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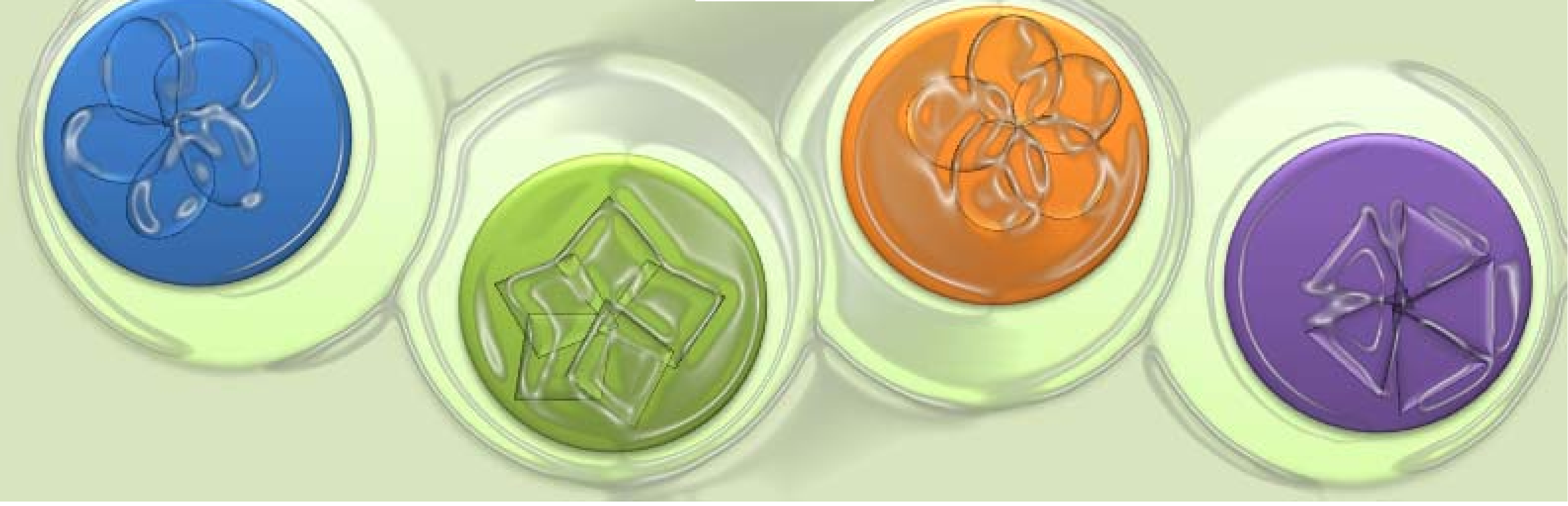

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Life cycle indicators for resources, products and waste

RESOURCES, RESOURCE-EFFICIENCY, DECOUPLING

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Life cycle indicators for resources

DEVELOPMENT OF LIFE CYCLE BASED MACRO-LEVEL MONITORING INDICATORS FOR RESOURCES, PRODUCTS AND WASTE FOR THE EU-27

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AUTHORS AND ACKNOWLEDGEMENTS

This report contributes to the development of the resource life cycle indicators. These indicators are intended to be used to assess the environmental impact of European resource consumption, efficiency of the use of natural resources, and decoupling of environmental impacts from economic growth.

The work was carried out over many years and with contributions from many people:

- The authors of the original idea for life cycle indicators were Marc-Andree Wolf and David Pennington (European Commission, DG Joint Research Centre).
- Project leaders were Ugo Pretato (2009) and Małgorzata Góralczyk (2010-2011).
- The report was written by a team of consultants: Sven Lundie, Alexander Stoffregen, Neil D'Souza, Jeff Vickers (PE International), Helmut Schütz, Mathieu Saurat (Wuppertal Institute for Climate, Environment, Energy).
- The weighting scheme was developed by Gjalt Huppes and Lauran van Oers (Institute of Environmental Sciences (CML) of Leiden University).
- Contributors to this report were Małgorzata Góralczyk, Marc-Andree Wolf, David Pennington, Ugo Pretato and Camillo de Camillis (European Commission, DG Joint Research Centre).
- Comments and scientific advice were provided by Stephan Moll and Julio Cabeca (European Commission, DG Eurostat).
- Comments were provided by Stefan Bringezu (Wuppertal Institute for Climate, Environment, Energy).
- The leading editor of this report was Małgorzata Góralczyk (European Commission, DG Joint Research Centre).

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DISCLAIMER

EXECUTIVE SUMMARY

OVERVIEW

The purpose of resource indicators is to track the overall environmental impact of the European Union (EU-27), and ultimately of each Member State, in relation to resource consumption and economic growth. This type of eco-efficiency indicators is supported by a set of sub-indicators.

The significance and expected applicability of the identified resource indicators in the context of policy development, implementation and monitoring are as follows:

- The eco-efficiency indicator allows monitoring the decoupling of economic growth from the overall environmental impact associated with apparent prevalent consumption levels and related use of natural resources.
- Sub-indicators allow addressing more specific questions. This includes, among others:
  - evaluating the significance of international impact shifting via trade, and monitoring the development of impacts with regard to distinct environmental problems such as climate change, acidification, ecotoxic impacts, energy resource depletion, and others;
  - understanding where burdens are shifted to by looking at specific imported products and relevant countries of production; and
  - assessing the success of specific policies by monitoring distinct pressures (e.g. individual emissions, extractions of specific materials), indicating whether specific policies on these have been successful.

The general framework and methodology for the calculation of the resource indicators is presented in the indicators framework (JRC, 2012a). Here, we explain how to calculate the resource indicators and describe the underlying data. We also present first results and observed constraints regarding data availability and precision. We present data sources, content and the structure used for the calculation of the resource indicators. The inventories have been developed for the EU-27 as well as initially for one Member State (Germany). They include data on emissions to air, water and soil; metals; minerals; water; various renewable and non-renewable energy resources; and land use (chapter 2). The inventories have been developed for years: 2004-2006.

METHODOLOGY

External trade statistics have been used in a systematic manner to select the 15 most important imported and exported product groups and suitable representative products. Imports are differentiated for each product by the three most relevant trade partners (see chapter 3 for details).

