eq. 1-4-dichlorobenzene	4 919 799 882	0	1 285	0	13 915	1 157	16 261	3 364 964 868	2 983 870
Years of Life Lost	year	0.003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
Linked to ecotoxicological risk										
Aquatic Ecotoxicity	g eq. 1-4-dichlorobenzene	884 072 296	0	0	0	2 816	152	22 320	677 340 556	591 626
Sediment Ecotoxicity	g eq. 1-4-dichlorobenzene	2 846 557 737	0	0	0	8 999	389	22 754	2 181 197 341	1 904 834
Terrestrial Ecotoxicity	g eq. 1-4-dichlorobenzene	252 913	0	0	0	30	0	5 423	33 152	720
B/ Other Environmental Indicators		Values								
Primary energy	MJ	160 516	3	977	7 200	183	234	65	1 412	-617
Fossil energy	MJ	7 207	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Consumption of raw materials	kg	540 897	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Dusts	g	6 819	0	0	0	1	37	1	619	7
Dioxins	g	1.E-06	0.0E+00	0.0E+00	1.5E-08	8.4E-12	0.0E+00	4.4E-12	3.1E-11	1.8E-07
Metals into air	g	863	0	0	0	0	0	0	12	-1
Metals into water	g	3 568	94	0	219	0	1	0	42	5
Metals into soil	g	155	0	0	0	0	0	0	45	58
Municipal and industrial waste	kg	669	87	58	115	0	0	115	10	575
Hazardous waste	kg	17	0	0	2	0	0	0	0	5
Inert waste	kg	1 290	0	0	0	0	0	0	2	4

2.1.3 External Cost of the Environmental Impacts Generated in the EU

2.1.3.1 Total of all the Categories

External Costs Generated at the EU level
Total for all categories & LC Stages Contribution

Functional unit: Consumption per Capita per Year in Europe

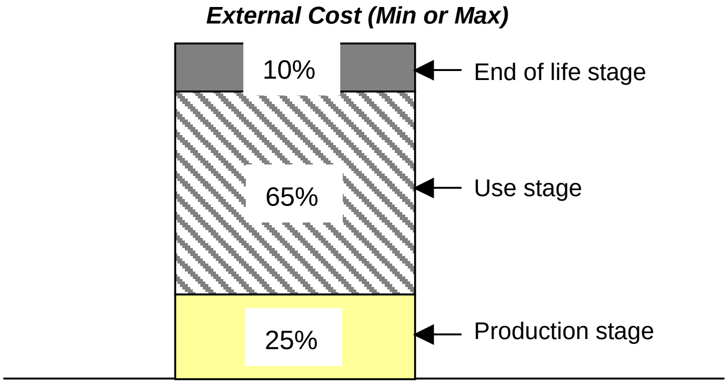
		Total				Production stage		Use stage		End of life stage	
C/ External Cost		Values		% total external cost							
Linked to air emissions		min	max	min	max	min	max	min	max	min	max
Greenhouse effect (direct, 100 yrs)	Euros	169	426	77%	45%	31	79	128	323	10	24
Stratospheric Ozone Depletion	Euros	0.0021	0.0021	0.0%	0.0%	4.E-04	4.E-04	2.E-03	2.E-03	5.E-06	5.E-06
Air acidification	Euros	7	69	3%	7%	2	20	5	49	0	0
Photochemical oxidation	Euros	11	14	5%	1%	4	5	6	8	1	1
Linked to water effluents											
Eutrophication	Euros	12	12	6%	1.3%	9	9	1	1	2	2
Linked to solid waste											
Disaminity caused by incineration	Euros	0.3	1.2	0.2%	0.1%	0.1	0.3	0.0	0.0	0.3	1
Disaminity caused by landfilling	Euros	10	30	4%	3%	2	5	0	0	8	25
Linked to human health											
Carcinogenic potential of heavy metals	Euros	0.2	0.2	0.1%	0.0%	0.1	0.1	0.1	0.1	0.1	0.1
Human health effects caused by dusts	Euros	9	404	4%	42%	3	108	6	258	1	36
Human health effects caused by dioxins	Euros	0.0149	0.032	0.0%	0.0%	1.E-03	3.E-03	9.E-03	2.E-02	5.E-03	1.E-02
Total External Cost	**Euros**	**219**	**958**	100%	100%	**51**	**228**	**146**	**639**	**21**	**89**
						23%	24%	67%	67%	10%	9%

Considering the current state of the art of environmental impacts monetarisation applied to LCA (see § 1.3.3.3), the range in which **the external cost varies** is large (at least a 4-factor): **the minimum is likely to be near 220 and the maximum is higher than 960 Euros / capita per yr** (several environmental impacts are not monetarised).

More than 50% can be allocated to **greenhouse effect** and another significant proportion to **human health effects caused by dusts**.

The **use stage** of the products consumed in the EU is at the origin of **more than 60%** of the overall external cost.

Life Cycle Stages Contribution to External Cost



Remark: **as explained in several previous sections of the report, the accuracy of the absolute figures is likely to be quite low. They are subject to both statistical errors and uncertainties / omissions difficult to quantify. This lack of accuracy may be less important when considering the relative weights of the categories, even if it is difficult to be certain of that**.

2.1.3.2 Contribution of the Different Categories

As shown in the tables and graphs next pages and summarised below, the main categories contributing to the overall external cost are obviously those contributing the most to greenhouse effect, photochemical oxidation and dusts emissions: **transport (goods transport and personal cars) and building occupancy (mainly space heating of domestic and commercial building)**.

But it should be noted that the relative contribution of different categories is quite homogeneous (all the categories contribute to less than 30% and most of them to less than 20%). As shown above (see §2.1.2.2), it is different compared to the environmental impacts themselves where major contributions are identified (some categories generate more than 40% or even 60% of a given impact).

External Cost at the EU level
Summary of the Contribution of the Different Categories

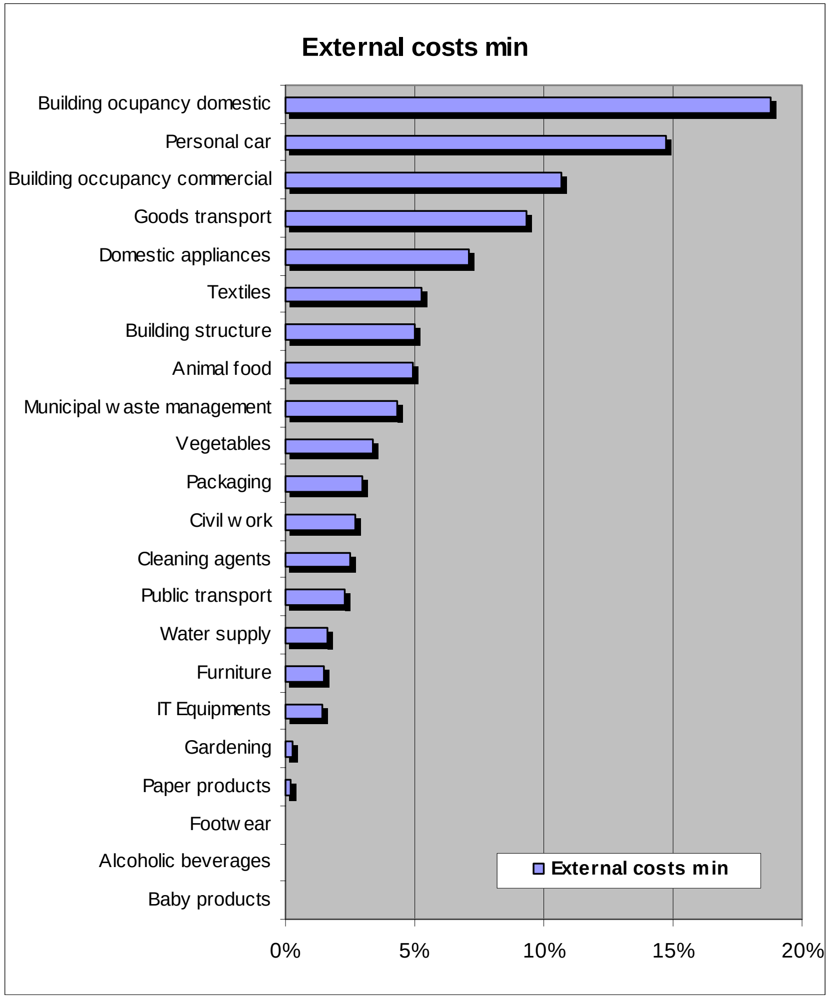
	Contribution of the categories to the total EU external cost			
	<10%	***10-20%***	***20-30%***	***>30%***
External cost - min	All the others	EEE Building structure	**Building occupancy**[28] **Transport**[29]	
External cost - max	All the others	Building occupancy	**Transport**	

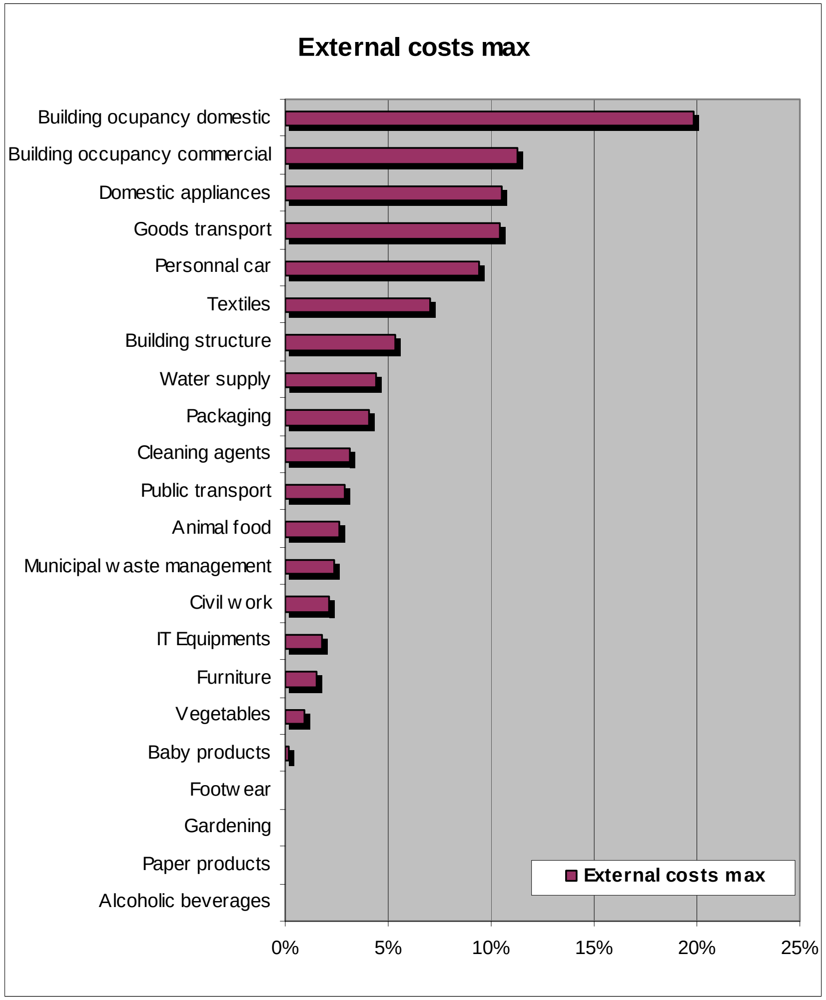
In **bold** characters, the most significant category for min and max.

[28] the total of 2 categories represented in the graphs below: “building occupancy domestic”, “building occupancy commercial”

[29] the total of 3 categories represented in the graphs below: “personal car”, “goods transport” and “transport services”

Contribution of the Different Categories to the Overall External Cost at the EU Level
(in % of the total generated by all the categories studied)





External Cost at the EU Level – Contribution of the Different Categories (1/4)

Functional unit: Consumption per Capita per Year in Europe

		TOTAL	Transports				Civil work	Building structure	EEE		
			Total	Goods	Personal cars	ransport service	**Total**	**Total**	**Total**	EEE IT	EEE Domestic appliances
C/ External Cost MIN		**Values min**									
Linked to air emissions											
Greenhouse effect (direct, 100 yrs)	Euros	**169**	**50**	17	29	4	**1**	**5**	**15**	2	13
Stratospheric Ozone Depletion	Euros	**2.E-03**	**8.3E-04**	8.1E-04	2.0E-05	2.2E-06	**9.8E-06**	**7.5E-05**	**1.2E-04**	1.5E-05	1.0E-04
Air acidification	Euros	**7**	**2.0**	1.0	0.7	0.3	**0.1**	**0.4**	**0.9**	0.2	0.7
Photochemical oxidation	Euros	**11**	**4.2**	1.4	2.6	0.1	**0.1**	**0.8**	**0.6**	0.1	0.5
Linked to water effluents											
Eutrophication	Euros	**12**	**0.1**	0.0	0.0	0.0	**0.0**	**0.2**	**0.0**	0.0	0.0
Linked to solid waste											
Disaminity caused by incineration	Euros	**0.3**	**0.00**	0.00	0.00	0.00	**0.00**	**0.00**	**0.03**	0.01	0.02
Disaminity caused by landfilling	Euros	**10**	**0.0**	0.0	0.0	0.0	**4.3**	**3.7**	**0.2**	0.2	0.0
Linked to human health											
Carcinogenic potential of heavy metals	Euros	**0.2**	**0.05**	0.05	0.00	0.00	**0.00**	**0.05**	**0.07**	0.00	0.07
Human health effects caused by dusts	Euros	**9**	**1.6**	1.1	0.2	0.3	**0.0**	**0.5**	**1.6**	0.2	1.4
Human health effects caused by dioxins	Euros	**0.01**	**0.01**	0.00	0.01	0.00	**0.00**	**0.00**	**0.00**	0.00	0.00
Total External Cost	**Euros**	**219**	**57.7**	**20.4**	**32.2**	**5.1**	**6.0**	**11.0**	**18.7**	**3.1**	**15.6**
C/ External Cost MAX		**Values max**									
Linked to air emissions											
Greenhouse effect (direct, 100 yrs)	Euros	**426**	**125.9**	42.3	72.5	11.1	**3.7**	**13.6**	**38.5**	6.1	32.4
Stratospheric Ozone Depletion	Euros	**0.002**	**0.0**	0.0	0.0	0.0	**0.0**	**0.0**	**0.0**	0.0	0.0
Air acidification	Euros	**69**	**19.6**	10.2	6.9	2.5	**0.9**	**3.8**	**9.0**	1.9	7.1
Photochemical oxidation	Euros	**14**	**5.3**	1.8	3.3	0.2	**0.1**	**1.0**	**0.7**	0.1	0.6
Linked to water effluents											
Eutrophication	Euros	**12**	**0.1**	0.0	0.0	0.0	**0.0**	**0.2**	**0.0**	0.0	0.0
Linked to solid waste											
Disaminity caused by incineration	Euros	**1**	**0.0**	0.0	0.0	0.0	**0.0**	**0.0**	**0.1**	0.0	0.1
Disaminity caused by landfilling	Euros	**30**	**0.0**	0.0	0.0	0.0	**13.7**	**11.8**	**0.6**	0.5	0.1
Linked to human health											
Carcinogenic potential of heavy metals	Euros	**0.2**	**0.1**	0.1	0.0	0.0	**0.0**	**0.1**	**0.1**	0.0	0.1
Human health effects caused by dusts	Euros	**404**	**66.2**	45.5	7.0	13.7	**1.4**	**20.0**	**68.9**	8.6	60.4
Human health effects caused by dioxins	Euros	**0.03**	**0.0**	0.0	0.0	0.0	**0.0**	**0.0**	**0.0**	0.0	0.0
Total External Cost	**Euros**	**958**	**217.1**	**99.9**	**89.7**	**27.6**	**19.8**	**50.5**	**118.0**	**17.3**	**100.7**
Life cycle price	**Euros**	**5 922**			**955.1**	**101.3**		**2037.4**	**244.7**	**152.4**	**92.4**

External Cost at the EU Level – Contribution of the Different Categories (2/4)

Functional unit: Consumption per Capita per Year in Europe

		TOTAL	Building occupancy										
			Total	Domestic sector					Commercial building				
C/ External Cost MIN		Values min											
Linked to air emissions													
Greenhouse effect (direct, 100 yrs)	Euros	169	60	39	26	6	2	4	21	11	2	1	7
Stratospheric Ozone Depletion	Euros	2.E-03	6.5E-04	4.3E-04	3.0E-04	3.2E-02	2.3E-05	4.8E-05	2.2E-04	1.1E-04	2.0E-05	1.1E-05	7.4E-05
Air acidification	Euros	7	1.9	1.1	0.8	0.0	0.1	0.1	0.8	0.4	0.1	0.0	0.3
Photochemical oxidation	Euros	11	1.3	0.8	0.6	0.0	0.0	0.1	0.5	0.2	0.0	0.0	0.2
Linked to water effluents													
Eutrophication	Euros	12	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Linked to solid waste													
Disaminity caused by incineration	Euros	0.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Disaminity caused by landfilling	Euros	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Linked to human health													
Carcinogenic potential of heavy metals	Euros	0.2	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Human health effects caused by dusts	Euros	9	3.0	1.9	1.3	0.0	0.1	0.2	1.1	0.6	0.1	0.1	0.4
Human health effects caused by dioxins	Euros	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total External Cost	**Euros**	**219**	**65.9**	**42.5**	**29.1**	**5.9**	**2.3**	**4.7**	**23.4**	**12.2**	**2.1**	**1.2**	**8.0**
C/ External Cost MAX		Values max											
Linked to air emissions													
Greenhouse effect (direct, 100 yrs)	Euros	426	150.6	97.4	66.7	14.7	5.2	10.8	53.2	27.7	4.8	2.7	18.1
Stratospheric Ozone Depletion	Euros	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Air acidification	Euros	69	18.6	11.0	7.5	1.7	0.6	1.2	7.6	3.9	0.7	0.4	2.6
Photochemical oxidation	Euros	14	1.6	1.1	0.7	0.2	0.1	0.1	0.6	0.3	0.1	0.0	0.2
Linked to water effluents													
Eutrophication	Euros	12	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Linked to solid waste													
Disaminity caused by incineration	Euros	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Disaminity caused by landfilling	Euros	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Linked to human health													
Carcinogenic potential of heavy metals	Euros	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Human health effects caused by dusts	Euros	404	127.1	80.8	55.3	12.2	4.3	9.0	46.3	24.1	4.2	2.3	15.8
Human health effects caused by dioxins	Euros	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total External Cost	**Euros**	**958**	**298.0**	**190.3**	**130.3**	**28.7**	**10.1**	**21.1**	**107.8**	**56.0**	**9.7**	**5.4**	**36.6**
Life cycle price	**Euros**	**5 922**		**382.9**					**0.0**				

External Cost at the EU Level – Contribution of the Different Categories (3/4)