Emissions associated with imports and exports can have an important influence on the overall impacts associated with the apparent consumption[1] for both the EU-27 and Germany; results demonstrate this at the level of (1) inventory for emissions and (2) general impact assessment.

In the EU-27, environmental impacts associated with imports exceed those associated with the exports for most of the investigated impact categories. Hence, the impacts associated with the apparent consumption are higher than the domestic impacts alone. For Germany however, the opposite is the case for most of the impact categories, given the country's large trade surplus.

Eco-efficiency indicators suggest relative (e.g. with regard to climate change and acidification) and absolute decoupling (e.g. photochemical ozone formation). For the EU-27 in particular, the indicators

[1] Apparent consumption = domestic production plus imports minus exports.

are considered to provide reliable and meaningful results for the following impact categories: climate change, particulate matter/respiratory inorganics, photochemical ozone formation, acidification, terrestrial and marine eutrophication, as well as freshwater ecotoxicity.

RECOMMENDATIONS FOR IMPROVEMENT OF THE APPROACH AND DATA

Looking at the preliminary indicator results, the trends over time are strongly influenced by fluctuations in the volume of trade for the 15 selected product groups (due to economic cycles).

At the same time, most of the observed variations in emissions and impacts appear to be specifically linked to individual imported and exported product groups. We foresee that these distorting fluctuations may be reduced by (1) increasing the number of selected representative products for the products groups with the largest impact contributions and/or high heterogeneity, as well as (2) increasing the total number of product groups considered. The latter is especially relevant for extending the framework to all Member States.

In addition, emissions and resource consumption data for supply chains (life cycle inventory) of the traded products should be made country-specific where possible, also with regard to the EU-27 Member States. For products imported from non-EU-27 countries, such inventory data currently used are conservative, i.e. they might underestimate differences in production in the EU-27 and abroad. Further improvement of the country specific inventory data for non-EU-27 countries is expected to reveal the real extent to which burdens are shifted abroad.

In terms of statistics, additional domestic data are required, especially on a number of emissions types and on water use. Alternative statistical sources could be used to complement the official statistics; as an alternative approach to generate required domestic data, a bottom-up calculation by expanding and adjusting the separate basket-of-products indicators should be considered.

Finally, some inconsistencies between domestic inventories and life cycle inventories used for import/export should be overcome (e.g. the intake of heavy metals as micronutrient by biomass is considered in life cycle inventory but not in the domestic inventory).

CONCLUSIONS

Altogether, the development of the life cycle based resource indicators is a significant improvement for the monitoring of environmental impacts for entire economies and regions, giving due consideration to burden-shifting occurring through trade. Key improvements on previously available indicators are:

- comprehensive coverage of the most important resource uses and environmental pressures
- capturing the potential impacts of resource uses and related pressures on the natural environment (including biodiversity), human health, and resource availability (covering both fossil and renewable resources, including land productivity)
- applying a full life cycle approach for the entire production and consumption
- inclusion of burden shifting between countries, i.e. yielding both a territorial and a consumption-based set of indicators
- increased transparency and ability to analyse contributions to emissions and resource consumption.

The proposed indicators provide, already in their first calculations, a very useful tool to assess the decoupling of economic growth and environmental impacts.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TERMS AND ABBREVIATIONS

Term	Explanation
AP	Acidification Potential
BGS	British Geological Survey
CLRTAP	Convention on Long-range Transboundary Air Pollution
CML	Institute of Environmental Science of the University of Leiden
CRF	Common Reporting Framework
DMC	Domestic Material Consumption
EEA	European Environment Agency
ELCD	European Reference Life Cycle Database
Elementary flow	Resource or emission, but also other intervention with the ecosphere such as land use
EoL	End of Life
EPER	European Pollutant Emission Register
E-PRTR	European Pollutant Release and Transfer Register
EU-27	European Union *(27 Member States)*
EUREAU	European association of water supply and waste water treatment
FAO	Food and Agriculture Organization
FAOSTAT	FAO Statistical Database
GDP	Gross Domestic Product
LCA	Life Cycle Assessment
LCI **Life cycle inventory**	Emissions and resource extraction profiles of goods and services, i.e. list of all physical exchanges with the environment: inputs (resources, materials, land use and energy), and outputs (emissions to air, water and soil)
LCIA	Life Cycle Impact Assessment
LTAA	Long term annual average
LU	Land Use
LUC	Land Use Change
MFA	Material Flow Analysis
NIR	National Inventory Reports
NPRI	Canadian National Pollutant Release Inventory
NMVOC	Non Methane Volatile Organic Compounds
ODS	Ozone Depleting Substances
PRTR	Pollutant Release and Transfer Register
RBD	River Basin District
TRI	Toxic Release Inventory
UNEP	United Nations Environment Programme
UNSD	United Nations Statistics Division
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey
WEI	Water Exploitation Index

1 INTRODUCTION

1.1 POLICY CONTEXT

Sustainable development[2] is an underlying objective of the European Union treaties. To effectively steer the European economy towards sustainable development, it is necessary to monitor progress towards it. This message appeared as early as in the Thematic Strategy on the sustainable use of natural resources (EC, 2005a) and has been carried along subsequent policy development, up to the recent Europe 2020 strategy (EC, 2010a). This strategy calls for seven flagship initiatives; the most relevant being A resource-efficient Europe (EC, 2011a) to help decouple economic growth from the use of resources, support the shift towards a low carbon economy, increase the use of renewable energy sources, modernise our transport sector and promote energy efficiency.