Functional unit: Consumption per Capita per Year in Europe

		TOTAL	Cleaning agents			Furniture	Textiles	Footwear	Packaging
			Total	detergent textile	personal care	Total	Total	Total	Total
C/ External Cost MIN		Values min							
Linked to air emissions									
Greenhouse effect (direct, 100 yrs)	Euros	169	4	2	1	3	8	0	4
Stratospheric Ozone Depletion	Euros	2.E-03	6.4E-05	2.8E-05	1.1E-05	1.8E-05	7.5E-05	-1.3E-08	8.4E-05
Air acidification	Euros	7	0.3	0.1	0.1	0.1	0.6	0.0	0.4
Photochemical oxidation	Euros	11	0.7	0.3	0.1	0.1	1.0	0.0	0.3
Linked to water effluents									
Eutrophication	Euros	12	0.2	0.1	0.0	0.1	1.3	0.0	0.3
Linked to solid waste									
Disaminity caused by incineration	Euros	0.3	0.00	0.00	0.00	0.00	0.01	0.00	0.21
Disaminity caused by landfilling	Euros	10	0.0	0.0	0.0	0.1	0.1	0.0	0.8
Linked to human health									
Carcinogenic potential of heavy metals	Euros	0.2	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Human health effects caused by dusts	Euros	9	0.4	0.2	0.1	0.1	0.9	0.0	0.5
Human health effects caused by dioxins	Euros	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total External Cost	**Euros**	**219**	5.5	2.4	1.0	3.3	11.6	0.3	6.5
C/ External Cost MAX		Values max							
Linked to air emissions									
Greenhouse effect (direct, 100 yrs)	Euros	426	9.8	4.2	1.7	7.3	19.6	0.6	10.4
Stratospheric Ozone Depletion	Euros	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Air acidification	Euros	69	3.4	1.5	0.6	0.7	5.8	0.1	3.7
Photochemical oxidation	Euros	14	1.0	0.4	0.2	0.1	1.3	0.0	0.3
Linked to water effluents									
Eutrophication	Euros	12	0.2	0.1	0.0	0.1	1.3	0.0	0.3
Linked to solid waste									
Disaminity caused by incineration	Euros	1	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Disaminity caused by landfilling	Euros	30	0.1	0.0	0.0	0.4	0.2	0.1	2.5
Linked to human health									
Carcinogenic potential of heavy metals	Euros	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Human health effects caused by dusts	Euros	404	15.2	6.6	2.7	5.5	38.7	0.4	21.4
Human health effects caused by dioxins	Euros	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total External Cost	**Euros**	**958**	29.6	12.8	5.2	14.0	66.9	1.2	39.3
Life cycle price	**Euros**	**5 922**			90.9	306.1	534.4	114.8	

External Cost at the EU Level – Contribution of the Different Categories (4/4)

Functional unit: Consumption per Capita per Year in Europe

		TOTAL	Paper products	Food products		Beverage	Baby products	Gardening	Water supply	Municipal waste management
				Animal food	Vegetables	Alcoholic beverage				
C/ External Cost MIN		Values min								
Linked to air emissions										
Greenhouse effect (direct, 100 yrs)	Euros	169	0	9	-1	0	0	0	1	9
Stratospheric Ozone Depletion	Euros	2.E-03	1.0E-08	2.7E-05	9.4E-05	2.5E-07	0.0E+00	8.8E-09	6.7E-06	-2.0E-06
Air acidification	Euros	7	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.0
Photochemical oxidation	Euros	11	0.0	1.5	0.0	0.0	0.0	0.0	0.1	0.6
Linked to water effluents										
Eutrophication	Euros	12	0.0	0.0	7.8	0.1	0.0	0.7	1.4	0.1
Linked to solid waste										
Disaminity caused by incineration	Euros	0.3	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Disaminity caused by landfilling	Euros	10	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Linked to human health										
Carcinogenic potential of heavy metals	Euros	0.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Human health effects caused by dusts	Euros	9	0.0	0.0	0.0	0.0	0.1	0.0	0.9	0.0
Human health effects caused by dioxins	Euros	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total External Cost	**Euros**	**219**	0.4	10.7	7.4	0.1	0.1	0.7	3.5	9.4
C/ External Cost MAX		Values max								
Linked to air emissions										
Greenhouse effect (direct, 100 yrs)	Euros	426	0.0	23.2	-1.4	0.2	0.0	0.2	2.5	22.0
Stratospheric Ozone Depletion	Euros	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Air acidification	Euros	69	0.0	0.0	2.1	0.0	0.2	0.0	0.9	-0.1
Photochemical oxidation	Euros	14	0.0	1.9	0.0	0.0	0.0	0.0	0.1	0.7
Linked to water effluents										
Eutrophication	Euros	12	0.0	0.0	7.8	0.1	0.0	0.7	1.4	0.1
Linked to solid waste										
Disaminity caused by incineration	Euros	1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Disaminity caused by landfilling	Euros	30	1.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Linked to human health										
Carcinogenic potential of heavy metals	Euros	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Human health effects caused by dusts	Euros	404	0.0	0.0	0.0	0.1	2.2	0.1	36.7	0.4
Human health effects caused by dioxins	Euros	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total External Cost	**Euros**	**958**	1.2	25.1	8.5	0.3	2.4	0.9	41.7	23.1
Life cycle price	**Euros**	**5 922**	143.4	550.8	244.3	70.6			144.8	

2.1.4 Internalisation of Environmental External Costs

2.1.4.1 Important Preliminary Comment

■ This section about internalisation is an attempt to quantify the six indicators presented in detail in section 1.3.4.2.3. We will then compare external cost to environmental taxes, external cost to life cycle price and environmental taxes to life cycle price.

It is important to keep in mind **the two main limits of this quantification exercise**:

- External cost: **actual external costs are likely to be higher than those assessed in this study** because first cost factors do not exist today for all the environmental impacts quantified in LCAs (they concern more air emissions than eutrophication or depletion of resources for instance) and secondly several environmental impacts are not quantified in LCA and then not monetarised, including:
  - noise,
  - odour,
  - nature conservation (biodiversity, etc.),
  - land disturbance,
  - other disamenity,
  - risk of accidents (nuclear, oil slicks, transport…).

  The range obtained for external costs reflects the diversity of values existing in literature for the environmental impacts actually moneratised but the max values presented do not correspond to actual maximums (some external costs are missing).
- Environmental taxes: **actual environmental taxes are likely to be closer to the lowest values of the ranges assessed rather than the highest values**.

  This directly results from the way the ranges were built, in a context where available tax data were not in a format compatible with LCA: a tax factor was determined for each main input and output quantified in LC inventory and then applied to all the categories. Existing exemptions and variety of rates were taken into account through a range: the min corresponds to the minimum rates and the max corresponds to the maximum rates (without taking into account specific exemptions and subsidies applying to some categories and flows[30]).

  As a consequence, **the max value of the environmental tax range corresponds to a true maximum value (as if all the maximum rates would apply to all categories et flows) but is not reachable (because of exemptions and subsidies).**

The conclusions which are drawn in the following pages take that fact into consideration.

■ As in preceding chapters, we first analyse results for all the categories together then per category.

[30] This work would require an important and dedicated research program.

2.1.4.2 Total of all the Categories

Environmental Taxes and Internalisation of the External Costs

Functional unit: Consumption per Capita per Year in Europe		Total				Production stage		Use stage		End of life stage	
C/ External Cost											
Total External Cost	**Euros**	**219**	**958**			**51**	**228**	**146**	**639**	**21**	**89**
						23%	24%	67%	67%	10%	9%
D/ Internalisation of the external Cost											
		Values		**Taxes compo**							
Taxes paid (total)		**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
Denmark	Euros	1633	4484	100%	100%	1268	1792	330	2637	34	49
France	Euros	1565	4792	100%	100%	756	1505	621	3079	187	202
Poland	Euros	190	2238	100%	100%	40	475	148	1749	1	10
Part of the external cost internalised		**190**	**4 792**			**40**	**1 792**	**148**	**3 079**	**1**	**202**
Taxes paid - Linked to air emissions											
Denmark	Euros	85	136	5%	3%	19	27	66	108	0	0
France	Euros	3	3	0%	0%	1	1	2	2	0	0
Poland	Euros	6	6	3%	0%	1	1	6	6	0	0
Part of the external cost internalised		**3**	**136**			**1**	**27**	**2**	**108**	**0**	**0**
Taxes paid - Linked to water effluents											
Denmark	Euros	639	639	39%	14%	616	616	9	9	14	14
France	Euros	1389	1389	89%	29%	681	681	524	524	183	183
Poland	Euros	4	27	2%	1%	1	5	3	21	0	1
Part of the external cost internalised		**4**	**1 389**			**1**	**681**	**3**	**524**	**0**	**183**
Taxes paid - Linked to solid wast											
Denmark	Euros	30	34	2%	1%	11	13	1	1	18	21
France	Euros	6	8	0%	0%	2	3	0	0	4	5
Poland	Euros										
Part of the external cost internalised			**34**				**13**		**1**		**21**
Taxes paid - Linked to material consumption											
Denmark	Euros	533	533	33%	12%	523	523	11	11	0	0
France	Euros	42	242	3%	5%	41	238	1	5	0	0
Poland	Euros	8	87	4%	4%	8	85	0	2	0	0
Part of the external cost internalised		**8**	**533**			**8**	**523**	**0**	**11**	**0**	**0**
Taxes paid - Linked to energy consumption											
Denmark	Euros	214	2985	13%	67%	39	542	174	2425	1	14
France	Euros	97	3110	6%	65%	18	565	79	2527	0	14
Poland	Euros	171	2118	90%	95%	31	384	139	1721	1	10
Part of the external cost internalised		**97**	**3 110**			**18**	**565**	**79**	**2 527**	**0**	**14**
E/ Life-Cycle Price											
Life-Cycle Price	**Euros**	**5 922**									
External Cost Compared to Life-Cycle Price		**4%**	**16%**								

***Caveats*: in the following pages of this section, we tried the following exercise: to quantify the 6 internalisation indicators, all categories together. But since in all likelihood external costs are underestimated and environmental taxes are somewhere in a very large interval, conclusions have to be drawn carefully from the figures. This exercise must then be seen more as a feasibility test of the method and the indicators than their definitive quantification.**

■ Life cycle price

Let us remind (see §1.3.4.2.1) that the life cycle price considered here does not take into account only the selling price of the product or service paid by the consumer to the producer or retailer but also includes all the expenditures that the consumer will have to pay when using the product and then disposing of it at the end of its life.

Life cycle price = Selling price + Use & End-of-life expenditures

The **overall life cycle price (all categories altogether)** assessed in this study[31] amounts approximately to **5 920 Euros / capita / year**. That is to say each average European consumer spends approximately 6 000 Euros per year to buy, use and eliminate the products and services considered (i.e. about 15 000 Euros per household composed of an average of 2.5 persons).

■ Environmental taxes

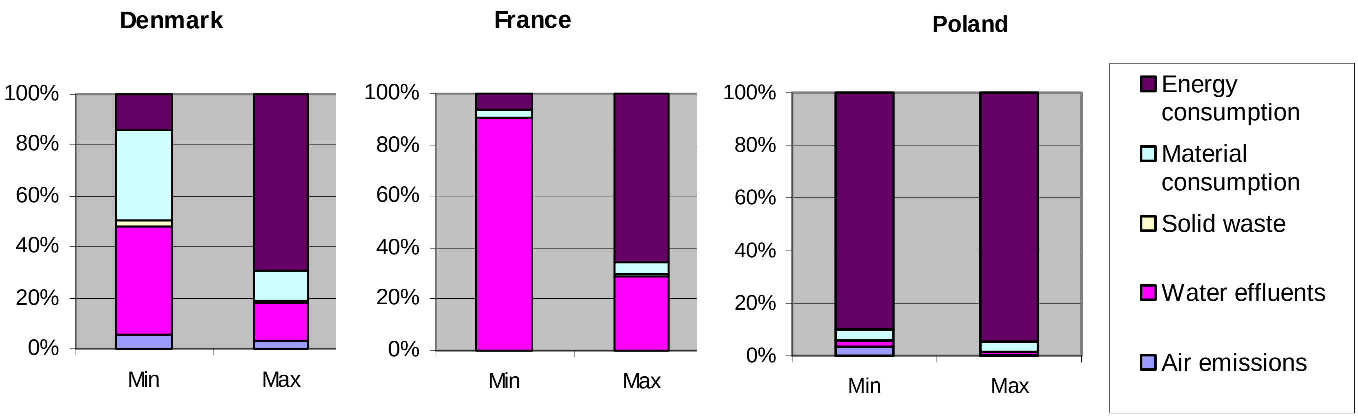
The total amount of environmental taxes linked to the considered product categories varies in very different ranges according to countries as expected, specially between Poland and the two other countries:

- Denmark: 1 630 to 4 485 Euros / capita / year,
- France: 1 565 to 4 790 Euros / capita / year,
- Poland: 190 to 2 240 Euros / capita / year.

The quite large ranges obtained result from the fact that in order to take into account the exemptions applying in particular to the different kinds of energy, the taxes related to energy were considered varying between the minimum tax (min value) and the maximum tax existing in the country (max value) as reminded above.

The highest environmental tax revenue is that from energy related taxes (for the 3 countries), and the second highest is linked to water effluents related taxes (except for Poland). For that reason, they are mainly linked to production and use stages.

Split of the Total Environmental Taxes Between Scope Concerned



[31] as explained in §1.4.3.4, it was approximated by considering the total domestic expenditures linked to the categories considered

It may be interesting to note that **environmental taxes represent a significant proportion of the life cycle price, which is somewhere between 25% and 80% of the life cycle price in Denmark and France and between 5 and 40% in Poland** (once again, this large range is due to the range considered for environmental taxes).

		Denmark		France		Poland	
		Min	Max	Min	Max	Min	Max
Total environmental taxes (Euros)	a	1 635	4 485	1 565	4 790	190	2 240
Total life cycle price (Euros)	b	5 920		5 920		5 920	
% of environmental taxes compared to life cycle price	c=a/b	**28%**	**76%**	**26%**	**81%**	**3%**	**38%**

- (A-indicator) % of environmental taxes compared to external cost

When comparing total environmental taxes to total external cost assessed, the results show that the total environmental taxes would represent more than 100% of the total external cost higher (somewhere between 265% and 810% in Denmark and France and somewhere between 30% and 380% in.Poland).

The fact that most of these percentages appear to be higher than 100% reflects that environmental taxes would be often much higher than external costs. As a matter of fact, external costs would "only" represent about 10% to 40% of environmental taxes in Denmark and France for instance.

		Denmark		France		Poland	
		Min	Max	Min	Max	Min	Max
Total external cost (Euros)		220	960	220	960	220	960
average[32]	a	590		590		590	
Total environmental taxes (Euros)	b	1 635	4 485	1 565	4 790	190	2 240
A-indicator	c=b/a	**277%**	**760%**	**265%**	**812%**	**32%**	**380%**
% of external cost compared to environmental taxes	d=a/b	**36%**	**13%**	**38%**	**12%**	**311%**	**26%**

One would then be tempted to conclude that the overall external cost (all categories altogether) is already very well internalised (at least in countries where environmental taxation is quite well developed).

But several distortions are hidden behind these figures as explained above:

- taxes are likely to be overestimated, due to exemptions applying to certain products and activities not well apprehended in the study,

[32] In order to facilitate the calculations of A-indicator, the average value of external cost is considered (otherwise, it would have been necessary to mix min and max of external cost with min and max of environmental taxes). This approximation was preferred (rather than considering the average value for environmental taxes) because the range obtained for external cost is relatively smaller.

- assessed external costs may be underestimated, being evaluated with the current level of scientific knowledge of monetarisation applied to LCA.

And indeed, it is not absurd to considerer that the external cost could be higher than 960 Euros if all the environmental impacts would be included, for instance 1 300 Euros or even more, and that the actual environmental taxes could be close to the lower value, for instance 1 800 Euros. In such cases, the overall external cost could still be considered totally internalised but maybe and even probably not.

- (D-indicator) current level of internalisation reached

Considering what has just been said about A-indicator, **it seems reasonable to conclude that it is unlikely that the actual external cost all categories together is already totally internalised. But the level of internalisation may be quite good already (with significant compensations between categories** – see section 2.1.4.3 hereafter).

- (B-indicator) % of external cost not yet internalised compared to LC Price

From the calculation of A-indicator, the external cost would be totally internalised and thus the external cost not yet internalised would be equal to 0.

But considering the impossibilities to quantify with more accuracy the actual external cost (which may be higher) and the current level of internalisation (which is likely to be less than 100%), it is likely that the external cost not yet internalised is not 0, without being able to quantify it.

As a consequence, it is not possible to quantify B-indicator without any further in-depth work.

- (C-indicator) % of external cost compared to LC price

The total external cost (all categories together) represent at least 5 to 15% of the life cycle price (since the high value of the external cost range is likely to be underestimated, this percentage may be higher).

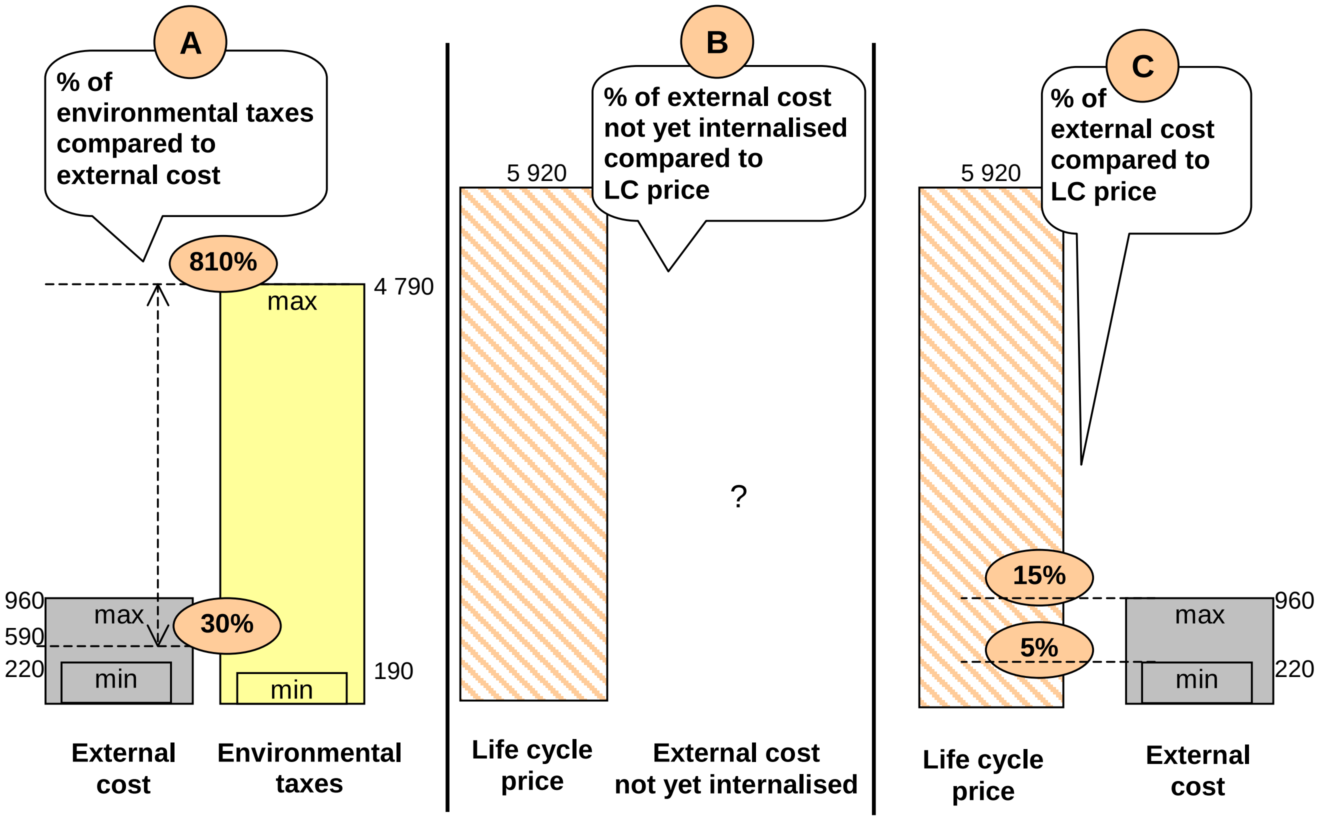
		Min	Max
Total external cost (Euros)	a	220	960
Total life cycle price (Euros)	b	5 920	
C-indicator	c=a/b	**5%**	**15%**

- (E- and F-indicators) importance of externalities not yet internalised and of overall externalities, compared to the overall life cycle price

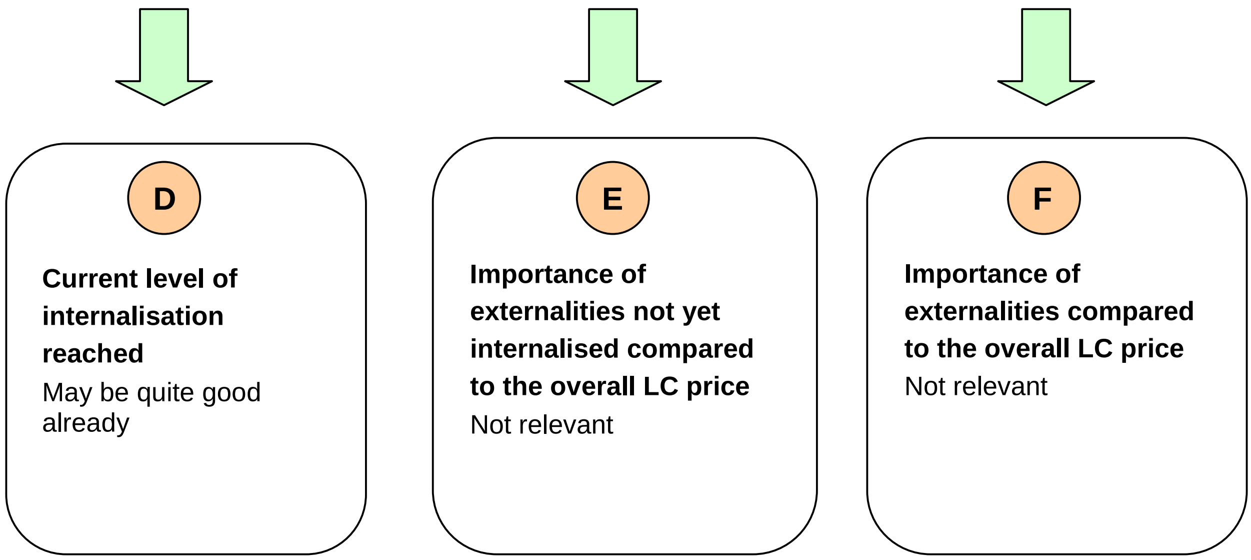
These indicators are more appropriate for a relative analysis (comparison of categories) than to analyse the overall situation. They will then be discussed in the next section.