Indicators supporting recent environmental policy developments, such as the resource efficiency agenda of the Europe 2020 strategy, need to take an integrated view of the links between consumption and production, as well as the resource use, environmental impacts and waste generation. These requirements are further reinforced by the Roadmap to a Resource Efficient Europe (EC, 2011b), that explicitly mentions such indicators:

> *[…] Because this provisional lead indicator[3] only gives a partial picture, it should be complemented by a 'dashboard' of indicators on water, land, materials and carbon and indicators that measure environmental impacts and our natural capital or ecosystems as well as seeking to take into account the global aspects of EU consumption .[…]*

The life cycle indicators assess the environmental impact of the European consumption, production and waste management, including impacts that relate to European demand for goods and services produced outside of the European Union. Therefore, they are a timely response to the needs expressed in the recent environmental policy documents. The development of the life cycle indicators was the result of the process that started with the identification of the need for such indicators during the 3rd International Life Cycle Thinking Workshop, organised by the JRC in Cyprus in January 2007 (Koneczny et al., 2007). At that time, three key policies required indicators for monitoring of the sustainable development in Europe:

1) Resource indicators: the Thematic strategy on the sustainable use of natural resources (EC, 2005a) required resource indicators and identified several key points that these indicators should address:

   a. natural resources are *"[…] used to make products or as sinks that absorb emissions (soil, air and water)[…]"*

   b. consideration of the entire life cycle: *"it is necessary to develop means to identify the negative environmental impacts of the use of materials and energy throughout life cycles (often referred to as the cradle to grave approach) and to determine their respective significance"*

   c. shifting of environmental burden in a globalised economy

   The strategy goes as far as to outline a set of three resource impact indicators monitoring

[2] Sustainable development definition is adopted after the well-known definition of World Commission on Environment and Development (1987): "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". (EC, 2001)

[3] Domestic Material Consumption (DMC)

resource productivity, resource-specific impacts, and overall eco-efficiency. The strategy states also the definition of resources that was late carried to the succeeding strategies and policies, and therefore creating the background for the development of indicators:

[…] natural resources, including raw materials such as minerals, biomass and biological resources; environmental media such as air, water and soil; flow resources such as wind, geothermal, tidal and solar energy; and space (land area). Whether the resources are used to make products or as sinks that absorb emissions (soil, air and water), they are crucial to the functioning of the economy and to our quality of life. […]

2) Basket-of-products indicators: according to the Integrated Product Policy (EC, 2003a) the consumption of goods and services (products) is the driver for resource use, resource consumption and depletion, waste generation, and environmental impacts in the EU-27. In addition, it contributes—through trade—to impacts that occur outside of the EU-27. The policy stresses the necessity to consider the full life cycle of products when assessing their environmental performance.

3) Waste management indicators: Thematic strategy on the prevention and recycling of waste (EC, 2005b) addresses the end-of-life stage of products' life cycles. It also highlights the importance of life cycle thinking. Environmental pressures and resource consumption caused by the generation and management of waste can be reduced through waste prevention. If treated, generated waste can yield secondary resources (including energy), and the availability of secondary resources can prevent the use of primary resources (and the related environmental impacts).

1.2 METHODOLOGICAL ASSUMPTIONS

This report outlines the calculation of the resource indicators, including an eco-efficiency indicator. Together, these indicators form one of the three indicator sets (completed by the basket-of-products indicators, and the waste indicators) designed to measure progress against sustainable development in the EU-27.

The resource life cycle indicators were developed for the EU-27 and, as a first example, for one Member State (Germany). The resource indicators have been developed for a baseline year (2004) and two additional years (2005 and 2006). The year 2004 was selected at the time when the project was initialised. This selection is a compromise between the requirement for recent data and the limited availability of consistent data for both territorial inventories and life cycle inventories (LCI). In future, the objective might be to work with more recent numbers, referring to years that are closer to the current year.

The methodology used for calculating the life cycle indicators is based on key features that include the life cycle perspective as the base, as well as the quantification of the environmental impacts, and accounting for the impacts linked with international trade (EU-27 import and export). The details of the framework for the calculation of the indicators are outlined in the EC report (2012a).

The general approach is to analyse data sources, ensure consistent system boundaries, adjust data, and address data gaps in statistics and life cycle inventory (LCI) data. This approach is designed to generate time specific indicator values and time series, and—providing clear guidance for relevant procedures—to develop a concept for updating the data and indicators on an annual basis.

The calculation of the resource life cycle indicators starts with preparation of inventories for the domestic (territorial) emissions and resource use (chapter 2), as well as for imports and exports (chapter 3). The calculation of the indicators follows in chapter 4, whereas the results are presented in the chapter 0 together with interpretation (chapter 6). A separate chapter (7) is devoted to the eco-efficiency indicators.

2 TERRITORIAL EMISSIONS AND RESOURCE USE INVENTORY

The inventories should capture comprehensive and detailed information (elementary flows) on resource use, which allows for calculating different impact categories. Taking a pragmatic approach with regard to data availability and in view of the broader resources definition of the Thematic Strategy on the sustainable use of natural resources, the inventories comprise:

- emissions to air, water and soil
- material use
- water consumption
- land use, land use change, and
- energy use.

Life cycle inventory (LCI) data need to be in a consistent format for territorial resources as well as for imports and exports of goods and services. Therefore the matching of elementary flows (resources and emissions) is important so that statistical data and LCI data do follow a common nomenclature. The reference data included in the life cycle inventory can then be used to evaluate and compare relevant impacts of e.g. imported or locally produced products with reference to the products' volume or weight (e.g. kg CO_2, methane, nitrate etc. emissions per kg imported wheat). To be consistent with other developments, the ILCD reference elementary flows (EC, 2010b) and related nomenclature (EC, 2010d) have been used.

2.1 EMISSIONS TO AIR

The term "air emissions" stands for the physical flow of gaseous or particulate materials from the economic system (production or consumption processes) to the environmental system (atmosphere). Natural sources, such as volcano ashes, are excluded from the inventory. The data and, where applicable, the estimation methods used to establish the domestic inventory of air emissions are presented below, sorted by relevant impact categories.

CLIMATE CHANGE

Raw data comprise total national emissions (excluding natural sources) of at least six greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6).

Data sources are national emissions reported to the United Nations Framework Convention on Climate Change (UNFCCC) and to the European Union Greenhouse Gas Monitoring Mechanism, as made publicly available by the EEA (2010a).

The inventory consists of the emissions of the separate greenhouse gases in Gg/year for CO_2, CH_4, N_2O and in Gg CO_2 equivalent for HFCs, PFCs, SF_6.

ACIDIFICATION

Raw data comprise total national emissions (excluding natural sources) of three acidifying gases (NH_3, NOx, and SO_2).