Summary of the results for the key indicators about internalisation

Amounts in Euros / capita / year (<u>all categories together</u>)



***Caveats*: the figures may be quite different in reality, because external cost may be underestimated and environmental taxes may be close the low value of their range**



E-indicator and F-indicator are mere relevant for a relative comparison between categories. They will be analysed at the category level in the next section.

2.1.4.3 For Each Category

Results are summarised first, based on detailed data presented in graphs and tables just after.

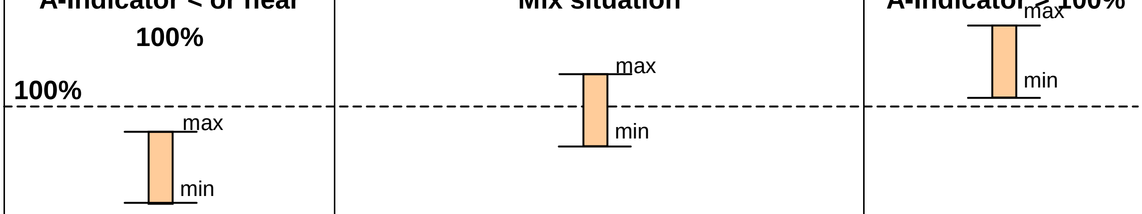
We decided to consider the range of environmental taxes Poland excluded, in order to reduce the interval and then to facilitate a little bit the analysis.

- (A-indicator) % of environmental taxes compared to external cost

From a quantification point of view, three situations could be distinguished:

- For some of the studied categories, the environmental taxes assessed are lower than the external cost calculated (A-indicator < 100%). In these cases, only a part of the external cost could be considered being internalised.
- For other categories, the environmental taxes are higher (A-indicator > 100%). External cost could then be considered being totally internalised.
- For several categories (third column in the table below), the results differ depending on the min or max value of A-indicator, i.e. depending on the actual level of external cost and environmental taxes in their respective ranges (which is not possible to assess more precisely in this study). For these categories, the external cost would be, or would not yet be, totally internalised.

(A-Indicator) % of environmental taxes compared to external cost



A-Indicator < or near 100%	Mix situation		A-Indicator > 100%
Vegetables MSW management	Goods transport Personal cars Passengers public transport Civil work Building occupancy – Domestic & Commercial sector	Cleaning agents – Textile detergent Cleaning agents – personal care EEE – IT EEE – Domestic appliances Food from animals Baby products	Water supply Building structure Furniture Textiles Beverage Gardening Packaging Paper products Footwear
Only a part of external cost would be internalised	***External cost could be totally internalised***		***External cost would be totally internalised***

But the relevance of the results of this quantification exercise is limited at that stage, once again due to the fact that the range considered for the environmental taxes is too large today.

■ (D-indicator) Current level of internalisation reached

The quantification of the current level of internalisation seems difficult considering the difficulties to interpret A-Indicator.

However, it seems possible to perform a comparative analysis between categories.

(D-indicator) Current Level of Internalisation of the External Cost
Relative Position of the Categories

\- → +

Vegetables	Goods transport	Water supply
MSW management	Personal cars	Building structure
	Passengers public transport	Furniture
	Civil work	Textiles
	Building occupancy – Domestic sector	Beverage
	Building occupancy – Commercial sector	Gardening
	Cleaning agents – Textile detergent	Packaging
	Cleaning agents – Personal care	Paper products
	EEE – IT	Footwear
	EEE – Domestic appliances	
	Food from animals	
	Baby products	

■ (B-Indicator) % of external cost not yet internalised compared to LC price and (E-Indicator) Importance of externalities not yet internalised compared to life cycle price

B-Indicator is not easy to quantify on a robust basis given the difficulty of interpreting the A-Indicator (mainly due to the large range of environmental taxes).

As a consequence, it is not easy to position the categories on the E-Indicator basis.

■ (C-Indicator) % of external cost compared to LC price and (F-Indicator) Importance of externalities compared to life cycle price

For all the studied categories, the external cost appears to reach an amount corresponding to at least 5 to 10 or 15% of the LC price.

(C-Indicator) % of External Cost compared to LC Price

C-Indicator = at least 1%	***C-Indicator = at least 5%***	***C-Indicator = at least 5 to 15%***	***C-Indicator = at least 5 to 25%***	***Not Been Assessed in the Study[33]***
Beverage Paper products Footwear Building structure	Furniture Cleaning agents Vegetables Food from animals	Personal cars EEE – IT Textiles	EEE – Domestic appliances (max = 110%) Building occupancy – Domestic sector (max = 50%) Water supply Passengers public transport	Goods transport Baby products Gardening MSW management Civil work Packaging Building occupancy – Commercial sector

(F-Indicator) Importance of externalities compared to life cycle price

- **+**

■ As an illustration, the following table and graphs give a summary of the detailed results for each category. But the figures have to be considered with precaution (in particular A- and B-Indicators, which directly depend on the large range of environmental taxes).

33 No data available to approximate the life cycle price.

Internalisation Indicators per Category

Functional unit: Consumption per Capita per Year in Europe				**Total**	Goods transports	Personal cars	Transport services	Civil work	Building structure	Building occupancy domestic sector	Building occupancy commercial sector
External cost	min	a	Euros	**219**	20	32	5	6	11	42	23
	max	b	Euros	**958**	100	90	28	20	50	190	108
	average (1)	c	Euros	**588**	60	61	16	13	31	116	66
Environmental taxes	min	d	Euros	**1 565**	26	29	3	3	59	43	25
(Poland excluded)	max	e	Euros	**4 792**	344	474	74	69	469	844	475
LC price		f	Euros	**5 922**	0	955	101	0	2 037	383	0
A-indicator	min	g	%	**266%**	43%	47%	16%	26%	193%	37%	38%
	max	h	%	**815%**	572%	778%	455%	533%	1526%	725%	724%
D-indicator	min	i	%	**100%**	43%	47%	16%	26%	100%	37%	38%
	max	j	%	**100%**	100%	100%	100%	100%	100%	100%	100%
External cost not yet internalised	min	k	Euros	**0**	0	0	0	0	0	0	0
	max	l	Euros	**0**	35	32	14	9	0	73	41
B-indicator	min	m	%	**0%**		0%	0%		0%	0%	
	max	n	%	**0%**		3%	13%		0%	19%	
C-indicator	min	o	%	**4%**		3%	5%		1%	11%	
	max	p	%	**16%**		9%	27%		2%	50%	

Functional unit: Consumption per Capita per Year in Europe				Detergent textiles	Soap & toiletries for personal care	Furniture	Textiles	Footwear	Packaging	EEE IT	EEE Domestic appliances
External cost	min	a	Euros	2	1	3	12	0	7	3	16
	max	b	Euros	13	5	14	67	1	39	17	101
	average (1)	c	Euros	8	3	9	39	1	23	10	58
Environmental taxes	min	d	Euros	4	2	20	678	6	30	7	24
(Poland excluded)	max	e	Euros	123	50	150	898	28	194	68	363
LC price		f	Euros	0	91	306	534	115	0	152	92
A-indicator	min	g	%	58%	58%	227%	1726%	849%	130%	67%	42%
	max	h	%	1623%	1623%	1724%	2288%	3786%	848%	671%	624%
D-indicator	min	i	%	58%	58%	100%	100%	100%	100%	67%	42%
	max	j	%	100%	100%	100%	100%	100%	100%	100%	100%
External cost not yet internalised	min	k	Euros	0	0	0	0	0	0	0	0
	max	l	Euros	3	1	0	0	0	0	3	34
B-indicator	min	m	%		0%	0%	0%	0%		0%	0%
	max	n	%		1%	0%	0%	0%		2%	37%
C-indicator	min	o	%		1%	1%	2%	0%		2%	17%
	max	p	%		6%	5%	13%	1%		11%	109%

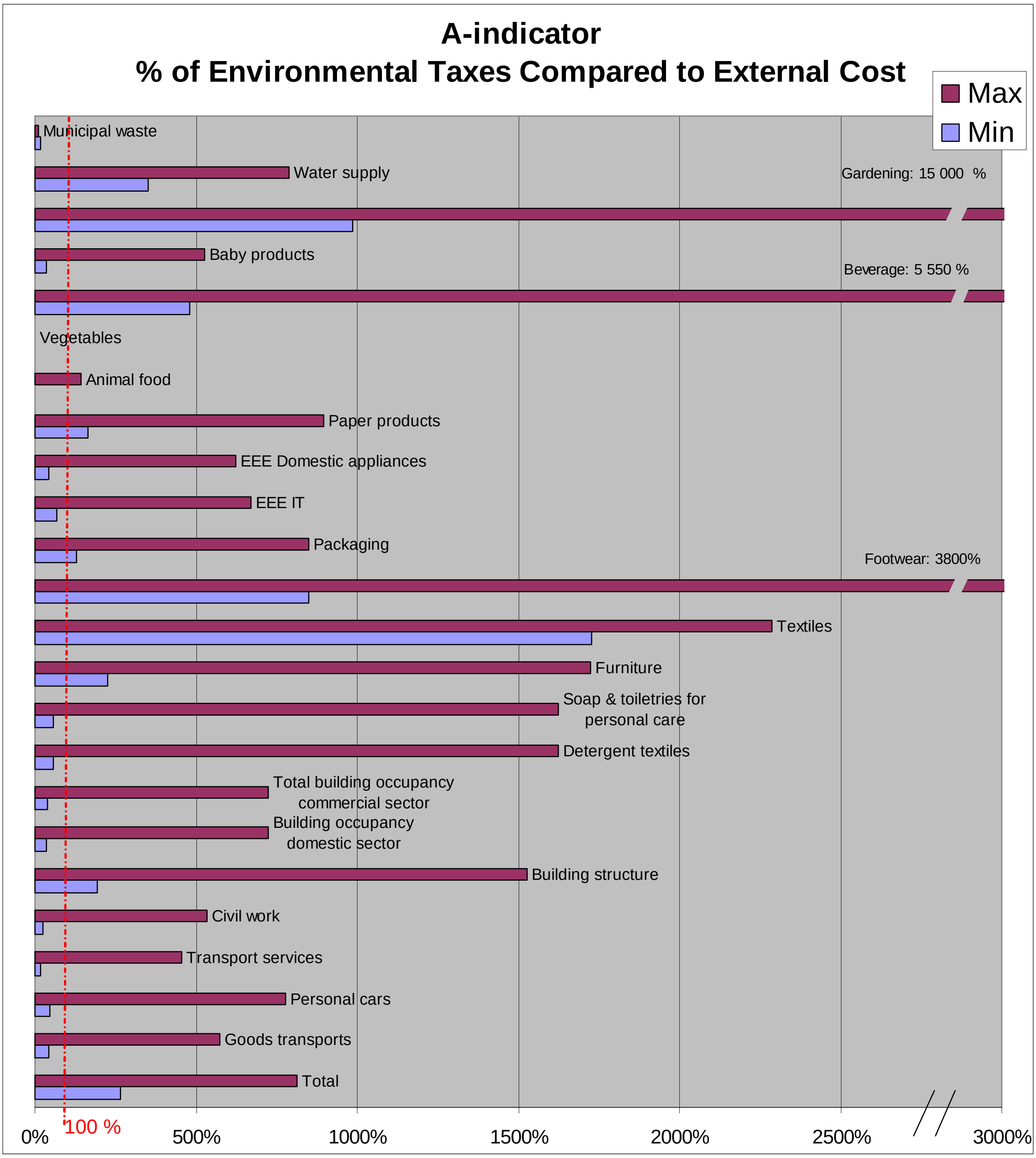
Internalisation Indicators per Category (Contd.)

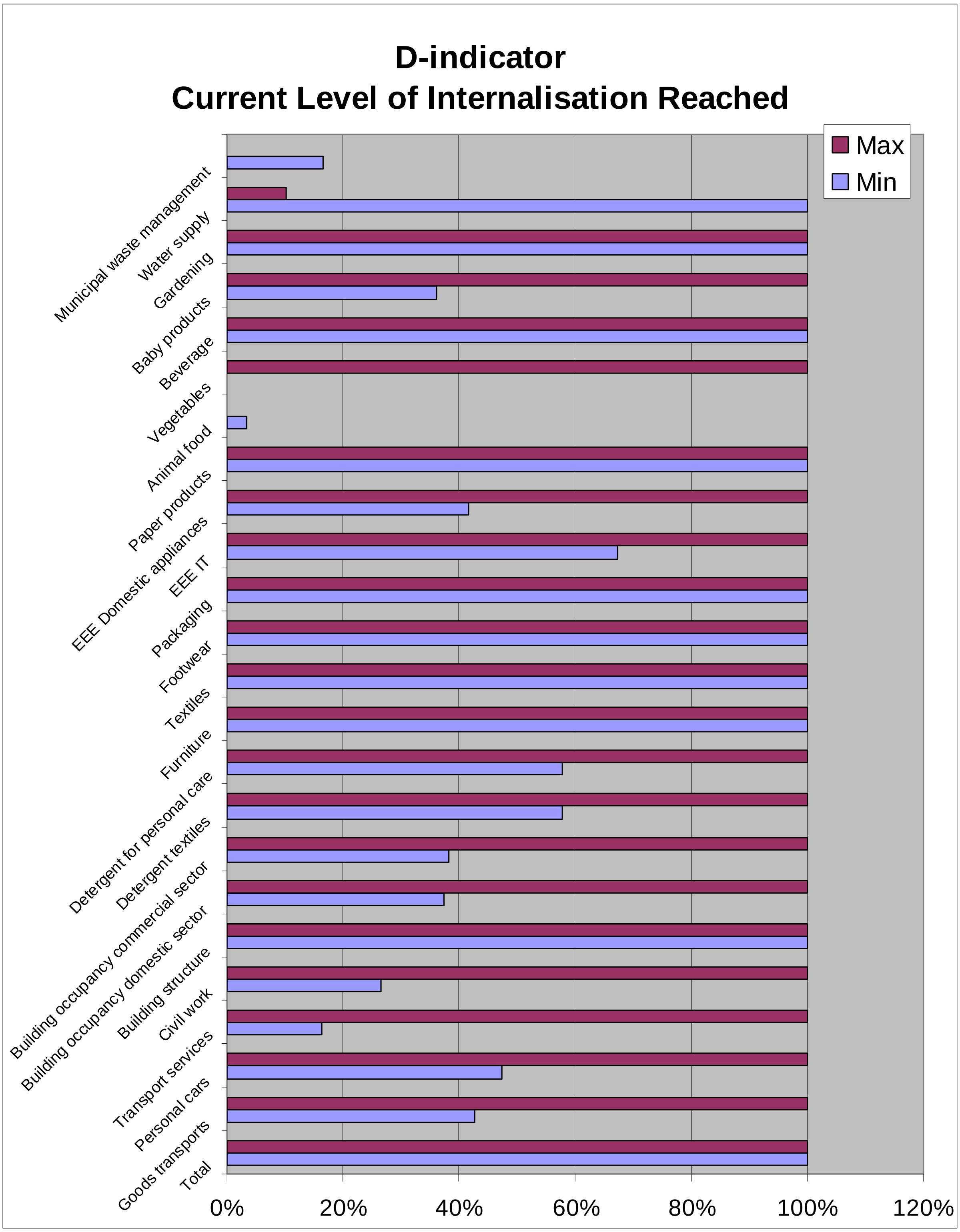
Functional unit: Consumption per Capita per Year in Europe				Paper products	Food from animals	Vegetables	Beverage	Baby products	Gardening	Water supply	Municipal waste
External cost	min	a	Euros	0	11	7	0	0	1	3	9
	max	b	Euros	1	25	9	0	2	1	42	23
	average (1)	c	Euros	1	18	8	0	1	1	23	16
Environmental taxes	min	d	Euros	1	1	0	1	0	8	80	3
(Poland excluded)	max	e	Euros	7	25	0	12	6	124	178	2
LC price		f	Euros	143	551	244	71	0	0	145	0
A-indicator	min	g	%	164%	3%	0%	480%	36%	984%	352%	17%
	max	h	%	896%	142%	0%	5541%	527%	15008%	790%	10%
D-indicator	min	i	%	100%	3%	0%	100%	36%	100%	100%	17%
	max	j	%	100%	100%	0%	100%	100%	100%	100%	10%
External cost not yet internalised	min	k	Euros	0	0	8	0	0	0	0	15
	max	l	Euros	0	17	8	0	1	0	0	14
B-indicator	min	m	%	0%	0%	3%	0%			0%	
	max	n	%	0%	3%	3%	0%			0%	
C-indicator	min	o	%	0%	2%	3%	0%			2%	
	max	p	%	1%	5%	3%	0%			29%	

(1) In order to facilitate the calculations of A-indicator and B-indicator, the average value of external cost is considered
(otherwise, it would have been necessary to mix min and max of external cost with min and max of envtal taxes). This approximation was prefer
(rather than considering the average value for envtal taxes) because the range obtained for external cost is relatively smaller.