Data sources are national emissions reported to the Convention on Long-range Transboundary Air Pollution (CLRTAP), as made publicly available by the EEA (2010b) as consolidated table for all countries in the NFR09.

CLRTAP (and UNFCCC) emissions inventories are estimated for the total economy, combining specific emission factors and activity rates of diverse processes. Emissions from governmental activities and private households are also obtained by combining technology specific emissions factors with rates of activity (e.g. derived from fuel use for small combustion installations). The method does not involve sampling for extrapolating general results. Furthermore, double counting is not an issue in CLRTAP (and UNFCCC) emissions inventories.

The inventory consists of the emissions of the separate acidifying gases in Gg/year.

PHOTOCHEMICAL OZONE CREATION

Raw data comprise total national emissions (excluding natural sources) of four photochemical ozone precursors (CO, NMVOC, NO_x, CH_4).

Data sources for CO, NMVOC are national emissions reported to the Convention on Long-range Transboundary Air Pollution (CLRTAP), as made publicly available by the EEA (2010c). Data for the two other gases (NOx, CH_4) relevant for this impact category are obtained as described above in the paragraphs on climate change and acidification.

The inventory consists of the emissions of the separate photochemical ozone precursors in Gg/year.

OZONE DEPLETION

Raw data comprise production volumes of the ozone depleting substances (ODS) CFCs, Halons, other Fully Halogenated CFCs, Carbon Tetrachloride, Methyl Chloroform, HCFCs, HBFCs, and Bromochloromethane. Publicly available data are "Calculated levels of Production", i.e. the amount of controlled substances produced minus the amount destroyed by technologies to be approved by the parties and minus the amount entirely used as feedstock in the manufacture of other chemicals.

The data source for production of ODS is the UNEP Ozone Secretariat (UNEP, 2010). The underlying data are not publicly available: the UNEP Ozone Secretariat is not able to directly share underlying data (e.g. quantities destroyed). For such data, the request would need to come directly from a government that is party to the protocol, who would also need to assure that the data would be treated as confidential (personal communication, Mutisya, 26 October 2010).

The inventory consists of the production of controlled ODS substances (all Annex Groups) as published by the UNEP Ozone Secretariat, negative production quantities are replaced with zeros (negative quantities are due to destruction of old gases but the underlying data are not available as mentioned above).

HUMAN HEALTH + ECOTOXICOLOGICAL EFFECTS

Raw data comprise total national emissions of 13 air pollutants (As, benzo(a), Cd, Cr, Cu, Hg, Ni, PAH, Pb, PM10, PM2.5, Se, Zn).

Data sources are air pollutant data aggregated, gap filled and published by the EEA, based on the national emissions reported to the Convention on Long-range Transboundary Air Pollution (CLRTAP Convention) (EEA, 2010d).

The inventory consists of the emissions of the different air pollutants in tonnes/year. The impact categories human health and ecotoxicity as calculated from this inventory will be compared to the normalization data[4] of the Institute of Environmental Sciences of the Leiden University (CML) in order to approximate the completeness of this inventory.

HUMAN HEALTH + ECOTOXICOLOGICAL EFFECTS BASED ON ESTIMATES

The estimation method consists in approximating the fraction of pesticides used in agriculture emitted to air. The PestLCI 1.0 model (Birkved and Hauschild, 2006), originally destined to estimate field emissions of pesticides in agricultural LCA, is used with reasoned assumptions on macro-level averages for the key input parameters on climate, soil, crop, and compounds (see Annex 4).

Raw data comprise consumption volumes of pesticides (FAO).[5]

Data sources for pesticide consumption are aggregated statistical data from Food and Agriculture Organization Statistical Database (FAOSTAT). The data source for the input parameters to PestLCI 1.0 is personal communication with the developer of the subsequent version of the model PestLCI 2.0 (Dijkman et al., 2012): average climate data for different European regions (personal communication, Dijkman, 2 June 2011) and average soil data for Europe (personal communication, Dijkman, 2 June 2011).

The inventory consists of the fraction emitted to air (in tonnes/year) of the pesticides used.

Note: at the time of the development of the indicators the new version of the PestLCI model was not yet available. However, this new version should be used for future inventories. The underlying assumptions and parameter input data will, however, will be largely similar to the present ones since climate and soil data from the database of the version 2.0 have been used (personal communication, Dijkman, 2 June 2011).

IONIZING RADIATIONS BASED ON ESTIMATES

The estimation method consists in extrapolating UK emissions data on the basis of nuclear power capacity ratios, which is the method behind that part of the CML normalization data (Wegener Sleeswijk et al., 2008).

Raw data (and sources) comprise emissions of radioactive substances in the UK between 2000 and 2005 (UK Environment Agency, 2006) and annual data on national installed nuclear power capacities from Eurostat[6].

The inventory consists of the emissions of radioactive substances to the air in kBq/year.

2.2 EMISSIONS TO WATER

Emissions to water consist of chemicals relevant for the impact categories human toxicity, ecological toxicity, eutrophication, and ionizing radiations.

HUMAN HEALTH + ECOTOXICOLOGICAL EFFECTS BASED ON ESTIMATES

Emissions of pesticides are estimated using the PestLCI model as described in the previous paragraph (more details in Annex 4).

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[4] CML-IA Characterisation Factors are available at http://cml.leiden.edu/software/data-cmlia.html

[5] Final list of compounds still pending (depends on the match between FAO and PestLCI classifications).

[6] http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database

HUMAN HEALTH + ECOTOXICOLOGICAL EFFECTS BASED ON ESTIMATES

The estimation method consists in gap filling emissions data from the EEA's Waterbase (EEA, 2010e). Using available reported emissions data and auxiliary data on connection rate to wastewater collection systems and industrial turnover, emissions factors are estimated and applied to the countries and years for which emissions data are not available (see Annex 5).

Raw data comprise data on emissions of hazardous substances to water, aggregated within River Basin Districts (RBDs), in the EEA member countries; data on resident population connected to wastewater collection and treatment systems; and data on industrial turnover.

Data sources are the database on emissions to water of the EEA, called Waterbase (EEA, 2010e) and the Eurostat datasets "Resident population connected to wastewater collection and treatment systems" (env_watq4) and "European Business - selected indicators for all activities (NACE divisions)" (ebd_all).