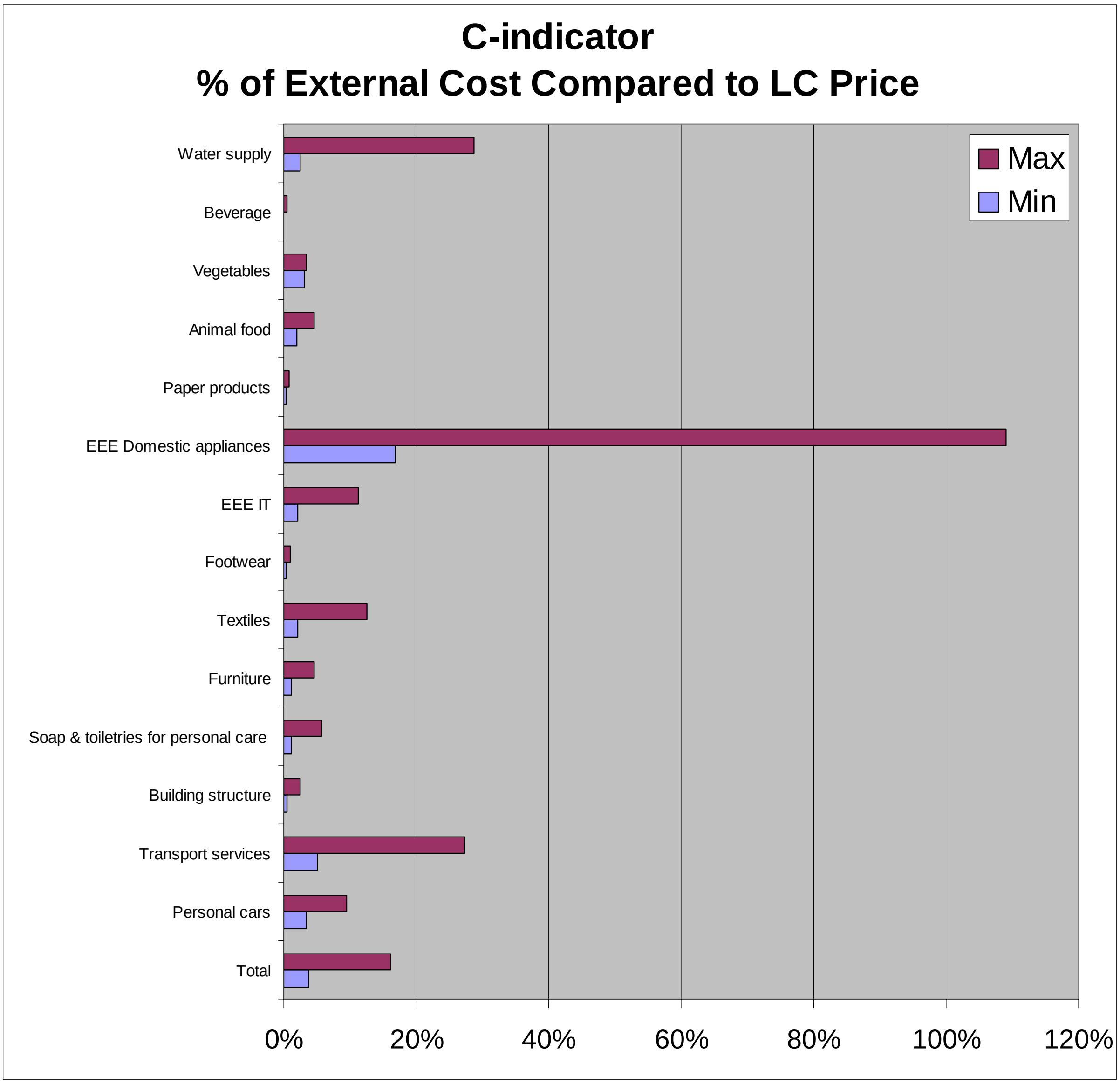
	c=(a+b)/2	k=0 si i=100% sinon c-e
A-indicator = % of environmental taxes vs external cost	g=d/c	l=0 si j=100% sinon c-d
D-indicator = current level of internalisation reached	h=e/c	m=k/f
B-indicator = % of external cost not yet internalised vs LC price	i=100% si g>100% sinon =g	n=l/f
C-indicator = % of external cost vs LC price	j=100% si h>100% sinon =h	o=a/f p=b/f

Internalisation Indicators per Category





D-indicator
Current Level of Internalisation Reached
Max
Min
Municipal waste management
Water supply
Gardening
Baby products
Beverage
Vegetables
Animal food
Paper products
EEE Domestic appliances
EEE IT
Packaging
Footwear
Textiles
Furniture
Detergent for personal care
Detergent textiles
Building occupancy commercial sector
Building occupancy domestic sector
Building structure
Civil work
Transport services
Personal cars
Goods transports
Total
0%
20%
40%
60%
80%
100%
120%


C-indicator
% of External Cost Compared to LC Price
Water supply
Beverage
Vegetables
Animal food
Paper products
EEE Domestic appliances
EEE IT
Footwear
Textiles
Furniture
Soap & toiletries for personal care
Building structure
Transport services
Personal cars
Total
0%
20%
40%
60%
80%
100%
120%
Max
Min

2.1.5 Summary of the Main Results

Indicators		***Main Categories Concerned***
Environmental Impacts	Air Pollution & Non Renewable Resources	Transport (use stage) Building occupancy (use stage)
	Water Pollution	Food (production stage)
	Human and Ecosystem Toxicity	Waste water treatment (end of life stage) Transport (use stage)
External Cost	Main categories concerned	Transport (use stage) Building occupancy (use stage)
	Main effects contributing	Greenhouse effect Human heath effects due to dusts emissions
Level of Internalisation of the External Cost Likely to be Reached	Higher Level	Water supply Building structure Furniture Textiles Beverage Gardening Packaging Paper products Footwear
	Intermediate Situation	Goods transport Personal cars Passengers public transport Civil work Building occupancy – Domestic sector Building occupancy – Commercial sector Cleaning agents – Textile detergent Cleaning agents – Personal care EEE – IT EEE – Domestic appliances Food from animals Baby products
	Lower Level	Vegetables MSW management

Importance of Environmental Externalities Compared to Life Cycle Price

- → **+**

Beverage Paper products Footwear Building structure	Furniture Cleaning agents Vegetables Food from animals	Personal cars EEE – IT Textiles	EEE – Domestic appliances Building occupancy – Domestic sector Water supply Passengers public transport

- Environmental impacts

The results of the study are in accordance with the main macro-economic tendencies already known for the environmental impacts:

- The sectors characterised by important energy consumptions, i.e. transport and building occupancy, generate an important part of the air pollution induced by the entire European economy.
- The food industry is responsible for a large proportion of the water pollution.
- Transports and waste water treatment are causing most of the human and ecosystem toxicity risks.

- External costs

Due to the different weight of the various environmental impacts in the external cost, a significant part of the total European external cost can be allocated to only two categories: transports and building occupancy.

More than 50% of the overall external cost can be allocated to greenhouse effect and another significant part to human health effects caused by dusts.

The use stage of the products consumed in the EU is at the origin of more than 60% of the overall external cost.

- Level of internalisation already reached

The quantification of the current level of internalisation seems difficult considering the difficulties to interpret some of the indicators quantified due in particular to too large a range for environmental taxes.

However, it was possible to position the categories in order to hierarchies them, which was the first purpose of the study, by considering:

- The level of internalisation likely to be reached,
- The importance of environmental externalities compared to life cycle price.

However, the conclusions should be considered as a first attempt to compare categories rather than as definitive prioritisation.

2.2 CASE STUDIES ON ALTERNATIVE OPTIONS

2.2.1 Objective of this Phase of the Study

This phase of the study aimed at testing how environmental impacts differences between various options providing the same function or service could be used by decision makers in the scope of the IPP.

Could the existence of these differences be used as a filter to define priority categories? Are some of these differences more relevant (or significant) than others?

Contrary to the first phase of the study (categories analysis), we were here more interested in the orders of magnitude of the differences between options than in the absolute figures of each option.

2.2.2 Presentation of Case Studies

■ 18 case studies were analysed, among which 4 include products awarded with a third party verified label. Up to 5 options are compared in each case study.

Case studies	One of the options correspond to a product awarded with a third party verified label[34]
♦ Personal Computer	✓
♦ Desktop Computer Display	
♦ Lamps	✓
♦ Car Fuels	
♦ Floor Covering	✓
♦ Road Paints	✓
♦ Liquid Packaging Systems	
♦ Space Heating	
♦ Energy Efficiency in buildings	
♦ Insulation Methods	
♦ Goods Transport	
♦ Passengers Transport	
♦ Table Cloths	
♦ Agricultural Systems	
♦ Car Pooling	
♦ Meeting	
♦ Flushing Systems	
♦ Plates	

[34] With available LCAs data

- The case studies were selected according to four main criteria:
  - products with relatively important environmental impacts,
  - products for which LCA data were available in the literature (no new calculation were expected at that stage),
  - some case studies had to correspond to products where substitution by services is possible,
  - some case studies had to include products awarded with a third party verified label (the choice of such case studies were limited by the fact that LCAs of labelled products have been carried out for only very few of all the product categories for which either an eco-label or another third party verified label exist[35]).

- The scope of each case study is described hereafter.

[35] And considering only the eco-labelling criteria (instead of a life cycle inventory) is not a solution given that many eco-labelling criteria do not refer to items quantified in a life cycle inventory (e.g. one of the textile eco-labelling criteria concerns acrylonitrile emission, which is not quantified in LCI.

Scope of the Case Studies

Case studies	Categories	Goal & Comments	Options compared					Functionnal unit	Main conclusion
Products with a third party verified label									
1	Personal computers	This study presents a LCA for a personal computer in order to establish the ecolabel criteria	different ways for disposal, reduction of energy consumption, extension of the life time in order to define the ecolabel criteria					10 personal computer	These studies demonstrate that LCA is an efficient instrument to analyse and assess the environmental performance of products through their entire life cycle, in order to identify weaknesses and to develop improvement strategies
2	Desktop computer display	Cooperative project among the Design for the Environment (DfE) Program in the Economics, Exposure, and Technology Division of the U.S. Environmental Protection Agency's (EPA) The DfE Computer Display Project (CDP) report provides a baseline analysis and the opportunity to use the model as a stepping stone for further analyses and improvement assessments for these technologies.	liquid crystal display	cathodes ray tubes				One desktop computer display over its lifespan	
3	Lamps	Rubrik &D'Haese were commissioned by the European Environmental Bureau (EEB) in Brussels to perform a study to frind ecolabeling criteria for lamps in general.	compact fluorescent	compact fluorescent with magnetic ballast	compact fluorescent with electronic ballast	incandescent lamp with electronic ballast		10 million lumen hour	
4	Car fuels	Most initiatives from Swiss parliament aim to promote ecological fuels with fiscal advantages. This study aims to give environmental profiles of different fuels for passengers and freigt transport.	diester	methanol and ethanol	natural gas	Liquid Petrol Gas	petrol and diesel	1 000 vehicle.km	
5	Floor covering	This summarises the study "Life Cycle Inventory with Life Cycle Analysis for Resilient Flooring Systems" for the European Resilient Floor Covering Manufacturers Institute". The purposes are to provide an overview of 32 floor covering systems, to focus on the different functionnal classes and the different material groups of floor coverings, and to concentrate on quantifiable, non locally relevant environmental impact potentials, for which accepted transformation rules from the life cycle inventory stage into an impact assessment stage exist.	linoleum	rubber polyolefin	PVC	cushioned PVC		1 000 m2 flooring over a period of 20 years	
6	Paints	This LCA makes a comparison between water paint and solvent based paint	water based paint	solvent based paint				100 m2 of road covered during 10 years	
7	Liquid packaging systems	This study presents a LCA comparing the potential environmental impacts associated with different existing or alternative packaging systems for beer and carbonated soft drinks that are filled and sold in Denmark.	Refillable packaging	Disposable packaging				Packaging and distribution of 1000 l of beverage	
Products with a particularly significant environmental impact									
8	Space heating	Analysis of 4 different energies in order to define the most environmental efficiency for space heating	heat from wood	heat from gas	heat from oil	heat from electricity		Energy consumption for space heating for one european during one year (calculated with 100 GJ)	LCA tool enables to increase the environmental performance of these product groups through the choice of the best alternative over the whole life cycle
9	Buildings	The LCA method is used in order to analyse a whole building and to identify its major environmental impacts, instead of analysing single elements within buildings or building materials itself.	5 houses with different energy efficiency, heating system and building materials					One semi-detached house over a life time of 80 years	
10	Insulation methods	This analysis intends to show the environmental benefit of using insulation and to compare different way to insulate a concrete wall with the same efficiency.	concrete	concrete+EPS	concrete+wood	concrete+mineral wood	concrete+particulate board	10 m2	
11	Goods transport	Analysis of different transport modes in order to define the most environmental efficiency for the goods transport.	rail	sea	inland waterway	road (truck)		1 000 tkm	
12	Passengers transport	This case study shows the advantages and drawbacks of personal car and different kinds of transport for passengers	car	bus	railway	air	water	10 000 pkm	
13	Tablecloths	Comparison between paper and textiles tablecloths	paper tablecloths	cotton tablecloths	cotton-EPS tablecloths	PES tablecloths		50 tables covered every day during 1 year	
14	Agriculture	The purpose of this LCA is to determine the differences in resource use and environmental impacts beween different systems with equivalent function: to provide 102 kg of protein with wheat	organic agriculture	integrated agriculture	intensive agriculture			Quantity of wheat containing 1000 kg of protein	
Product-service systems with an increasing degree of substitution of products by services									
15	Car pooling	This case intends to measure the environmental effect of increasing the use of car pooling.	Variant number of passengers in personal (1 to 3.5 pers/car)						These case studies show the environmental advantage of substitution of products by services
16	Meeting	What is the environmental benefit of using new technologies (Internet) for a meeting instead of travelling.	videoconference	train	plane			1 4h-conference in Brussels with 3 persons, 1 living in brussels and two living in Madrid	
Miscellaneous products									
17	Toilets rinsing	The study intends to analyse the advantages to use rain water for flushing systems from an environmental point of view	Conventional system	10% recovery of rain water	Economic system with drinkable water	10% recovery of rain water with economic flushing system	100% rain water recovery	The rinsing of 1 000 toilets	These case studies show that the use of renewable resources to substitute existing technics does not necessarily improve the environmental performance of the system under consideration
18	Plates	Comparison between paper and porcelain plates	paper plates	porcelain plates				100 000 meals	

2.2.3 Methodology

- A two-step methodology was elaborated:
  - Step 1: Environmental Relevance of Choosing Between Options – Micro-Economic Level,
  - Step 2: Environmental Relevance of Choosing Between Options – Macro-Economic Level.

- Step 1: Environmental Relevance of Choosing Between Options – Micro-Economic Level

This first step aims at assessing if the differences between the environmental impacts of various options providing the same function or service are significant or not.

For that purpose, various options are compared on the basis of a given functional unit:

- the environmental impacts of each option are first assessed,
- options are then compared and, for each major environmental impact assessed, the factor between the "worst" option and the "best" option is calculated (for instance, global warming generated by the "worst" option is 3 times higher than the "best" option).

These factors give an indication of the maximum micro-economic effect which can be expected when making choices between options in the category of products or services considered.

Caveats: the objective is not to identify if there is a "best" option (such an exercise would require to take into account pollution transfers which often exist when selecting one option among others) but to assess the level of relevance of the differences between options (are the differences significant or not?).

- Step 2: Environmental Relevance of Choosing Between Options – Macro-Economic Level

This second step aims at assessing if differences between the environmental impacts of various options which are significant at the micro-economic level are still significant at the macro-economic level, i.e. when considering the whole European economy.

Would the environmental benefits be significant at the European level if one of the option (the "best" one[36]) would be more developed that it is today?

To answer that question, two elements have to be taken into account:

- all the options are not similarly developed at the European level (for instance, space heating from gas is more developed that space heating from electricity or wood),
- the whole economy is constituted of many categories whose environmental impacts may "dilute" the environmental benefits of the option selected.

[36] at least for some of the environmental impacts considered

In order to attempt a quantification at the macro-economic level, two types of calculation are thus necessary:

- First, a sensitivity analysis has to be performed at the "category" level (the one the case study refers to).

  Options are no more considered individually but instead a mix of the options is assessed. One wants to analyse what the order of magnitude of the environmental benefits due to an evolution of this mix would be.

  The today "structure" of the category (i.e. the mix of the different options included in the category) is taken as a reference (this is the one assessed in the first phase of the study focusing on the categories).

  The mix of the options is then modified, for instance by increasing the proportion of the "best" option and the environmental benefits assessed as a difference between these two situations.

- Secondly, the analysis is performed at the European level.

  The environmental benefits assessed at the category level are compared to the environmental impacts of the entire European economy.

Remark: As far as the macro-economic analysis is concerned, it is of course relevant to be performed only for case studies where significant difference factors exist between options.

■ The quantification of the factors characterising the differences between options at the micro-economic level was performed for each of the case studies (see detailed figures in the appendix report and a synthesis on section 2.2.4.1 below).

As far as the macro-economic analysis is concerned, the quantification requires economic data (average European "consumption" of each option) and specific calculation which was not possible to carried out for all the case studies considering the limited resources of the study.

The quantification was performed for one of the case study, Space heating, whose difference factors between options are amongst the highest (when comparing with the other case studies) and which corresponds to one of the two categories (Building occupancy[37]) generating most of the environmental impacts linked to resources consumption and air emissions (i.e. the "dilution" phenomenon is the lowest one compared with the other case studies).

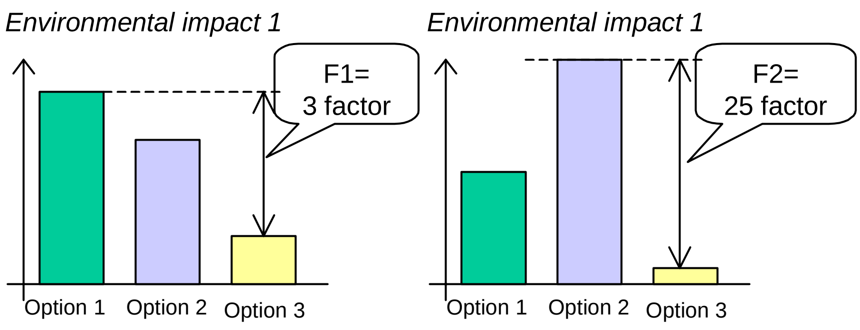
For the other case studies, a qualitative analysis is performed.

The results of the macro-economic analysis are given in section 2.2.4.2 below.

[37] the other one being Transport – see section 0 page 84

Micro level

Comparison between options for a same functional unit



➔ Are these difference factors (F1, F2…) significant?

Macro level

Sensitivity analysis on the mix of options

Hypotheses

Reference situation (option mix 1)		
Option 1	Option 2	Option 3
X %	Y %	Z %
Simulation (option mix 2)		
Option 1	Option 2	Option 3
X' %	Y' %	Z' %

Results

	Mix of options at the Eu level			Total all categories		
	Ref mix1	Simu mix2	Variation	with mix1	with mix2	Variation
Envtal impact 1	i1	i'1	%1	I1	I'1	%1
Envtal impact 2	i2	i'2	%2	I2	I'2	%2
…	…	…	…	…	…	…

➔ Are these variation % significant at the European level (first for the mix of options then for the entire European economy)?

2.2.4 Conclusion about Case Studies

2.2.4.1 Environmental Relevance of Choosing Between Options – Micro-Economic Level

- Detailed results are presented for each case study in an appendix report.

Example of Results for "Space heating" case study

Space Heating ***(4 options compared: Electricity vs. Petrol vs. Gas vs. Wood)***	**Factor between the option having the lowest environmental impact and the option having the highest environmental impact**
Primary Energy Consumption	3 [38]
Global Warming	275
Human Toxicity	520

Remark: the option having the lowest environmental impact ("best" option) and the one having the highest environmental impact ("worst" option) are not necessarily the same for each environmental impact (pollution transfers may exist – but as mentioned at the beginning of this section about case studies, the purpose of this analysis is not to determine which is the best option).

- The following table summarises the main results for all the case studies.

Repartition of the Case Studies according to the Level of the Differences between Options

	Factor between the option having the lowest environmental impact and the option having the highest environmental impact[39]			
	1.2 to 2[40]	2.1 to 10	11 to 100	101 to 1000
	- **Improvement potential** +			
Case Studies	▪ Personal computers*	▪ Screen computers ▪ Lamps* ▪ Floor coverings* ▪ Liquid packaging systems ▪ Car pooling ▪ Tablecloths ▪ Flushing systems	▪ Fuels for vehicles ▪ Road paint* ▪ Insulation ▪ Goods transport ▪ Passengers transport ▪ Agriculture ▪ Plates	▪ Space heating ▪ Meeting

38 i.e. the "worst" option has an impact 3 times higher than the "best" option for primary energy consumption

39 the highest factor reached for at least one environmental impact

40 i.e. the "worst" option has an impact 20% to 200% higher than the "best" option

Legend: the * indicates case studies including third party verified labelled products.

Reading of the table – Example for "Space heating" case study:
For at least one of the main environmental impacts considered, the difference between the "best" option and the "worst" option corresponds to a factor higher than 101 (and lower than 1000) (this is indeed the case for "primary energy consumption" and "global warming" as shown in the table above).

- Conclusions

- **For each case study, significant differences between options exist at a micro-economic level** (higher than 20% and up to more than a 100 factor), if not for all of the main environmental impacts considered (renewable resources, global warming, air acidification, photochemical oxidation, human toxicity), at least for some of them.
- The presence of labelled products does not differentiate the concerned case studies from the others.
- **The improvement potential is higher** (highest difference factors) **for space heating (thus building occupancy), meeting organisation (due to the possibility to avoid transport) and transport, but not only** since important difference factors exist also for several other cases (insulation, paints…).

2.2.4.2 Environmental Relevance of Choosing Between Options – Macro-Economic Level

- Quantification for "Space heating" case study

The sensitivity analysis focused on the mix of the different energy source options: electricity, petrol, gas and wood. The simulation performed consisted in increasing the proportion of wood (the "best" option for several environmental impacts[41]) to the detriment of fossil fuels ("wood scenario").

Mix used for space heating

Reference situation (the one assessed in the first phase of the study focusing on categories)				
	Electricity	**Petrol**	**Gas**	**Wood**
Domestic sector	8%	26%	56%	**10 %**
Commercial sector	10%	37%	50%	**1.5 %**
Sensitivity analysis (« wood scenario »)				
	Electricity	**Petrol**	**Gas**	**Wood**
Domestic sector	8%	17%	50%	**25%**
Commercial sector	8%	32%	50%	**10%**

[41] but not all

Results of the "Space heating" Sensitivity Analysis

		Domestic sector			Commercial sector			Total Building occupancy			TOTAL categories		
		Results corresponding to the reference situation	Results corresponding to the sensitivity analysis	Evolution from the reference situation	Results corresponding to the reference situation	Results corresponding to the sensitivity analysis	Evolution from the reference situation	Results corresponding to the reference situation	Results corresponding to the sensitivity analysis	Evolution from the reference situation	Results corresponding to the reference situation	Results corresponding to the sensitivity analysis	Evolution from the reference situation
A/ Environmental Impacts													
Linked to resources consumption													
Depletion of non renewable resources	kg antimony eq.	13.7	12.3	-10.0%	7.6	7.3	-3.6%	21.3	19.6	-7.8%	52.9	51.2	-3.1%
Linked to air emissions													
Greenhouse effect (direct, 100 yrs)	g CO_2 eq.	2.0E+06	1.8E+06	-10.5%	1.1E+06	1.1E+06	-3.9%	3.1E+06	2.9E+06	-8.2%	8.9E+06	8.6E+06	-2.9%
Stratospheric Ozone Depletion	g CFC-11 eq.	0.6	0.5	-19.0%	0.3	0.3	-8.0%	1.0	0.8	-15.3%	3.0	2.9	-4.9%
Air acidification	g SO_2 eq.	7.5E+03	7.4E+03	-1.1%	5.2E+03	5.1E+03	-2.1%	1.3E+04	1.3E+04	-1.5%	4.7E+04	4.7E+04	-0.4%
Photochemical oxidation	g ethylene eq.	1 145	1 088	-5.0%	624	607	-2.7%	1 768	1 695	-4.2%	15 139	15 066	-0.5%
Linked to water effluents													
Eutrophication	g PO4 eq.	64	84	31.0%	26	30	12.9%	91	114	25.8%	6859	6882	0.3%
Linked to human health													
Human Toxicity	g eq. 1-4-dichlorobenzene	3.7E+07	3.0E+07	-19.2%	1.8E+07	1.7E+07	-8.1%	5.5E+07	4.6E+07	-15.5%	4.9E+09	4.9E+09	-0.2%
Years of Life Lost	year	3.5E-04	3.7E-04	6.6%	2.3E-04	2.3E-04	0.2%	5.8E-04	6.0E-04	4.1%	2.50E-03	2.53E-03	0.9%
Linked to ecotoxicological risk													
Aquatic Ecotoxicity	g eq. 1-4-dichlorobenzene	7.3E+06	5.8E+06	-19.4%	3.6E+06	3.3E+06	-8.2%	1.1E+07	9.1E+06	-15.7%	8.8E+08	8.8E+08	-0.2%
Sediment Ecotoxicity	g eq. 1-4-dichlorobenzene	2.3E+07	1.9E+07	-19.4%	1.2E+07	1.1E+07	-8.2%	3.5E+07	2.9E+07	-15.7%	2.8E+09	2.8E+09	-0.2%
Terrestrial Ecotoxicity	g eq. 1-4-dichlorobenzene	7.1E+04	7.0E+04	-0.9%	5.5E+04	5.4E+04	-2.4%	1.3E+05	1.2E+05	-1.6%	3.2E+05	3.2E+05	-0.6%
B/ Other Environmental Indicators													
Primary energy	MJ	4.1E+04	4.0E+04	-0.9%	2.3E+04	2.3E+04	-1.0%	6.4E+04	6.3E+04	-0.9%	1.6E+05	1.6E+05	-0.4%
Fossil energy	MJ												
Consumption of raw materials	kg	1085.2	1181.7	8.9%	557.0	571.2	2.5%	1642.2	1752.8	6.7%	540896.3	541007.0	0.0%
Dusts	g	1361.9	1690.2	24.1%	781.1	827.0	5.9%	2143.1	2517.3	17.5%	6818.6	7192.8	5.5%
Dioxins	g												
Metals into air	g	268.4	268.9	0.2%	219.5	214.5	-2.3%	487.9	483.3	-0.9%	863.0	858.4	-0.5%
Metals into water	g	865.8	847.2	-2.1%	680.8	662.4	-2.7%	1546.6	1509.6	-2.4%	5435.9	5398.9	-0.7%
Metals into soil	g												
Municipal and industrial waste	kg												
Hazardous waste	kg												
Inert waste	kg												

Conclusion of the “Space heating” sensitivity analysis:

- A modification of the space heating options mix compared to the current situation may generate **significant evolutions of the environmental impacts generated by the Building Occupancy category**, up to about 15-20% for certain environmental impacts.
- **When considering the total environmental burden generated by the entire European economy** (total of all categories studied), these evolutions may **approximately** give **a 5% variation for some of the major environmental impacts.**

- The other case studies

Similar orders of magnitude can be expected for transport options since the first phase of the study showed that “Transport” category generates, with “Building occupancy” category, most of the environmental impacts linked to resources consumption and air emissions.

For the other case studies, the “dilution” phenomenon is much higher because they refer to categories whose contribution to the overall environmental burden at the European level is much lower.

2.2.5 Main Lessons from the Case Studies

- **Significant differences between options exist at a micro-economic level** (higher than 20% and up to more than a 100 factor for the case studies performed), if not for all of the main environmental impacts considered (renewable resources, global warming, air acidification, photochemical oxidation, human toxicity), at least for some of them.

- **The choice between various options corresponding to a given function can make a significant difference at the European level** (i.e. can provide significant environmental benefits – several percents) **for mainly two categories**:

- **goods and passengers transport** (in particular transportation means and type of fuels),
- **building occupancy** (in particular type of energy consumed and energy efficiency).

- **For the other categories**, options exist which provide significant environmental benefits at a micro-economic level, i.e. for a given functional unit. But these benefits are “diluted” when the whole European economy is considered.

However, **this dilution phenomenon does not prevent these choices between options from being important because when adding all these relatively minor environmental benefits, the decrease of environmental burdens becomes significant at the European level**, with an order of magnitude which can be, for certain environmental impacts, comparable to those of transport and building occupancy.

- The choice of eco-labelled products provide environmental benefits at a micro-economic level.

But because eco-labelling criteria existing today do not concern transport or building occupancy, it is only when they are added altogether that the environmental benefits due to eco-labelled products can become significant at the macro-economic level.

2.3 Limits of the Study and Further Research Work to be Performed

2.3.1 Product and Services Classification

In the domain of environmental policy, there is no standard approach to classify products and services consumed in the EU within a life cycle perspective (life cycle assessment is a tool which has been generally applied at a microeconomic level).

Existing official classifications present several drawbacks regarding the purpose of the study that did not allow us to use them directly, even the statistical classification of products by activity (CPA).

A new classification of products and services had then to be established:

- based on final products and services (not intermediary products) and focusing on major transversal activities / products / services,
- split into 13 families and 34 different categories covering most of the entire EU economy,
- generating few double counting.

We had to find a compromise between being exhaustive and life-cycle oriented. But the categorisation used in this study still presents some weaknesses (e.g. products or services consumed by businesses and administration are not very well covered) which will not be overcome without a standardisation work.

2.3.2 Environmental Impacts Assessment

Although the availability of LCA data has improved immensely over the last years, the proliferation of LCA data on the information market has lead to problems with data quality, comprehensiveness, comparability and equal distribution of LCA data. A solution to these problems would be a concerted European effort to establish a whole easily accessible LCA database of good quality.

Such a database would present the advantage to fulfil not only the need of this specific IPP issue but several others identified in other IPP areas (elaboration of environmental product declarations, development of eco-labelling criteria, eco-design, product-oriented environmental management system…) by improving the comparability of environmental information and facilitating access to LCA data with reduced cost, especially for SMEs but also for Member states and other interested parties.

It should also be reminded that some environmental impacts are not or poorly addressed by LCA, in particular toxicity and ecotoxicity issues, as well as other important impacts likely to generate high external costs (such as noise, odor, land disturbance…).

Specific means will have to be developed in parallel to be able to integrate these issues into the IPP approach.

2.3.3 Environmental Impacts Monetarisation (External Costs)

Monetarisation is a very specific and complex field of research where important works are still in progress. Some recent works are focusing on how to apply monetarisation methods in an LCA context (in particular the ExternE studies as well as the more recent Ecosit project).

In this study, we made no attempts to be exhaustive on that subject but it may be useful to mention that we encountered important difficulties linked to the lack of comprehensive and homogeneous external cost factors related either to inputs / outputs quantified in Life Cycle Inventory or to environmental impacts assessed from inputs / outputs quantified in Life Cycle Inventory[42].

On-going and further works will certainly help to address the following issues:

- The choice of the most relevant method to assess the external costs of products of services life cycle starting from LCA results, to be chosen between:
  - Method 1 - Monetarisation of inputs / outputs quantified in LC Inventories,
  - Method 2 - Monetarisation of environmental impacts assessed from LC Inventory inputs and outputs.
- The limits induced by the approach due to the fact that it combines potential global impacts (LCA) with actual location and source-specific external cost factors (monetarisation).
- The scope of the environmental impacts assessed in LCAs which are actually monetarised (e.g. eutrophication and depletion of non renewable energy are poorly monetarised).

Eventually, the development of a database of external cost factors applicable to LCI data (inputs and outputs occurring all along the life cycle of products and services) would be useful. The on-going DG Research RED project may give interesting inputs on that issue.

2.3.4 Environmental Taxes

The use of environmental taxes to assess the level of internalisation of external costs entails specific difficulties in such an LCA-based, macro-economic and European study, including:

- LCA-based study: a difficulty has to do with the lack of available tax data in a format compatible with LCA (tax data are necessary for inputs and outputs quantified in life cycle inventories).
- Macro-economic study: another difficulty is linked to existing exemptions and subsidies applying to some categories and some flows.
- European dimension of the study: the fact that environmental taxes vary according to the country requires a country-based analysis.

In this study, three countries were considered and, for each of them, a catalogue of taxes in a format compatible with LCA was established. Although this task required important efforts, the results are still improvable.

Besides, existing exemptions and variety of rates were taken into account through a range: the min corresponds to the minimum rates and the max corresponds to the maximum rates. And this range was applied to all the categories, without any distinction.

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[42] using impact factors

The next step would build a method to better take into account specific exemptions and subsidies applying to only some categories and flows. This work would require an important and dedicated research program.

2.3.5 IPP Indicators

In this study, which constitutes one of the pioneer works in the IPP field due to its large scope and ambitious objectives, IPP indicators were developed and tested (see section 2 – Results):

- two indicators to characterise the representativeness of the results (see section 1.2.2),
- several environmental indicators (see section 1.3.2.5),
- six key indicators about external costs and their internalisation (see section 1.3.4.2.3).

They only constitute a first attempt to define indicators allowing:

- to summarise the huge number of figures gathered in such a work,
- to help key actors in their decision-making process.

Further in-depth work is necessary to define more precisely relevant IPP indicators in order to satisfy decision-makers expectations and in the same time take into account the uncertainties which are still important for several basis data.

2.3.6 Temporal Dimension

The purpose of this study was a first description of the today's situation, which constituted a great challenge.

In view of defining an IPP policy, this can just constitute a starting point**.** A prospective evaluation, taking into account the possible evolutions of technologies in the mid term, will have to be integrated.

1 APPENDIX 1: SOME EXISTING CLASSIFICATIONS OF PRODUCTS / SERVICES OR ACTIVITIES

1.1 COICOP: CLASSIFICATION OF INDIVIDUAL CONSUMPTION BY PURPOSE

This is one of the 'reference classification'[43] in the family of international classifications.

01 - Food and non-alcoholic beverages

02 - Alcoholic beverages, tobacco and narcotics

03 - Clothing and footwear

04 - Housing, water, electricity, gas and other fuels

05 - Furnishings, household equipment and routine household maintenance

06 - Health

07 - Transport

08 - Communication

09 - Recreation and culture

10 - Education

11 - Restaurants and hotels

12 - Miscellaneous goods and services

1.2 CPA: STATISTICAL CLASSIFICATION OF PRODUCTS BY ACTIVITY IN THE EUROPEAN ECONOMIC COMMUNITY

A Products of agriculture, hunting and forestry

B Fish and other fishing products; services incidental to fishing

C Products from mining and quarrying

D Manufactured products

E Electrical energy, gas, steam and hot water

F Construction work

G Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods

H Hotel and restaurant services

I Transport, storage and communication services

[43] Reference Classifications are products of international agreements approved by the United Nations Statistical Commission.

J Financial intermediation services

K Real estate, renting and business services

L Public administration and defence services; compulsory social security services

M Education services

N Health and social work services

O Other community, social and personal services

P Private households with employed persons

Q Services provided by extra-territorial organisations and bodies

1.3 NACE: Statistical Classification of Economic Activities in the European Community

A Agriculture, hunting and forestry

B Fishing

C Mining and quarrying

D Manufacturing

E Electricity, gas and water supply

F Construction

G Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods

H Hotels and restaurants

I Transport, storage and communication

J Financial intermediation

K Real estate, renting and business activities

L Public administration and defence; compulsory social security

M Education

N Health and social work

O Other community, social and personal service activities

P Private households with employed persons

Q Extra-territorial organisations and bodies

1.4 SITC: STANDARD INTERNATIONAL TRADE CLASSIFICATION

This is one of the 'derived classification'[44] in the family of international classifications.

0 - Food and live animals

1 - Beverages and tobacco

2 - Crude materials, inedible, except fuels

3 - Mineral fuels, lubricants and related materials

4 - Animal and vegetable oils, fats and waxes

5 - Chemicals and related products, n.e.s.

6 - Manufactured goods classified chiefly by material

7 - Machinery and transport equipment

8 - Miscellaneous manufactured articles

9 - Commodities and transactions not classified elsewhere in the SITC

I - Gold, monetary

II - Gold coin and current coin

1.5 UNESCO BASIC HUMAN NEEDS

The UNESCO defines basic human needs as 'the minimum requirements for a decent standard of life: adequate food, shelter, clothing, community services. They also include needs relating to human rights, public participation in decision-making, productive employment.'

Basic needs listed by the UNESCO:

- Educational needs
- Food
- Housing needs
- Human development
- Human rights
- Living conditions
- Participatory development
- Poverty alleviation
- Quality of life

[44] Derived Classifications are based on Reference Classifications, but may be enlarged or rearranged.

2 APPENDIX 2: EXISTING METHODS TO MONETARISE EXTERNAL ENVIRONMENTAL IMPACTS

As existing monetarisation methods are dependent on their social and cultural references, we focused our attention on European studies, or, when European valuations were not available, on valuations made in the United States, Canada, or Australia, that are socially and culturally rather similar to European countries.

Five main[45] approaches to valuate environmental goods and services can be indicated. Two of them are based on the observation or evaluation of the expenditures related to environmental purposes. The three others are based on the measure of the willingness of consumers to pay for.

Principle of Some Main Environmental Impacts Monetary Valuation Methods

Method	***Principle***	***Type of data on which the method is based***
Preventive expenditures or **Avoiding costs method**	Observation of expenditures made in an attempt to avert damages from pollution (e.g. process fumes filters)	Expenditures observation or evaluation
Restoration costs or **Replacement costs method**	Observation of the cost of replacing or restoring a damaged environmental asset to its original state and use of this cost as a measure of the benefit of restoration	
Hedonic prices	The price of a marketed good (e.g. a house) is related to its characteristics or the service it provides (e.g. limiting the exposure to noise)	Measure of the willingness of consumers to pay for
Contingent valuation	Measure of how much people would be willing to pay for various reductions of environmental impacts	
Travel costs	People going to a leisure resort (e.g. a forest), achieve a trade-off between the satisfaction they get from using the leisure resort and the cost of the travel	

The Impact pathway approach (also called Dose-response or Damage costs approach) sits between life cycle assessment and valuation. It is based on the use of a damage functions to link an environmental alteration to its consequences (e.g. on health) and then the imputation of the costs of these consequences to the environmental damage. In particular contingent valuation, preventive and restorative expenditures provide the data that are used for valuation in the impact pathway approach.

[45] Other approaches exist, such as top-down approaches, which are not listed here.

2.1 Preventive Expenditures Method or Avoiding Cost Method

Principle: The method consists of an observation of expenditures made in an attempt to avert damages from pollution. This technique examines actual expenditures in order to determine the importance individuals, firms or state institutions attach to environmental and health impacts.

Hypothesis: There is no secondary benefits associated with the expenditures.

Uses: This method is limited to cases where households, firms or state authorities, spend money to offset environmental hazards, but these can be important (for example noise insulation expenditures, installation of catalytic convertors, improving safety measures against toxic chemical spills in storage, factory use, transportation, diverting a road out of a site of special environmental value). It has not been used to estimate non-use values though arguable that payments to some wildlife societies can be interpreted as insurance payments for conservation.

Method: Expenditures undertaken and designed to offset some environmental risk need to be identified and accounted. Technique needs to be managed by experts as significant econometric modelling is usually required.