The inventory consists of the emissions of the separate hazardous substances to water in kg/year.

EUTROPHICATION

The estimation method consists in allocating to EU countries the nitrogen and phosphorus emissions predicted at river basin level by a dedicated model developed by the European Commission, Joint Research Centre (Bouraoui et al., 2011).

Raw data comprise data emissions of nitrogen and phosphorus at international river basin level (i.e. can cover several countries) as modeled by the European Commission, Joint Research Centre, and data (area, country name) on the national sub-basins (i.e. laying completely within one country) constituting the river basins.

Data sources are model data of nitrogen and phosphorous emissions to water generated at the European Commission, Joint Research Centre (Bouraoui et al., 2011), which are the most comprehensive emissions data available for the eutrophication impact category, consisting of diffuse and point source emissions of nitrogen and phosphorus into water (tonnes/year).

The inventory consists of the emissions of nitrogen and phosphorus to water in tonnes/year.

IONIZING RADIATIONS

The method to obtain a national inventory of the emissions of radioactive substances to water is the same as for emissions to air.

2.3 NOTE ON EMISSIONS TO AIR, WATER AND SOIL

Emissions to soils consist of chemicals relevant for the impact categories human toxicity and ecological toxicity. These emissions could not be covered within this project due to the lack of suitable territorial data. A case in point is the EPER/E-PRTR dataset include emissions to soils, but were generally considered as unsuitable for this project. Also, the PestLCI model—used to estimate emissions of pesticides to air and water—does not appropriately support emissions of pesticides to soils (they appear as zero in the modeling results). PestLCI 2.0—which should be used from 2011 onwards—will not support emissions to soils at all (Dijkman et al., 2012).

Other potential data sources for emissions (to air, water or soil) relevant for human health and ecotoxicological effects were investigated, but judged not suitable for this development.

First was the European Pollutant Release and Transfer Register (E-PRTR) compiles point-source emissions data for 91 pollutants from about 24,000 industrial facilities. Facilities have to report if they release pollutants which exceed specific thresholds specified for each media: air, water and land. Accounting for diffuse sources is in the planning, but not yet fully operational. This data collection is tailored to feed into a GIS. For the territorial inventory of this project, however, the coverage of pollutants emissions is incomplete and there is no indication of the degree of incompleteness that could be used for gap-filling.

Second source is the CML normalization data (Wegener Sleeswijk et al., 2008) for pollutants emissions relevant for human health and ecotoxicological effects which are built using the US Toxic Release Inventory (TRI), the Canadian National Pollutant Release Inventory (NPRI) and the Japanese Pollutant Release and Transfer Register (PRTR), which are comparable to the European PRTR. Emissions reported to these three programs are added up and extrapolated for Europe, using the ratio of Europe's Gross Domestic Product (GDP) over the GDP of the USA+Canada+Japan. The legitimacy of this approach is not questioned for building a normalisation data set against which other emissions data can be compared. The structural parallels of the territorial data developed in this project and the normalization data further commend the comparison. Nonetheless, the normalisation emissions data cannot be used for the territorial inventory built as part of this project. This is mainly due to the fact that the normalisation data set draws largely on non-EU sources and moreover uses a GDP-based approach to modelling and scaling. Such an approach is incompatible with the intended aim of deriving a final eco-efficiency indicator in the form of [aggregated impact/GDP of Europe], building on the territorial inventory.

2.4 MATERIALS

Material resources extracted from the EU-27 territory are grouped into biomass[7], metals and minerals. Fossil energy resources are material resources, but they also belong to energy resources (see point 2.6). The categorization follows the Eurostat material flow accounts, but has been extended where additional details were needed for the inventory.

RESOURCES RELATED TO BIOMASS

At the first level, biomass is grouped into[8]:

A.1.1 Primary crops

A.1.2 Crop residues (used), fodder crops and grazed biomass

A.1.3 Wood

A.1.4 Fish catch and other aquatic plants/animals

Raw data are acquired for A.1.1 to A.1.4.

Raw data comprise of:

- Harvested mass in 1000 t fresh weight
- Water content of harvested mass in %
- Energy content as net calorific value in MJ, and

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[7] Biomass is not a primary resource, unless wild extraction from unmanaged nature. However, what is inventoried for products from agriculture and forestry is the amount of CO_2 extracted from the atmosphere (i.e. harvested crops and - ideally - CO_2-binding in growing trees etc.). Furthermore the solar energy harvested (i.e. stored in wood and crops). As data are available however, these elementary flows are already separately inventoried.

[8] The Eurostat MFA includes a fifth category which is hunting and gathering, however, it seems to be of minor relevance and also data are not readily available. It was therefore skipped in this development.

- Carbon (C) content of harvested mass

The data source for harvested mass in fresh weight, and respectively for the standardised water content of grassland biomass and wood, is the Eurostat online dataset "material flow accounts". This dataset, however, only relates to the EU-27 total biomass harvest, and covers the period from 2000 to 2007. Hence, additional data needed to be acquired, and the international online database of FAOSTAT was used as a data source for primary crops, wood and fish capture. For this kind of data, FAOSTAT is judged to grant sufficient quality, but still some adjustments had to be made (on water content, of fodder crops and grazing, and estimations of crop residues used).

The inventory for territorial biomass comprises:

- net CO_2 intake (intake and release) expressed as C content[9]
- Land use in m^2 per year and
- Land conversion/transformation in m^2 per year

The latter two indicators are addressed under point 2.7.

In addition, there is data on unused biomass that is not further used in the economy, referring to the same categories as for the harvest that is utilized within the economy. The data were compiled from national studies and estimates based on the Wuppertal Institute (WI) database for material flows.