Advantages: It is an easy way to evaluate the minimum costs of the environmental problems studied.

Drawbacks: Actual expenditures may be constrained by income or budget.

2.2 Restoration Costs Method or Replacement Costs Method

Principle: This technique looks at the cost of replacing or restoring a damaged environmental asset to its original state and uses this cost as a measure of the benefit of restoration. Information on replacement costs can be obtained from direct observation of actual spending (of individual, firm or state institutions) on restoring damaged assets or from professional estimates of what it costs to restore the asset.

Hypothesis: This method doesn't provide strict measure of economic values; instead, it assumes that the costs of restoring environmental goods or services provide useful estimates of the values of these environmental goods or services.

Uses: This approach is widely used because it is often relatively easy to find estimates of such costs. It is for example useful for estimating benefits of water quality.

Method: The first step is to assess the environmental services provided. The second step is to account the expenditures made to restore these services, or the expenditures people should make if they want to restore it (and then, expenditures are estimated, according to the costs of actions that are needed to restore it).
Advantages: It is easier to measure the costs of producing benefits than the benefits themselves when goods and services are non-marketed, as in the case of environmental goods. The method is not very data- and resource-intensive (so it is usually very inexpensive). It provides surrogate measures of value that are as consistent as possible with the economic concept of use value, for services which may be difficult to value by other means.

Drawbacks: The environmental goods or services being restored represent only a portion of the full range of benefits provided by the natural resource. Measuring costs thus only provides part of the target valuation.

2.3 DOSE-RESPONSE APPROACH OR IMPACT PATHWAY METHOD OR DAMAGE COSTS METHOD

Principle: This approach uses a damage function to link an environmental alteration to its consequences (on health for example), and imputes the costs of these consequences to the environmental damage.

Hypothesis: The consequences studied are really and only due to the environmental alteration.

Uses: This technique is used extensively where dose-response relationships between some cause of damage, such as pollution, and impacts are known. For example, it is used to look at the effect of pollution on health, physical depreciation of material assets such as metal and buildings, aquatic ecosystems, vegetation and soil erosion.

Method: The damage function is statistically estimated by relating series of pollution indicators with series of studied impact indicators, relating physical/biological changes in the ambient environment to the level of the cause of the change. A monetary value is then associated to this function, by assessing in monetary terms the impact indicators (using when necessary other methods). In particular, as one of the mainly used indicator is the number of deaths due to pollution, it is necessary to estimate the cost of these deaths (it is to say, the willingness to pay to save these lives). Many studies give different results for that cost, according to various methods to calculate it. Two main methods are used in studies. The first gives the value of statistical life (VSL); the ExternE reports use a European-wide value of 3,1 M€. The second method gives the value of cumulative reduction in lifetime expectancy, based on the value of a year of lost life (YOLL); the ExternE reports use 0,083 M€ for chronic mortality and 0,155 M€ for acute mortality.

Advantages: When individuals are unaware of the impact on utility of a change in environmental quality then direct valuation is an appropriate measure and so dose-response procedures, which do not rely on individuals preferences, can be used. And, if the damage functions already exist, this method can be very inexpensive, with low time demands and yet provide reasonable first approximations to the true economic value measures.

Drawbacks: The major limitation is related to the value of statistical life. Many techniques exist to estimate this value, giving very different results. Work is continuing in this area to explore how VOSL varies according to context.

2.4 HEDONIC PRICES METHOD

Principles: It supposes that the price of a marketed good is related to its characteristics, or the services it provides. If we take, for instance, the case of noise, it is clear that the degree of exposure to noise is an important component in the price of houses or flats.

Hypothesis: It is assumed that the context is perfect market, where people are completely aware of the linkages between the environmental attribute and benefits to them or their property, and have the opportunity to select the combination of features they prefer, given their income.

Uses: The method is most often used to value environmental amenities (such as aesthetic views or proximity to recreational sites) or environmental quality (air pollution, water pollution or noise) that affect the price of residential properties.

Method: The first step is to collect data on residential property sales (selling prices and locations, property characteristics, neighbourhood characteristics, accessibility characteristics and environmental characteristics). The second step is to statistically estimate a function that relates property values to the property characteristics. The resulting function measures the portion of the property price that is attributable to each characteristic.

Advantages: Estimated values are based on actual choices. Property records are typically very reliable. Data on property sales and characteristics are readily available through many sources. The method can be adapted to consider several possible interactions between market goods and environmental quality.

Drawbacks: High sensitivity to omission of variables or choice of non relevant variables. This method is limited to the set of environmental services that can be capitatured by residents through their choice of residential location. It is relatively complex to implement and interpret, requiring a high degree of statistical expertise. The results depend heavily on model specification.

2.5 TRAVEL COST METHOD

Principle: The idea is that people going to a leisure resort, such as a forest, achieve a trade-off between the satisfaction they get from using the leisure resort and the cost of the travel.

Hypothesis: Changes in the quantities consumed of a complementary market good, i.e. travel to the site, reflect the demand for nonmarket recreational services.

Uses: This method, akin to hedonic prices, is mostly used for the value of leisure resorts, in particular for the value of natural settings.

Method: First, a detailed sample survey is made at the entrance of the setting, about where the visitors come from, what means of transport they use, how often they come and possibly socio-cultural characteristics. The result is a frequenting rate, decreasing function of the travel costs. It is then assumed that people are indifferent between a travel costs rise and an entrance payment. By instituting fictitious entrance payments that are added to the travel costs, we can deduct a visit curve, function of the entrance payments, that is in reality the demand curve of the setting.

Advantages: The measured values are based on the actual choices of people. This method gives relatively reliable results; it is theoretically correct, but complicated where there are competing sites and multi-purpose trips.

Drawbacks: The visitor may make this travel in order to visit several settings; so, only a part of the travel costs might be attributable to the specific site. Visiting this setting may be the only activity proposed in the area, so people come to this setting, not really by choice, but because they have nothing to do instead.

2.6 CONTINGENT VALUATION METHOD

Principle: It consists in interviewing directly a sample of people to express how much they would be willing to pay for various reductions of environmental impacts.

Hypothesis: People express their actual willingness to pay.

Uses: many possible uses.

Method: The method involves setting up a carefully worded questionnaire which asks people their WTP and/or WTA through structured questions. Various forms of 'bidding game' can be devised involving 'yes/no' answers to questions and statements about maximum WTP. Resulting survey results need econometric analysis to derive mean values of WTP bids. Literature tends to suggest that most sensible results come from cases where respondents are familiar with the asset being 'valued'.

Advantages: Its flexibility which enables it to be applied to estimate use benefits associated with any one or all ecosystem services, as well as non-use benefits (so, with this method, we can also estimate non-use value, which is not possible with the others). It is a widely accepted method, because, among other reasons, people are directly consulted.

Drawbacks: The main limitation is that responses to hypothetical questions may not reflect what people would actually pay for the resource in a real economic or policy choice setting (strategic bias). There is also an information bias, due to the fact that individuals are not always well informed about the environment, and, as it is moreover unusual for them to evaluate the price of the environment, they may give figures that are not coherent with real choices (hypothetical bias).

3 APPENDIX 3: CHARACTERISATION FACTORS USED FOR ENVIRONMENTAL IMPACTS EVALUATION

Depletion of non renewable resources (kg antimony eq.)		
(r) Bauxite (Al2O3, ore)	kg	2.10E-09
(r) Chromium (Cr, in ore)	kg	8.58E-04
(r) Coal (in ground)	kg	1.34E-02
(r) Copper (Cu, in ore)	kg	2.20E-05
(r) Iron (Fe, in ore)	kg	8.43E-08
(r) Iron (Fe, ore)	kg	4.80E-08
(r) Lead (Pb, in ore)	kg	1.35E-02
(r) Lignite (in ground)	kg	6.71E-03
(r) Manganese (Mn, in ore)	kg	1.38E-05
(r) Natural Gas (in ground)	kg	1.87E-02
(r) Nickel (Ni, in ore)	kg	1.08E-04
(r) Oil (in ground)	kg	2.01E-02
(r) Phosphate Rock (in ground)	kg	8.44E-05
(r) Silver (Ag, in ore)	kg	1.84E+00
(r) Sulphur (S, in ground)	kg	3.58E-04
(r) Uranium (U, ore)	kg	2.87E-03
(r) Zinc (Zn, in ore)	kg	9.92E-04

IPCC-Greenhouse effect (g eq. CO2)				
		(direct, 100 years)	(direct, 20 years)	(direct, 500 years)
(a) Carbon Dioxide (CO2, fossil)	g	1	1	1
(a) Carbon Tetrafluoride (CF4)	g	5700	3900	8900
(a) CFC 11 (CFCl3)	g	4600	6300	1600
(a) CFC 114 (CF2ClCF2Cl)	g	9800	7500	8700
(a) CFC 12 (CCl2F2)	g	10600	10200	5200
(a) CFC 13 (CF3Cl)	g	14000	10000	16300
(a) Halon 1301 (CF3Br)	g	6900	7900	2700
(a) HCFC 22 (CHF2Cl)	g	1700	4800	540
(a) Methane (CH4)	g	23	62	7
(a) Nitrous Oxide (N2O)	g	296	275	156

CML-Stratospheric Ozone Depletion (g eq CFC11)		
(a) CFC 11 (CFCl3)	g	1
(a) CFC 114 (CF2ClCF2Cl)	g	0.85
(a) CFC 12 (CCl2F2)	g	0.82
(a) Halon 1301 (CF3Br)	g	12
(a) HCFC 22 (CHF2Cl)	g	0.034

Air Acidification (g SO2 eq.)		
(a) Ammonia (NH3)	g	1.6
(a) Nitrogen Oxides (NOx as NO2)	g	0.5
(a) Sulphur Oxides (SOx as SO2)	g	1.2

Photochemical oxidation (g ethylene eq.)		
(a) Acetaldehyde (CH3CHO)	g	0.65
(a) Acetic Acid (CH3COOH)	g	0.16
(a) Acetone (CH3COCH3)	g	0.18
(a) Acetylene (C2H2)	g	0.28
(a) Alcohol (unspecified)	g	0.44
(a) Aldehyde (unspecified)	g	0.75
(a) Alkane (unspecified)	g	0.6
(a) Alkene (unspecified)	g	0.91
(a) Aromatic Hydrocarbons (unspecified)	g	0.96
(a) Benzene (C6H6)	g	0.33
(a) Butane (n-C4H10)	g	0.6
(a) Butene (1-CH3CH2CHCH2)	g	1.13
(a) Carbon Monoxide (CO)	g	0.027
(a) Ethane (C2H6)	g	0.14
(a) Ethanol (C2H5OH)	g	0.45
(a) Ethyl Benzene (C6H5C2H5)	g	0.81
(a) Ethylene (C2H4)	g	1
(a) Formaldehyde (CH2O)	g	0.55
(a) Halogenated Hydrocarbons (unspecified)	g	0.11
(a) Heptane (C7H16)	g	0.77
(a) Hexane (C6H14)	g	0.65
(a) Hydrocarbons (except methane)	g	0.42
(a) Hydrocarbons (unspecified)	g	0.38
(a) Methane (CH4)	g	0.034
(a) Methanol (CH3OH)	g	0.21
(a) Nitrogen Oxides (NOx as NO2)	g	0.028
(a) Pentane (C5H12)	g	0.62
(a) Polycyclic Aromatic Hydrocarbons (PAH, unspecified)	g	0.96
(a) Propane (C3H8)	g	0.41
(a) Propionaldehyde (CH3CH2CHO)	g	0.75
(a) Sulphur Oxides (SOx as SO2)	g	0.048
(a) Toluene (C6H5CH3)	g	0.77
(a) VOC (Volatile Organic Compounds)	g	0.38

CML-Eutrophication (water) (g eq. PO4)		
(w) Ammonia (NH4+, NH3, as N)	g	0.35
(w) COD (Chemical Oxygen Demand)	g	0.022
(w) Nitrate (NO3-)	g	0.1
(w) Nitrite (NO2-)	g	0
(w) Nitrogenous Matter (Kjeldahl, as N)	g	0.42
(w) Nitrogenous Matter (unspecified, as N)	g	0.42
(w) Phosphates (PO4 3-, HPO4--, H2PO4-, H3PO4, as P)	g	1
(w) Phosphorus (P)	g	3.06
(w) Phosphorus Pentoxide (P2O5)	g	1.336

Problem oriented approach (CML, 1999) g 1,4-dichlorobenzene eq.					
		Aquatic ecotoxicity	Human toxicity	Sedimental ecotoxicity	Terrestrial ecotoxicity
(a) Ammonia (NH3)	g		1.00E-01		
(a) Antimony (Sb)	g	3.72E+00	6.71E+03	9.07E+00	6.11E-01
(a) AOX (Adsorbable Organic Halogens)	g	2.13E+06	1.93E+09	6.85E+06	1.20E+04
(a) Aromatic Hydrocarbons (unspecified)	g	8.37E-05	1.90E+03	6.36E-05	1.56E-05
(a) Arsenic (As)	g	4.95E+01	3.48E+05	1.27E+02	1.61E+03
(a) Barium (Ba)	g	4.28E+01	7.56E+02	9.68E+01	4.86E+00
(a) Benzene (C6H6)	g	8.37E-05	1.90E+03	6.36E-05	1.56E-05
(a) Benzo(a)pyrene (C20H12)	g	8.78E+01		2.52E+02	2.41E-01
(a) Beryllium (Be)	g	1.71E+04	2.27E+05	2.01E+04	1.77E+03
(a) Cadmium (Cd)	g	2.89E+02	1.45E+05	7.42E+02	8.12E+01
(a) Carbon Disulphide (CS2)	g	3.30E-02		2.70E-02	5.14E-03
(a) Chromium (Cr III, Cr VI)	g	1.92E+00		4.93E+00	3.03E+03
(a) Cobalt (Co)	g	6.39E+02	1.75E+04	1.06E+03	1.09E+02
(a) Copper (Cu)	g	2.22E+02	4.30E+03	5.55E+02	6.99E+00
(a) Dioxins (unspecified)	g	2.13E+06	1.93E+09	6.85E+06	1.20E+04
(a) Dust	g		8.20E-01		
(a) Ethyl Benzene (C6H5C2H5)	g	1.31E-04	9.73E-01	8.75E-05	1.43E-06
(a) Ethylene (C2H4)	g	1.43E-11	6.37E-01	8.98E-12	1.35E-12
(a) Formaldehyde (CH2O)	g	8.26E+00	8.31E-01	4.47E+00	9.40E-01
(a) Hydrogen Chloride (HCl)	g		5.00E-01		
(a) Hydrogen Fluoride (HF)	g	4.64E+00	2.85E+03	3.77E+00	2.95E-03
(a) Hydrogen Sulphide (H2S)	g		2.20E-01		
(a) Lead (Pb)	g	2.40E+00	4.67E+02	6.15E+00	1.57E+01
(a) Mercury (Hg)	g	3.17E+02	6.01E+03	8.12E+02	2.83E+04
(a) Metals (unspecified)	g	4.95E+01	6.01E+03	1.27E+02	1.61E+03
(a) Molybdenum (Mo)	g	9.73E+01	5.43E+03	2.15E+02	1.75E+01
(a) Nickel (Ni)	g	6.29E+02	3.50E+04	1.61E+03	1.16E+02
(a) Nitrogen Oxides (NOx as NO2)	g		1.20E+00		
(a) Particulates (unspecified)	g		8.20E-01		
(a) Phenol (C6H5OH)	g	1.52E+00	5.18E-01	5.61E-01	3.31E-03
(a) Polycyclic Aromatic Hydrocarbons (PAH, unspecified)	g	1.72E+02	5.72E+05	5.56E+02	1.02E+00
(a) Selenium (Se)	g	5.46E+02	4.77E+04	6.35E+02	5.35E+01
(a) Sulphur Oxides (SOx as SO2)	g		9.60E-02		
(a) Thallium (Tl)	g	1.55E+03	4.32E+05	3.93E+03	3.40E+02
(a) Tin (Sn)	g	2.54E+00	1.73E+00	1.30E+00	1.44E+01
(a) Toluene (C6H5CH3)	g	7.04E-05	3.27E-01	5.04E-05	1.59E-05
(a) Vanadium (V)	g	1.73E+03	6.24E+03	4.14E+03	6.65E+02
(a) Xylene (C6H4(CH3)2)	g	9.31E-05	1.25E-01	7.44E-05	1.27E-06
(a) Zinc (Zn)	g	1.78E+01	1.04E+02	4.56E+01	1.20E+01
(s) Arsenic (As)	g	1.34E+02	1.02E+03	3.44E+02	3.34E+03
(s) Cadmium (Cd)	g	7.76E+02	6.67E+01	1.99E+03	1.67E+02
(s) Chromium (Cr III, Cr VI)	g	5.25E+00	3.00E+02	1.35E+01	6.30E+03
(s) Cobalt (Co)	g	1.71E+03	5.91E+01	2.83E+03	2.23E+02
(s) Copper (Cu)	g	5.95E+02	1.25E+00	1.49E+03	1.44E+01
(s) Lead (Pb)	g	6.53E+00	2.93E+02	1.67E+01	3.25E+01
(s) Mercury (Hg)	g	8.48E+02	1.08E+03	2.17E+03	5.60E+04
(s) Nickel (Ni)	g	1.69E+03	1.98E+02	4.32E+03	2.39E+02
(s) Zinc (Zn)	g	4.77E+01	4.22E-01	1.22E+02	2.46E+01

Problem oriented approach (CML, 1999) g 1,4-dichlorobenzene eq.					
		Aquatic ecotoxicity	Human toxicity	Sedimental ecotoxicity	Terrestrial ecotoxicity
(w) AOX (Adsorbable Organic Halogens)	g	1.73E+08	8.58E+08	5.56E+08	5.87E+02
(w) Aromatic Hydrocarbons (unspecified)	g	9.14E-02	1.83E+03	6.95E-02	1.37E-05
(w) Arsenic (As3+, As5+)	g	2.07E+02	9.51E+02	5.29E+02	1.04E-17
(w) Barium (Ba++)	g	2.28E+02	6.30E+02	5.15E+02	5.08E-19
(w) Benzene (C6H6)	g	9.14E-02	1.83E+03	6.95E-02	1.37E-05
(w) Cadmium (Cd++)	g	1.52E+03	2.29E+01	3.90E+03	1.42E-20
(w) Chloroform (CHCl3, HC-20)	g	4.23E-02	1.25E+01	2.18E-02	3.92E-05
(w) Chromium (Cr III)	g	6.91E+00	2.05E+00	1.77E+01	2.27E-19
(w) Chromium (Cr III, Cr VI)	g	2.77E+01	2.05E+00	7.09E+01	2.27E-19
(w) Chromium (Cr VI)	g	2.77E+01	3.42E+00	7.09E+01	2.27E-19
(w) Cobalt (Co I, Co II, Co III)	g	3.41E+03	9.67E+01	5.64E+03	2.69E-18
(w) Copper (Cu+, Cu++)	g	1.16E+03	1.34E+00	2.90E+03	4.06E-21
(w) Ethyl Benzene (C6H5C2H5)	g	5.46E-01	8.27E-01	3.64E-01	1.19E-06
(w) Formaldehyde (CH2O)	g	2.81E+02	3.71E-02	1.52E+02	1.56E-03
(w) Lead (Pb++, Pb4+)	g	9.62E+00	1.23E+01	2.47E+01	4.77E-22
(w) Mercury (Hg+, Hg++)	g	1.72E+03	1.43E+03	4.40E+03	9.30E+02
(w) Metals (unspecified)	g	2.07E+02	1.43E+03	5.29E+02	1.04E-17
(w) Methylene Chloride (CH2Cl2, HC-130)	g	1.23E-02	1.84E+00	8.85E-03	3.90E-06
(w) Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	g	4.76E+02	5.51E+03	1.05E+03	2.31E-18
(w) Nickel (Ni++, Ni3+)	g	3.24E+03	3.31E+02	8.28E+03	1.03E-18
(w) Phenol (C6H5OH)	g	2.37E+02	4.92E-02	8.77E+01	2.49E-06
(w) Polycyclic Aromatic Hydrocarbons (PAH, unspecified)	g	2.75E+04	2.80E+05	8.92E+04	2.12E-03
(w) Selenium (Se II, Se IV, Se VI)	g	2.92E+03	5.60E+04	3.40E+03	1.55E-17
(w) Tetrachloroethylene (C2Cl4)	g	6.96E-01	5.72E+00	6.66E-01	7.94E-03
(w) Tin (Sn++, Sn4+)	g	1.02E+01	1.73E-02	5.20E+00	7.86E-22
(w) Toluene (C6H5CH3)	g	2.95E-01	3.03E-01	2.11E-01	1.42E-05
(w) Trichloroethane (1,1,1-CH3CCl3)	g	1.10E-01	1.62E+01	9.04E-02	1.75E-04
(w) Trichloroethylene (CCl2CHCl)	g	9.70E-02	3.35E+01	8.20E-02	4.59E-06
(w) Vanadium (V3+, V5+)	g	8.97E+03	3.16E+03	2.14E+04	1.02E-17
(w) Xylene (C6H4(CH3)2)	g	5.65E-01	4.25E-01	4.51E-01	1.17E-06
(w) Zinc (Zn++)	g	9.17E+01	5.84E-01	2.35E+02	2.53E-21

Years Of Lost Life		
(a) Dust	g	5.67E-08
(a) Hydrocarbons (except methane)	g	1.2E-09
(a) Hydrocarbons (unspecified)	g	1.2E-09
(a) Nitrogen Oxides (NOx as NO2)	g	4.49E-08
(a) Particulates (unspecified)	g	5.67E-08
(a) Sulphur Oxides (SOx as SO2)	g	3.02E-08
(a) VOC (Volatile Organic Compounds)	g	1.2E-09

Metals in air (g)		
(a) Aluminium (Al)	g	1
(a) Antimony (Sb)	g	1
(a) Cadmium (Cd)	g	1
(a) Chromium (Cr III, Cr VI)	g	1
(a) Cobalt (Co)	g	1
(a) Copper (Cu)	g	1
(a) Iron (Fe)	g	1
(a) Lanthanum (La)	g	1
(a) Lead (Pb)	g	1
(a) Manganese (Mn)	g	1
(a) Mercury (Hg)	g	1
(a) Metals (unspecified)	g	1
(a) Molybdenum (Mo)	g	1
(a) Nickel (Ni)	g	1
(a) Scandium (Sc)	g	1
(a) Thallium (Tl)	g	1
(a) Thorium (Th)	g	1
(a) Tin (Sn)	g	1
(a) Titanium (Ti)	g	1
(a) Uranium (U)	g	1
(a) Vanadium (V)	g	1
(a) Zinc (Zn)	g	1
(a) Zirconium (Zr)	g	1
Metals in soil		
(s) Aluminium (Al)	g	1
(s) Cadmium (Cd)	g	1
(s) Chromium (Cr III, Cr VI)	g	1
(s) Cobalt (Co)	g	1
(s) Copper (Cu)	g	1
(s) Iron (Fe)	g	1
(s) Lead (Pb)	g	1
(s) Manganese (Mn)	g	1
(s) Mercury (Hg)	g	1
(s) Nickel (Ni)	g	1
(s) Zinc (Zn)	g	1
Metals in water		
(w) Aluminium (Al3+)	g	1
(w) Aluminium Hydroxide (Al(OH)3)	g	1
(w) Arsenic (As3+, As5+)	g	1
(w) Cadmium (Cd++)	g	1
(w) Cerium (Ce++)	g	1
(w) Chromate (CrO4--)	g	1
(w) Chromium (Cr III)	g	1
(w) Chromium (Cr III, Cr VI)	g	1
(w) Chromium (Cr VI)	g	1
(w) Cobalt (Co I, Co II, Co III)	g	1
(w) Copper (Cu+, Cu++)	g	1
(w) Iron (Fe++, Fe3+)	g	1
(w) Lead (Pb++, Pb4+)	g	1
(w) Manganese (Mn II, Mn IV, Mn VII)	g	1
(w) Mercury (Hg+, Hg++)	g	1
(w) Metals (unspecified)	g	1
(w) Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	g	1
(w) Nickel (Ni++, Ni3+)	g	1

(w) Rubidium (Rb+)	g	1
(w) Silver (Ag+)	g	1
(w) Tin (Sn++, Sn4+)	g	1
(w) Titanium (Ti3+, Ti4+)	g	1
(w) Vanadium (V3+, V5+)	g	1
(w) Zinc (Zn++)	g	1

Hazardous waste		
Waste (hazardous)	kg	1
Waste: Slags and Ash (unspecified)	kg	1

Municipal waste		
Waste (incineration)	kg	1
Waste (municipal and industrial)	kg	1
Waste (unspecified)	kg	1
Waste (unspecified, to incineration)	kg	1
Waste: Non Mineral (inert)	kg	1
Waste: Non Toxic Chemicals (unspecified)	kg	1

Inert waste		
Waste: Mineral (inert)	kg	1

4 APPENDIX 4: BRIEF PRESENTATION OF THE MONETARISATION WORKS CONSIDERED IN THIS STUDIES

- **ExternE**

The ExternE project is the first comprehensive attempt to use a consistent 'bottom-up' methodology to evaluate the external costs associated with a range of different fuel cycles. The European Commission launched the project in collaboration with the US Department of Energy in 1991.

Impact assessment and valuation are performed using the « damage function » or « impact pathway » approach, assessing impacts in a logical manner, using the most appropriate models and data available. The applied methods include, among others, the use of simple statistical relationships (as in the case of occupational health effects), and the use of a series of complex models and databases (as in the cases of acid rain and global warming effects). In some cases, it has been possible to use market prices of goods and services to value a given impact (such as reduced crop yield, or reduced lifetime of paint on a building). In cases where the damaged good is not openly traded, such as human health or the aesthetic quality of a landscape, it has been necessary to use the results of alternative methods, such as contingent valuation or hedonic pricing.

The results of the ExternE project are available on http://externe.jrc.es.

- **Spadaro & Rabl (1999)**

Spadaro & Rabl (1999) use monetary valuations as an evaluation step for LCA. The impact pathway analysis is applied to evaluate the impact of a pollutant. More than 98% of the damage costs are due to health effects. In this study, the value assumed per YOLL (Years Of Lost Life) is 0,084 M€ for chronic mortality, 0,155 M€ for acute mortality. For the cost of a cancer, the authors assume 1,5 M€, averaged in ExternE over fatal and non fatal cancers (ExternE, 1998).

The results obtained by Spadaro & Rabl are presented in the following table:

Pollutant	Impact	External cost in €/kg of pollutant
PM2,5 (primary), cars, Paris	mortality and morbidity	2190
PM2,5 (primary), cars, Paris-Lyon	mortality and morbidity	159
PM2,5 (primary), cars, rural	mortality and morbidity	21,5
PM10 (primary)	mortality and morbidity	15,4
SO_2 (primary)	crops, material	0,3
SO_2 (primary)	mortality and morbidity	0,3
SO_2 (via sulfates)	mortality and morbidity	9,95
NO_2 (primary)	mortality and morbidity	small
NO_2 (via nitrates)	mortality and morbidity	14,5
NO_2 (via O_3)	mortality and morbidity	1,15
NO_2 (via O_3)	crops	0,35
VOC (via O_3)	crops, mortality and morbidity	0,9
CO (primary)	morbidity	0,002
As (primary)	cancer	171
Cd (primary)	cancer	20,9
Cr (primary)	cancer	140
Ni (primary)	cancer	2,87
dioxins, TEQ	cancer	18 500 000
CO_2	global warming	0,029

- **RDC-Environment & Pira International (2001)**

RDC Environment & Pira International (2001) is a study that aimed at evaluating costs and benefits for the achievement of reuse and recycling targets for the different packaging materials in the frame of the packaging and packaging waste directive 94/62/EC. The economic valuations was based on a variety of reports and documents. As far as possible, damage cost values were applied. However, when necessary, prevention costs were used.

The monetary values used by RDC & Pira are presented in the following table:

Impact	Unit	Valuation
GWP (kg CO_2 eq.)	€/kg CO_2	0,01344
Ozone depletion (kg CFC11 eq.)	€/kg CFC11	0,68
Acidification	€/kg H^+	8,70
Toxicity carcinogens (Cd equiv.)	€/kg cadmium (carcinogenic effects only)	22
Toxicity gaseous non carcinogens (SO_2 equiv.)	€/kg SO_2 from electricity production	1
Toxicity metals non carcinogens (Pb equiv.)	€/kg Pb	62
Toxicity particulates & aerosols (PM10 equiv.)	€/kg PM10 from electricity production	24
Smog (VOC)	€/kg VOC	0,73
Black smoke (kg dust equiv.)	€/kg smoke	0,66
Fertilisation	€/kg expressed as NO_2 mass equivalents	-0,7
Traffic accident (risk equiv.)	€/1000km travelled on an average road	17
Traffic congestion (car km equiv.)	€ per 1000 car km equivalents	86
Traffic noise (car km equiv.)	€ per 1000 car km equivalents	3
Water quality eutrophication (P equiv.)	€/kg P	4,7
Disamenity (kg LF waste equiv.)	€/kg waste in landfill	0,037

5 APPENDIX 5: EXTERNAL COST FACTORS USED IN EXISTING STUDIES FOR MONETARY VALUATION

5.1 CONVERSION OF ALL THE EXTERNAL COST FACTORS INTO A SINGLE CURRENCY

The currency we selected to give the data in is **euros of the year 2000**.

To obtain this same unit for all data, we proceeded according to the following stages:

- The data were converted in dollars of the same year, using the converter of the site http://www.oanda.com/converter at the date of 31/12 of the given year. For the data given in ECU (ExternE studies), we have used the conversion rate given in these studies: 1 ECU = 1.25 $ of 1995.
- In order to take into account inflation, we have had the dollar inflation table that gives as inflation conversion factors:

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2000	0.759	0.791	0.815	0.839	0.861	0.885	0.911	0.932	0.947	0.968

  Using this table, we converted the data in dollars of the year 2000.

- Finally, the data were converted in euro of the year 2000, using the conversion rate given by the previously quoted site at the date of 31/12/2000: 1 $ = 1.06202 e.

5.2 NON-EXHAUSTIVE LIST OF STUDIES IDENTIFIED PER IMPACT DOMAIN

Air Emissions - List of Studies

author (year)	***bibliography***	***source of emission studied***	***method used***	***scale of the study***
Study 1 (1998)	European Commission (Oct 2000)	incineration	health effects	
Coopers & Lybrand, CSERGE & EFTEC (1993)	European Commission (Oct 2000)	incineration and landfilling	health effects + other quantifiable effects	
CSERGE (1993)	European Commission (Oct 2000)	landfilling	based on Fankhauser	
ECON (1995)	European Commission (Oct 2000)	incineration and landfilling		
ETSU (1996)	European Commission (Oct 2000)	incineration	health effects + other quantifiable effects	
RDC & Pira (2001)	RDC-Environment & Pira International (2001)		damage cost estimates	
Eskeland (1994)	Rietbergen, McCracken & Abaza (2000)		benefits of air pollution control	Santiago, Chile
ExternE (1998)	ExternE (1998)		impact pathway method	
Johansson (1999)	Johansson (1999)		based on Swedish taxes	Sweden
ME3 (1997)	ME3 (1997)			Minnesota

Water Emissions - List of Studies

author (year)	***bibliography***	***source of emission studied***	***method used***	***scale of the study***
ECON (1995)	European Commission (Oct 2000)	landfilling	control cost methodology	
Johansson (1999)	Johansson (1999)		based on Swedish taxes	Sweden

Soil Emissions - - List of Studies

author (year)	***bibliography***	***source of emission studied***	***method used***	***scale of the study***
ECON (1995)	European Commission (Oct 2000)	landfilling	control cost methodology	

Waste - List of Studies

author (year)	***bibliography***	***method used***	***scale of the study***
CSERGE (1993)	European Commission (Oct 2000)		
Miranda & Hale (1997)	European Commission (Oct 2000)		
Cohen de Lara et Dron (1997)	Cohen de Lara et Dron (1997)		
European Commission (2000)	European Commission (2000)		
RDC & Pira (2001)	RDC-Environment & Pira International (2001)	damage cost estimates	

Energy - List of Studies

author (year)	***bibliography***	***method used***	***scale of the study***
Pearce (1993)	Pearce (1993)		USA
ExternE studies of UE countries (1997 or 1998)	ExternE	impact pathway method	countries of the UE

Noise - List of Studies

author (year)	***bibliography***	***method used***	***scale of the study***
Barde and Pearce (1991)	Barde and Pearce (1991)	noise reduction costs	Netherlands

Natural Resources - List of Studies

author (year)	bibliography	method used	scale of the study
Rietbergen, McCracken and Abaza (2000)	Rietbergen, McCracken and Abaza (2000)		
Swanson (1991)	Pearce (1993)		
Drake (1992)	Bateman & Willis (1999)	CV	Sweden
Western & Thresher (1973)	Pearce & Moran (1994)		
Fankhauser (1995)	No author (1995)		
Titus (1992)	No author (1995)		
Johansson (1999)	Johansson (1999)	based on Swedish taxes	Sweden
Titus et al (1991)	No author (1995)	based on US wetlands preservation programmes	US
Cline (1992)	No author (1995)		
Costanza et al (1989)	Pearce & Moran (1994)	CV	Louisiana
Bergstrom et al (1990)	Pearce & Moran (1994)		Louisiana
de Groot (1992)	Pearce & Moran (1994)		Galapagos
Posner et al (1981)	Pearce & Moran (1994)		Virgin Islands

5.3 How the External Cost Factors Used in this Study Were Selected / Build

5.3.1 Air Emissions

5.3.1.1 Global Warming Potential

Concerning the estimation of global warming, uncertainties exist both in terms of scientific studies and in terms of economic valuation. The most substantial variation is due to the assumed discount rate. While economists can estimate social discount rates for a single nation, the relevant discount rate for the world as a whole is much more difficult and controversial. Here, the choice was made to keep the estimation given in the ExternE project: **0.019 – 0.048 €/kg CO_2**. This is the illustrative restricted range of the recommended global warming damage estimates for use in the ExternE national implementation studies. It is composed of the base-case estimates for the 1 and 3 % discount rates.

5.3.1.2 Acidification Potential

In ExternE national implementation studies, estimates of the external effects of SO_2 emissions are calculated, giving an interval of 1.07 – 15.9 €/kg SO_2. But these estimates include all the environmental impacts of SO_2 emissions, and not only its impacts on acidification.

It was therefore decided to use the results of Spadaro & Rabl (1999) and RDC-Environment & Pira International (2001). As these authors estimated acidification effects on different targets, a combination has been made in order to have a whole estimate (impacts on crops, material, forests and lakes). The result is 0,350 €/kg SO_2.

In Spadaro & Rabl (1999), multipliers for variation with site (proximity of big city, local climatic conditions) and stack conditions (stack height, temperature, exhaust velocity) are proposed. For primary pollutants (such as SO_2 for its impacts on acidification), these multipliers are 0,5 to 5 for site, 0.6 to 3 for stack conditions. Applying the multipliers to the value of 0.350 €/kg SO_2, the obtained results are: **0.11 – 5.25 €/kg SO_2**

5.3.1.3 Ozone Depletion Potential

The only available estimate for ozone depletion potential is given by RDC-Environment & Pira International (2001) in CFC11 equivalent: **0.68 €/kg CFC11.** This is based on an estimated cost, associated with increased radiation, of 177 billion dollars and cumulative emissions of an estimated 200 billion kg and should be considered as very approximate. This value was derived by Pira International.

5.3.1.4 Tropospheric Ozone Creation

In LCA, the production of ozone in the troposphere is characterised in terms of ethylene equivalence. However, economic valuation of this impact is based on NOx emissions.

NOx, which also contributes to the formation of low level ozone, is given in a value equivalent to 1.19 kg ethylene eq./kg NOx in RDC-Environment & Pira International, 2001 and to 0.028 kg ethylene/kg NOx in CML, 2002.

Impacts on tropospheric ozone creation of NO_x emissions are estimated both within the framework of ExternE and in Spadaro & Rabl (1999). The results are quite the same: the first estimate is 1.56 €/kg NOx, the second one 1,5 €/kg NOx, distributed in 1,15 €/kg NOx from health impacts and 0,35 from impacts on crops.

In Spadaro & Rabl (1999), multipliers for variation with site and stack conditions are also given for secondary pollutants: 0,5 to 2,0.

The values considered are then:

	Min	Max
Cost factors for NOx (ExternE)	1.56 €/kg NOx	
Multipliers for variation with site and stack conditions (Spadaro & Rabl)	0.5	2
Cost factors for NOx including multipliers	1.56 x 0.5 = 0.78 €/kg NOx	1.56 x 2 = 3.12 €/kg NOx
Impact factors	0.028 kg ethylene eq./kg Nox (CML)	
Cost factors for Ethylene (result of the calculation)	0.78 / 0.028 = **0.279 €/kg ethylene**	3.12 / 0.028 = **111 €/kg ethylene**

5.3.1.5 Particles Emissions

Environmental impacts of particles emissions were estimated in the three studies. They were evaluated in the ExternE national implementation studies based on the impact pathway methodology and the ECOSENSE model; the interval of values is **1.39 – 59.3 €/kg particles**. This interval was kept for this study. Estimates of the other two studies are about the same range of values : 24 €/kg PM10 in

RDC-Environment & Pira International (2001), refered to damages to human health by emissions arising from production processes and electricity generation, and 15.4 €/kg PM10 in Spadaro & Rabl (1999), of which more than 95% of the damage costs are health impacts.

5.3.1.6 Dioxins Emissions

Impacts of dioxins emissions were monetarised in Spadaro & Rabl (1999), using the impact pathway method. The only impacts quantified were health impacts through cancers (for a population density of 80 persons/km^2). Non-inhalation pathways were taken into account in the calculation because dioxins are persistent and bioaccumulate, concentrated in milk, meat and fish. The estimate is nonetheless very uncertain and controversial. It is 18 500 000 €/kg TEQ, for all dioxins (as well as the closely related furans). A weak site variation exists, about 0.7 to 1.5.

The interval of monetary estimates for dioxins emissions is therefore: **12.95 E+06 – 27.75 E+06 €/kg TEQ.**

5.3.2 Water Emissions

5.3.2.1 Eutrophication Potential

Through the literature review, only one economic valuation is available on the eutrophication due to water emissions, in RDC-Environment & Pira International (2001). It is given in phosphor equivalent: **4.7 €/kg P**.

This value is based on the costs of increased abatement capacity at sewage or industrial plants necessary to reduce these emissions. It is derived from Gren et al. (1996).

5.3.2.2 Emissions of Waste Water

Not available.

5.3.3 Waste

An overview of all the external effects from landfill and incineration of municipal solid waste is provided in European Commission (2000), a study launched by the European Commission and conducted by COWI. Economic assessments used in this study were identified through a literature review. Environmental external effects of waste management were estimated, taking into account global warming contribution, air pollution, leachate impacts, and disamenity effects. These main externalities were quantified according to typical scenarios for landfill disposal and incineration of waste in terms of physical impacts and monetary values, for old obsolete and new modern waste disposal plants. The results were expressed in terms of a range of values, thus including the considerable uncertainty.