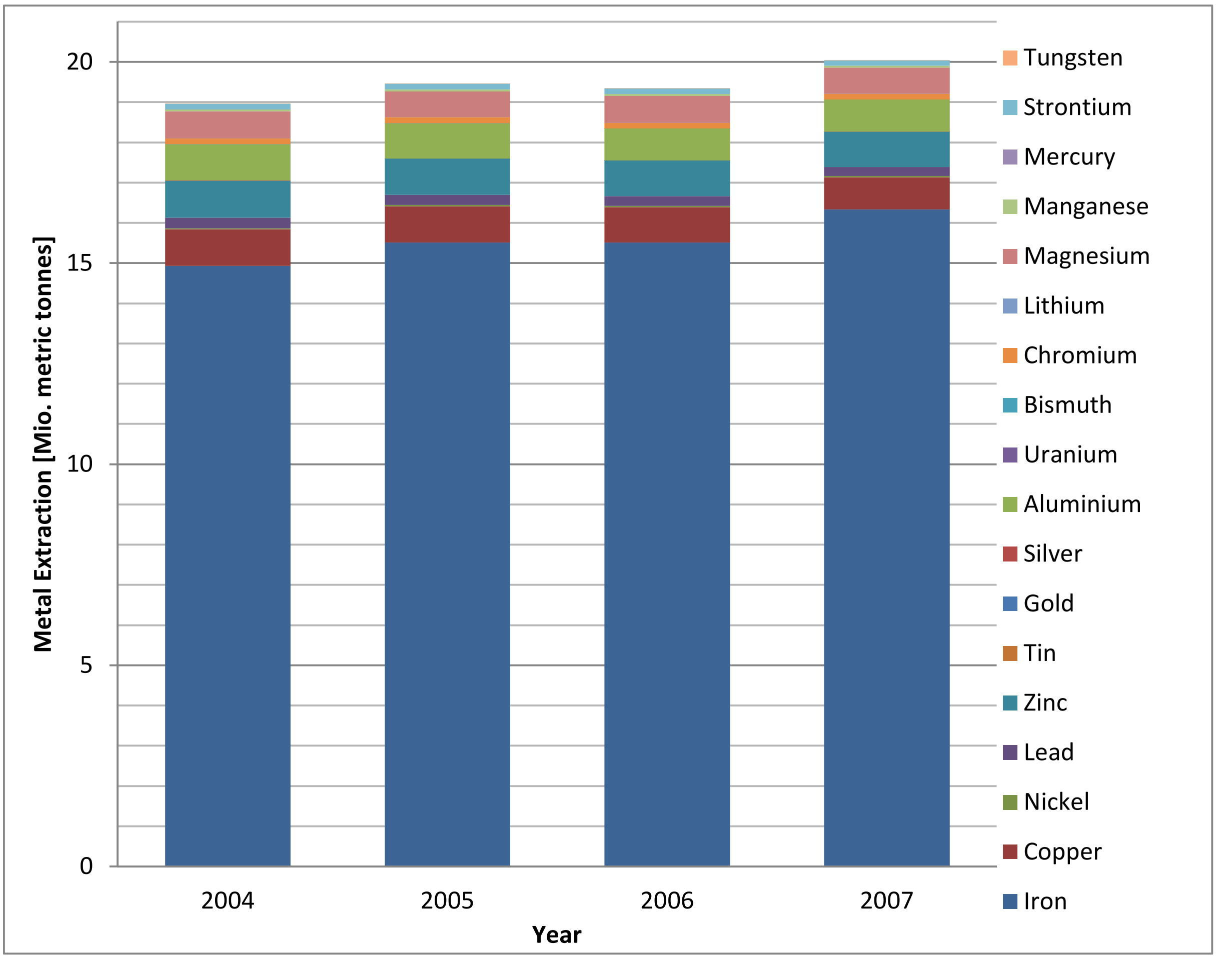

FIGURE 1 METAL RESOURCE EXTRACTION (METAL CONTENT) IN THE EU-27 (2004-2007)

[9] Biogenic methane emissions (from rice fields) are already included in greenhouse gas emission inventories of EU-27.

METALS

At the first level, metal resources are grouped into:

A.2.1 Iron ores, and

A.2.2 Non-ferrous metal ores

Raw data are acquired as extracted mass both in gross ore and in metal content (and derived ore grades as % metal in gross ore). For gross ore, coupled production needs to be taken into account following the principles of Eurostat for compiling material flow accounts (Eurostat, 2009a).

Data sources for gross ore are the Eurostat online data under "material flow accounts"[10] which, however, only covers the EU-27 total gross ore extraction in the period from 2000 to 2007. Hence, additional data needed to be acquired from international data sources, in particular from the mineral statistics of United States Geological Survey (USGS) and British Geological Survey (BGS). For metal contents these data sources are judged to be high quality. For gross ore, on the other hand, separate accounts needed to be used, building on available Eurostat country data. The total EU-27 metal account hence equals the sum of the accounts of all EU-27 Member States.

Data for territorial metal resources (metal contents) extracted in the EU-27 illustrate that iron clearly dominates by mass, while copper, zinc and aluminium contribute significant metal amounts as well (Figure 1).

All metals listed in the legend of Figure 1 are extracted through EU-27 mining operations. However, for some metals the extracted quantity does not become visible in the graph, due to the relatively small amounts that are extracted and the large scale of the graph.

Special issues for the territorial inventory of metals are:

- Raw data on territorial metals extraction generally relates to the metal content of the extracted mass (e.g. Cu in metric tonnes). Alternatively, raw data on gross ore production (run-of-mine production, taking coupled production of metals into account) can be referred to. Gross ore data is beneficial for mass balances, and has hence been used for the territorial inventory where available.
- The selection of the metals included in the territorial inventory was dependent on the available data. Besides the statistical sources of USGS and BGS, the critical raw materials report (EC, 2010e and 2010f) was a key reference for ensuring all relevant metal extractions were captured in the inventory (Table 1). Of the twelve identified critical raw metallic minerals, only tungsten is mined within the EU-27.

In addition, the data include the amounts of unused primary material extracted along with metallic minerals, which is not put to further use in the economy. The data were compiled from national studies and estimates based on the WI data base for material flows.

MINERALS

At the first level, mineral (non-metallic) resources are grouped into

A.3.1 Non-metallic minerals—stone and primarily industrial use, and

A.3.2 Non-metallic minerals—bulk materials used primarily for construction

Raw data are acquired as extracted mass as reported in the data source.

Data sources for non-metallic minerals extracted in EU-27 are the Eurostat online data under

[10] http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Material_flow_accounts

"material flow accounts" (Figure 2). However, this covers only the EU-27 total minerals extraction, and does not provide data beyond the period from 2000 to 2007. Hence, additional data from international data sources needed to be referred to. The main additional data sources were mineral statistics provided by USGS and BGS. The two critical raw non-metallic minerals, fluorspar and graphite, are both mined within the EU-27.

TABLE 1 NOTES FROM THE CRITICAL RAW MATERIALS REPORT

1) with regard to the list of 14 critical raw materials at EU level (here for metals only):
Antimony: the EU is dependent entirely on imports; there is successful exploration for antimony in Italy and in Slovakia (Strieborna Silver/Copper/Antimony Deposit, at the conceptual stage).
Beryllium: Beryllium is not mined within the EEA. However, given estimated global reserve levels and annual usage, it appears that there is a abundant supply in the USA of the ores from which all Beryllium based materials are produced, reserves which could satisfy EU and world demand for over 100 years at current usage rates.
Cobalt: There is no mine production of cobalt in Europe.
Gallium: no mine production. Gallium is produced in Germany and UK, but as recycled metal from new scrap. Gallium metal is further produced in other EU countries (CZ, FR, HU, SK).
Germanium: Germanium raw material is not recovered within the European Union.
Indium: As Europe is import dependent on the hosts of indium, it can be stated that Europe is import-dependent on Indium, too. This observation will be amplified by the fact that Belgium seems to be the only European country active in refining indium metal.
Magnesium: The alkaline earth metal "Magnesium" cannot be found as a free element (Mg) naturally on earth. Although magnesium is found in over 60 minerals, only dolomite, magnesite, brucite, carnallite, and olivine are of commercial importance. Magnesium and other magnesium compounds are also produced from seawater, well and lake brines and bitterns. Magnesite ($MgCO_3$) is mined in AT, EL, SK, ES. In the MFA classification, it is grouped under industrial minerals. For consistency reasons, we shift Magnesium here to the metals account.
Niobium: European countries exported some tantalum and niobium, although there is no domestic production.
PGMs: There is no direct PGM mining in EU 27-countries according to the BGS, although there is some marginal production of platinum and palladium (as by-products) in EU 27-countries for 2007.
Rare earths: Rare earths are not produced within the European Union. However, known deposits in amounting to approximately 500.000 t exist in Sweden, with further prospecting underway.
Tantalum: the EU tantalum industry is practically entirely dependent on access to raw materials on the international market (only small quantities of scrap are sourced from the EU market).
Tungsten: There are two tungsten mines in production in the EU, in Portugal and in Austria (production of the latter is captive).
2) with regard to metals of both rather low economic importance and supply risk (apart from Cu and Ag):
Lithium: Lithium is produced in the EU by Portugal and Spain (in lepidolite mineral). Lepidolite is classified in mineral statistics as industrial mineral. We shift it here to metals.
Titanium: Titanium is not produced within the European Union. European production of titanium minerals is limited to Norway, which contributed 7% of worldwide production, although the country only mines ilmenite. Several ilmenite deposits are reported for Western Finland. Deposits in Sweden are not exploited currently, due to economical and environmental issues. In 2007, the whole consumption was imported (about 28% of the world production) mainly from Canada, Norway and Australia.
3) with regard to metals of high economic importance and low supply risk (apart from Fe, Al, Cr, Mn, Zn, Ni):
Molybdenum: According to the BGS and the USGS there is no molybdenum production in Europe. Also the Austrian World Mining Data 2009 does not mention any EU-based production. However, there are two EU based companies involved in this business: Rio Tinto and Anglo-American. In contrast to these reports, the German BGR states that there is some small molybdenum ore production in Bulgaria. This is said to be limited to 0.2% of worldwide production. As molybdenum is a by-product in copper mining and Bulgaria is mining some copper, this figure is possible. Apart from the mine production, some companies in Belgium, the Netherlands and UK roast molybdenum concentrates to molybdenum trioxide. We have no reliable number for Mo mine production in the EU, so we leave it out but keep the category in the list.
Rhenium: There is no reported mining of rhenium in any European country. Therefore, Europe is completely dependent on imports.
Tellurium: The EU mainly imports from Norway (67%), followed by Morocco (20%).
Vanadium: South Korea is the largest exporter to the EU market, with a share of over 90%.

Source: EC, 2010e and 2010f

In addition, there are data on the amounts of unused primary material extracted along with non-metallic minerals, which is not put to further use in the economy. The unused extracted material also comprises soil excavated for constructions, sediments from the dredging of harbours and waterways, and soil erosion from arable land. The data were compiled with reference to national studies and estimates derived from the WI data base for material flows.

All non-metallic minerals listed in the legend of Figure 2 are extracted through EU-27 mining operations. However, for some minerals the extracted quantity does not become visible in the graph due to the relatively small amounts that are extracted, and the large scale of the graph. The minerals dominating the picture are limestone; sand and gravel for construction; and crushed stone (from bottom).