The values selected for the present study however only take into account one type of environmental impact, the disamenity effects, in order to prevent double counting in the final results.

landfill	incineration
6 - 19 €/t	**4 - 14 €/t**

Caveats: The long-term effects especially from landfill sites, are highly difficult to consider today, due to the mere fact that such sites have not existed for very long. These data are therefore to be taken with caution, according to the warning mentioned in that COWI study: "there is no easy and straightforward answer as to whether incineration or landfill disposal is preferable from the point of view of external effects".

5.3.4 Human Toxicity Due to Heavy Metals Emissions

Among the different heavy metals, arsenic, cadmium, chrome and nickel are considered to be carcinogenic. Their carcinogenic toxicity was evaluated in Spadaro & Rabl (1999), based on the impact pathway methodology. Only the inhalation dose were taken into account. The results are:

- Cd: 20.9 €/kg
- Cr VI: 140 €/kg
- Ni: 2.87 €/kg
- As: 171 €/kg

5.3.5 Summary of External Cost Factors Used in this Study

In the following table, the estimations proposed in this study are summarised (second column). In addition, the results found in a wider literature are included (third column), in order to show the considerable differences that can be found depending on the sites studied and the methods applied in the different existing monetarisation studies.

Impacts	**Values proposed in this study**	**Intervals of values from literature**	**Unit**
emissions to air			
global warming potential	0,019 – 0,048	0,00034 – 0,058	€/kg CO_2 equ.
acidification potential	0,11E-03 – 5,25E-03	0,35E-03 – 12E-03[46]	€/g SO_2 equ.
ozone depletion potential	0,68	0,68	€/kg CFC equ.
tropospheric ozone creation	0,66E-03 – 3,12E-03	1,35E-03 – 15,4E-03[47]	€/g ethylene equ.
emissions of particulates	1,39E-03 – 59,3E-03	9,5E-03 – 28,7E-03	€/g PM10
emission of dioxins	12,95 – 27,75	0,002 – 18,5	€/pg TEQ
emissions to water			
eutrophication potential	4,7	4,7	€/kg P equ.
waste			
landfilled waste	6 - 19	0 - 44	€/t
incinerated waste	4 - 14	10 - 124	€/t
human health			
human toxicity due to heavy metals emissions	Cd: 20,9 Cr VI: 140 Ni: 2,87 As: 171	Cd: 18,3 – 81,4 Cr VI: 123 – 819 Ni: 2,53 – 16,8 As: 150 - 999	€/kg Cd €/kg Cr VI €/kg Ni €/kg As

[46] This interval is to be taken with caution because impacts of SO_2 emissions were not only evaluated for acidification.

[47] Results for NO_x from literature were converted in g ethylene equivalent

Some remarks concerning the results:

There is substantial literature and research on the quantification and valuation of the impacts and conventional **air emissions** and their resulting damages. Valuation results in this field can thus be taken as fairly robust, although they are of course still subject to uncertainties. These uncertainties are reflected in wide ranges of estimates. Other air emissions such as dioxins are, however, quantified relatively rarely.

Concerning **water emissions**, very few attempts have been made to quantify and valuate their externalities. Pollution pathways of emissions to water are quite site specific (for example, largely dependent on groundwater reservoirs and receiving waters) and difficult to measure. Therefore, calculations on water externalities must be considered as highly uncertain.

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6 APPENDIX 6: ENVIRONMENTAL TAXES CONSIDERED FOR DENMARK, FRANCE AND POLAND

6.1 TAXES ON NATURAL RESOURCES EXTRACTION

6.1.1 Taxes on Aggregates

Such taxes are frequently discussed in the context of promoting recycling materials. A tax on the extraction of primary material is expected to make recycling economically more viable. Furthermore, the extraction rate of non-renewable resources has given rise to concerns, at different times, for the sustainability of dependence on resource extraction. The linkage to waste taxes is therefore clear. A further link is that the absence of taxes or regulation on mineral resource extraction will inevitably lead to the presence of "holes in the ground". Many countries are still dependent upon landfill as the principal means of waste disposal, and there are links between such dependence and the creation of void space for future landfilling. Taxes on mineral extraction can, therefore, have an indirect effect of waste disposal costs through tightening (in the longer-term) the supply of void space available for landfilling.

Source: ECOTEC, 2001

Denmark	France	Poland
0,67€/m^3 i.e. 1,12 €/t gravel	0,09€/t gravel	0

6.1.2 Taxes on Water Extraction

Extraction taxes are relatively rare in the EU member states, and where they exist, they often reflect administrative payments. Abstraction charges, other than administrative fees, have been used for several decades in France and Spain for the financing of river basin management. The charge revenues are used for water management and administrated by special purpose agencies in water management. More pure abstraction taxes with a fiscal function have been in operation at regional level in Germany, and they have been introduced recently at the national level in Denmark (1993) and the Netherlands (1995). The two recent tax schemes differ considerably in scope and effective tax rate. While the Dutch tax is relatively low, it does not exempt industry. The Danish tax is quite high, but applies to households and some service businesses only. Both taxes exempt agriculture.

source: ECOTEC 2001

Denmark	France	Poland
831€/1000m³	abstraction: 83€/1000m³ distribution: 21€/1000m³ (domestic use) 12€/1000m³ (industrial and agricultural use)	**surface water:** 17€/1000m³ (energy and heat production) 73€/1000m³ (other production) **groundwater:** 59€/1000m³ (production of food and medicines) 187€/1000m³ (other production) households and agriculture: 5,7€/1000m³

6.2 Taxes on Air Pollution

Air pollutants are a category of pollutants that give special cause for concern in the environmental field. The fact that they are unseen and unavoidable, allied to the fact that some are known to have impacts upon human health, makes it important to seek to minimise their effect.

Looking at the tax on NO_x emission, the systems vary significantly in various dimensions. It is however notable that the most striking difference is the level of the charge itself. The charge level in Sweden is very high (5430 €/ton) whereas the tax level in France is relatively low (45,73 €/ton). The overall conclusion in ECOTEC (2001) is that a high charge like the Swedish one is the only really effective way of getting a sizeable reduction in emissions.

Denmark	France	Poland
HFC, PFAC, SF_6: 26,2€/kg CFC: 4,03€/kg	SO_x: 38,11€/t HCl: 38,11€/t NO_x: 45,73€/t nitrogen oxide: 57,16€/t hydrocarbons, solvents…: 38,11€/t paid by power stations and waste incineration plants (capacity>20MW), and any production plant which emits more than 150t/year of any pollutant.	NO_x: 98,1€/t CH_4: 0,0001€/t CO: 27,3€/t aliphatic hydrocarbons: 27,3€/t arsenic: 69,5€/kg SO_2: 0,1€/t Mg: 4€/t molybdenum: 2,3€/t tin: 1€/t 1,1,1trichloroethane: 34,7€/t lead: 7,9€/t mercury: 34,7€/t asbestos: 69,5€/kg benzene: 1,59€/kg chromium: 9,93€/kg nickel: 69,5€/kg zinc: 1,04€/kg dioxins and furans: 69,5€/kg cadmium: 34,7€/kg cobalt: 9,93€/kg CO_2: 0,05€/t halon 1211, 1301, 2402 (ozone depleting substances): 34,7€/t

6.3 TAXES ON WATER POLLUTION

User charges for waste water treatment are applied in most EU member states, although with different degrees of cost-coverage. Several member states combine user charges with subsidies for sewage treatment, either from domestic sources or from the EU's structural funds. The waste water tax is a classical emission tax on a flow pollutant and was among the first economic instruments to be introduced in environmental policy. There are, as a result, some interesting lessons to be learnt over the relatively long timespan over which they have been in operation. A waste water tax scheme was introduced in France and in the Netherlands around 1970, while Germany followed suit with a scheme that took effect in 1981. Denmark recently introduced a waste water tax which took effect in 1997. In other member states, waste water taxes are applied at the regional level, such as in Flanders (Belgium) and in Italy and Spain.

Source: ECOTEC (2001)

Denmark	**France**	**Poland**
sewage discharge: 1,75€/m3 nitrate content: 2,68€/kg phosphate content: 14,8€/kg organic material content: 1,48€/kg exemptions: fish processing, cellulose and sugar beet industries (97% reduction), industries producing organic pigments, pectins or vitamins (70% reduction)	suspended materials: 26,2€/kg oxidizible materials: 61,9€/kg inhibitive materials: 1495€/k.equitox. soluble salts: 548€/mho reduced nitrogen (organic and ammoniac): 65,5€/kg total phosphorus: 55,9€/kg organo-halogenated adsorbed: 403€/kg metals and metalloids: 403€/kg	heavy metals: 11,2€/kg volatile phenol: 4,17€/kg total chloride and sulphate ions: 0,03€/kg suspended solids: 0,10€/kg food production: BOD5: 0,56€/kg COD: 0,37€/kg social institutions: BOD5: 0,22€/kg COD: 0,13€/kg chemical industry, energy/fuel production, steelworks, textile industry: BOD5: 2,22€/kg COD: 1,55€/kg timber/paper industry: BOD5: 0,95€/kg COD: 0,56€/kg

Other data are also used. All of the environmental taxes about water used in the study are summarised in the following tables.

		Denmark - min	Denmark - max	France - min	France - max	Poland - min	Poland - max
Flow	Units						
(w) Ammonia (NH4+, NH3, as N)	Euros/g	2,68E-03	2,68E-03	5,13E-02	5,13E-02	0,00E+00	0,00E+00
(w) Arsenic (As3+, As5+)	Euros/g	0,00E+00	0,00E+00	1,52E+00	1,52E+00	1,12E-02	1,12E-02
(w) BOD5 (Biochemical Oxygen Demand)	Euros/g	0	0	0,0187	0,0187	0,00022	0,00222
(w) Cadmium (Cd++)	Euros/g	0,00E+00	0,00E+00	7,60E+00	7,60E+00	1,12E-02	1,12E-02
(w) Chlorides (Cl-)	Euros/g					3,00E-05	3,00E-05
(w) Chromium (Cr III)	Euros/g	0,00E+00	0,00E+00	1,52E-01	1,52E-01	1,12E-02	1,12E-02
(w) Chromium (Cr III, Cr VI)	Euros/g	0,00E+00	0,00E+00	1,52E-01	1,52E-01	1,12E-02	1,12E-02
(w) Chromium (Cr VI)	Euros/g	0,00E+00	0,00E+00	1,52E-01	1,52E-01	1,12E-02	1,12E-02
(w) COD (Chemical Oxygen Demand)	Euros/g	0	0	0,0374	0,0374	0,0001	0,0016

(w) Dissolved Organic Carbon (DOC)	Euros/g	1,47E-03	1,47E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00
(w) Lead (Pb++, Pb4+)	Euros/g	0,00E+00	0,00E+00	1,52E+00	1,52E+00	1,12E-02	1,12E-02
(w) Mercury (Hg+, Hg++)	Euros/g	0,00E+00	0,00E+00	7,60E+00	7,60E+00	1,12E-02	1,12E-02
(w) Nickel (Ni++, Ni3+)	Euros/g	0,00E+00	0,00E+00	7,60E-01	7,60E-01	1,12E-02	1,12E-02
(w) Nitrate (NO3-)	Euros/g	2,68E-03	2,68E-03	5,13E-02	5,13E-02	0,00E+00	0,00E+00
(w) Nitrite (NO2-)	Euros/g	2,68E-03	2,68E-03	5,13E-02	5,13E-02	0,00E+00	0,00E+00
(w) Nitrogenous Matter (Kjeldahl, as N)	Euros/g	2,68E-03	2,68E-03	5,13E-02	5,13E-02	0,00E+00	0,00E+00
(w) Nitrogenous Matter (unspecified, as N)	Euros/g	2,68E-03	2,68E-03	5,13E-02	5,13E-02	0,00E+00	0,00E+00
(w) Organic Dissolved Matter (chlorinated)	Euros/g	1,47E-03	1,47E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00
(w) Organic Dissolved Matter (unspecified)	Euros/g	1,47E-03	1,47E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00
(w) Organic Matter (unspecified)	Euros/g	1,47E-03	1,47E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00
(w) Phenol (C6H5OH)	Euros/g					4,17E-03	4,17E-03
(w) Phosphates (PO4 3-, HPO4--, H2PO4-, H3PO4, as P)	Euros/g	1,47E-02	1,47E-02	1,96E-01	1,96E-01	0,00E+00	0,00E+00
(w) Phosphorus (P)	Euros/g	1,47E-02	1,47E-02	1,96E-01	1,96E-01	0,00E+00	0,00E+00
(w) Phosphorus Pentoxide (P2O5)	Euros/g	6,30E-03	6,30E-03	8,38E-02	8,38E-02	0,00E+00	0,00E+00
(w) Sulphate (SO4--)	Euros/g					3,00E-05	3,00E-05
(w) Water (unspecified)	Euros/litre	0,00157	0,00157	0,00124	0,00124	0	0
(w) Water: Chemically Polluted	Euros/litre	0,00157	0,00157	0,00124	0,00124	0	0
(w) Zinc (Zn++)	Euros/g	0,00E+00	0,00E+00	1,52E-01	1,52E-01	1,12E-02	1,12E-02

6.4 TAXES ON WASTE

EU legislation on waste, with the Waste Framework Directive as its basis, increasingly requires member states to move waste management up the so-called waste hierarchy, at the bottom of which is landfill. Different countries have taxes with differing scope. For example, Denmark (and Norway) apply a tax on waste which covers not only landfill but also incineration with or without energy recovery. Interestingly, no EU member state apart from Austria differentiates tax rates for landfills with and without gas collection for energy recovery. Other countries, such as the Netherlands, resort to bans on the landfilling of specific waste streams. Landfilling of municipal waste is banned other than in exceptional circumstances.

Source: ECOTEC (2001)

Denmark	France	Poland
Hazardous waste: 34-6710€/t Municipal waste: 185€/household/year Landfill: 50,3€/t Incineration: 44,3€/t	Landfill: - domestic waste and assimilated: 11,44€/t - special industrial waste: 18,3€/t Incineration: - special industrial waste: 9,15€/t	Industrial waste in landfill: - low risk category: 2,13€/t - medium risk category: 3,30€/t - high risk category: 27,7€/t

6.5 TAXES ON ENERGY PRODUCTS

6.5.1 Taxes on Motor Fuels

All European countries levy one or more taxes on motor vehicle fuels, but the tax rates applied vary between countries and between fuels. Except from few countries, the tax rates for diesel are always lower than for petrol, in many cases the difference is very substantial, which is counterproductive from an environmental point of view.

6.5.2 Taxes on Heating Fuels

Fuels are taxed less heavily when they are used for heating than when they are used for transport.

(in €)

product	**Denmark**	**France**	**average for all the member states (with interval)**	**Poland**
motor fuels				
unleaded petrol (1000l)	518	586	489 (325-782)	390
leaded petrol (1000l)	606	627	554 (344-876)	430
diesel (1000l)	346	367	347 (246-766)	280
LPG (1000kg)	393	107	213 (0-795)	70
kerosene (1000l)	350	366	372 (245-759)	-
natural gas (GJ)	9,8	0	0, except for Denmark	-
heating purposes				
gasoil (1000l)	268	78	105 (5-403)	fuel oils: 40€/1000l
mazout lourd (1000kg)	304	23	60 (6-304)	
kerosene (1000l)	263	78	120 (0-337)	
LPG (1000kg)	333	0	114 (7-333) for 9 countries 0 for the others	
natural gas (GJ)	0,98	0	1,5 (0,3-5,74) for 7 countries 0 for the others	
solid energy products (GJ)	7,1	0	2,2 (0,4-7,1) for 5 countries 0 for the others	
electricity (MWh)	14	6,4	9,87 (0-50)	

Source: European Environment Agency (2000), calculations made according to European Commission and OECD reports. Data for Poland are based on the OECD database.

6.6 TAXES ON TRANSPORT

According to IPCC (1999), emissions from aircraft represent about 40% of total emissions at high altitudes. Because of special circumstances in the atmosphere upper strata, aircrafts contribute to global warming two to four times more than a same level of emission in the troposphere.

	Denmark	**France**	**Poland**
private cars	petrol private car: 1044€/year diesel private car: 1340€/year (based on fuel consumption)	-	-
buses	petrol buses: 261€/year diesel buses: 395€/year (based on weight)	-	-
heavy good vehicles	284€/year (based on weight and axles) road user charge: 1123€	-	-
air transport	7,5€/passenger	5€/t aircraft	

6.7 SPECIFIC TAXES IN THE AGRICULTURAL SECTOR

Taxes in the agricultural sector are still not very common in EU member States and are restricted to Scandinavian countries plus the Netherlands and Belgium.

6.7.1 Taxes on Pesticides

The environmental problems associated with the use of pesticides are widely discussed. Pesticides, however, are an extremely heterogeneous group of products. The unit upon which the tax is based varies in the design of the taxes. Different countries use taxes levied on dose, on kg of active ingredient and AVT. There is still much dispute around which of these constitutes the best base for taxes. Taxes on pesticides are yet applied in six countries: Belgium (not in agriculture), Denmark, Finland, France, Norway and Sweden. It is discussed in the Netherlands.

Sources: ECOTEC (2001) and European Environment Agency (2000)

6.7.2 Taxes on Fertilisers

These taxes are little used or were abandoned by countries when joining the EU, as was the case for Austria and Finland. Again a forerunner in terms of new taxes is Denmark, which introduced a tax on growth promoters in 1998. Denmark increased the tax rates levied on agricultural inputs over the period 1997-2000. According to a report by the European Fertilisers Manufacturers' Association, the reduction in fertiliser use has been significant in the Netherlands and in Denmark. Both countries have large intensive rearing sectors and have implemented economic instruments in the agricultural sector

Source: ECOTEC (2001)

	Denmark	France	Poland
pesticides	average 37% of retail price excl.VAT (1998)	0-1677 €/t	-
artificial fertilisers used by households	0,67€/kg	-	-
antibiotics and growth promoters	0,16€/g of hazardous chemical	-	-

6.8 TAXES ON SPECIFIC PRODUCTS

Products become waste at the end of their life. Implementing taxes on products permits therefore to act upstream on waste management. It is in particular the case for packaging, which are produced and consumed in important quantities, and batteries, which become hazardous waste. The complementary instruments are important elements of the overall environmental strategy concerning packaging and batteries waste (deposit systems, recycling systems, …). A variety of different schemes have emerged to deal with these materials.

	Denmark	France	Poland
packaging	glass containers for drinks: 0,20€/item cardboard containers for drinks: 0,12€/item containers for other products: made of glass and ceramics = 0,25€/kg made of aluminium: 4,47€/kg made of wood: 0,07€/kg made of EPS and PVC: 2,73€/kg made of paper and cardboard: 0,10€/kg made of steel and tinplate: 1,12€/kg made of plastics, except EPS and PVC: 1,30€/kg	0,3ct €/unit of packaging	made of PP or PE: 10% made of PC, PS and PET: 20%
oil products and lubricants		38,11€/t	
washings		79,3€/t	
batteries	2,42€/unit sealed NiCd batteries: 0,81€/cell		
carrier bags	made of paper: 1,34€/kg made of plastics: 2,95€/kg		
chlorinated solvents	0,27€/kg hazardous substance		
disposable tableware	2,58€/kg		

	Denmark	**France**	**Poland**
electric bulbs and electric fuses	0,5 €/piece		
PVC and phthalates	0,23 €/kg		
tyres	0,8 €/tyre		

7 APPENDIX 7: DETAILED RESULTS PER PRODUCT OR SERVICE CATEGORY

Cf appendix report.

8 APPENDIX 8: DETAILED CASE STUDIES

Cf appendix report.