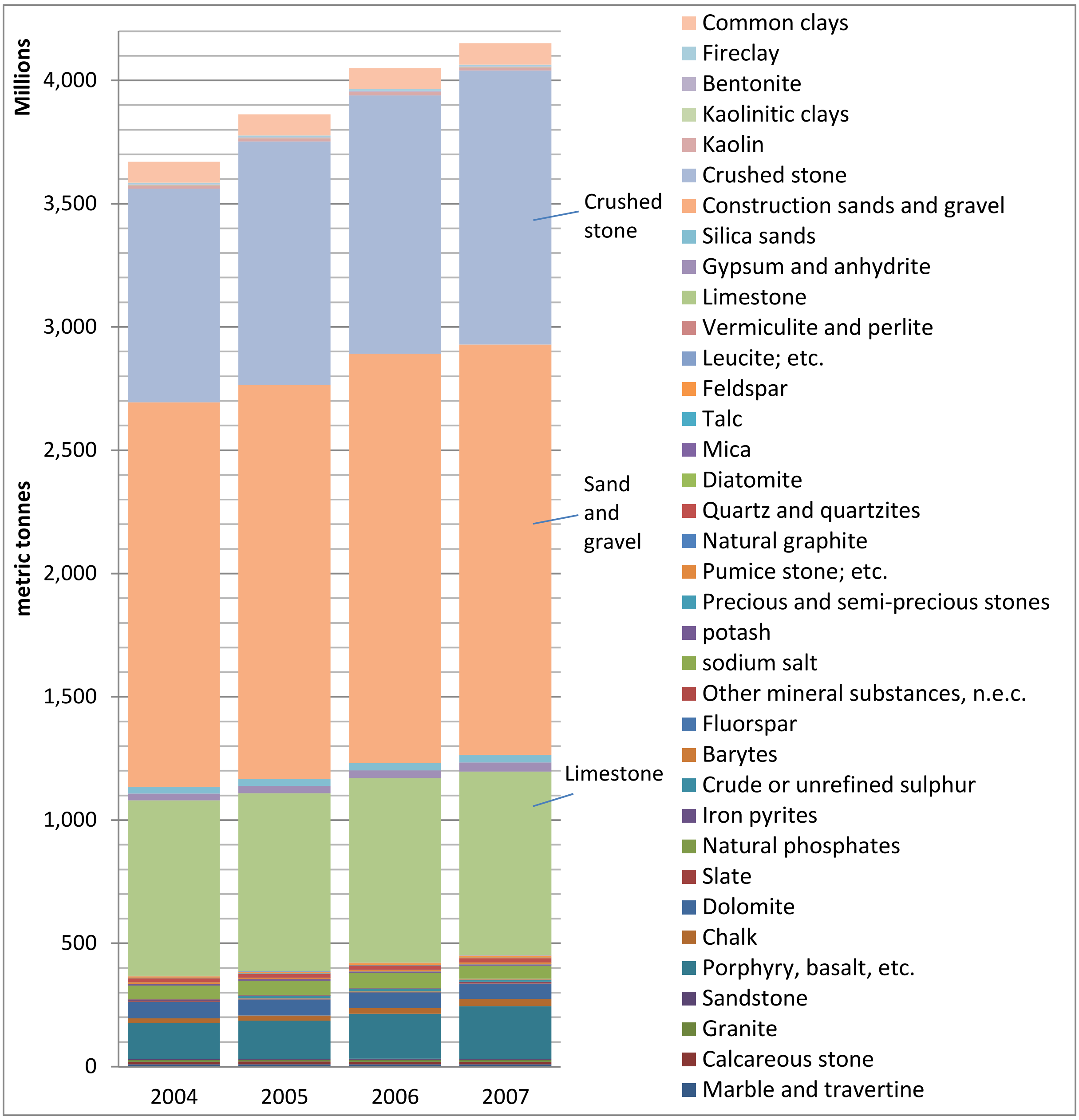

FIGURE 2 NON-METALLIC MINERALS RESOURCE EXTRACTION IN EU-27 (2004-2007)

TABLE 2 WATER FLOW CATEGORIES IN STATISTICS AND ELEMENTARY WATER FLOWS IN LCA

Water flows in statistics		Comments	Elementary water flows in LCA
Code	Label		
W16_1	Total gross abstraction of freshwater	elementary flow which needs further differentiation	ground water (input)
			fossil ground water (input)
			river water (input)
			lake water (input)
W16_2	Returned water (before or without use)	is covered in LCA by quantifying the in-stream and off-stream water use and consumption	
W16_3	Total net fresh water abstraction	is covered in LCA by quantifying the in-stream and off-stream water use and consumption	
W16_4	Desalinated water		(desalinated) sea water (input)
W16_5	Reused water	is not an elementary flow as the water is returned within the technosphere from one process to another	
W16_6	Imports of water	no elementary flow	
W16_7	Exports of water	no elementary flow	
W16_8	Total water available for use within the territory	relevant information for indexes and midpoint calculation; no information that is needed on an inventory level	
W16_9	Losses during transport, total	no elementary flow	
W16_9_1	Losses by evaporation	elementary flow which needs further differentiation	evaporation from plants (output)
			evaporation from soils (output)
			steam to atmosphere (output)
W16_9_2	Losses by leakage	no elementary flow	
W16_9_3	Total water available for end users within the territory	relevant information for indexes and midpoint calculation; no information that is needed on an inventory level	
W16_10	Total cooling water discharged	no elementary flow	
W16_10_1	Cooling water discharged to inland waters	elementary flow which needs further differentiation	(waste)water discharged to river (output)
			(waste)water discharged to lake (output)
W16_10_2	Cooling water discharged to marine waters		(waste)water discharged to sea (output)
W16_11	Total waste water generated	can be calculated based on elementary flows	
W16_11_1	Waste water discharged to inland waters	elementary flow which needs further differentiation	(waste)water discharged to river (output)
			(waste)water discharged to lake (output)
W16_11_2	Waste water discharged to marine waters		(waste)water discharged to sea (output)
W16_12	Reused water	no elementary flow	
W16_13	Discharges of used water	can be calculated based on elementary flows	
W16_14	Consumptive water use	can be calculated based on elementary flows	
W16_15	Total water consumption	can be calculated based on elementary flows	
			rainfall (input)
			water contained in the product (?) (output)

2.5 WATER

For the assessment of the impact category “resource depletion water”, information is required as to where the water consumption has taken place. The required detail of information is not available, neither for the domestic inventory nor for the life cycle inventory (LCI) data.

The water resource use in EU-27 on a territorial basis can be assessed as abstraction beyond safe limits, i.e. "overuse" of water. The European Environmental Agency (EEA) has developed an assessment scheme as water exploitation index (WEI) (EEA, 2007). WEI has a regional breakdown and it is defined in the following way:

WEI = total freshwater abstraction / total renewable freshwater resources Eq.1

Data for renewable freshwater resources come from the United Nations Statistics Division (UNSD). Renewable freshwater resources cover, so-called, “internal flows” which include river run-offs and newly generated ground water plus actual external inflows of surface and ground waters (UNSD, 2007).

The EEA report (2009a) promotes WEI, but points out that high regional differences and seasonal changes are not reflected in WEI.

Table 2 introduces statistical raw data categories from Eurostat[11] for the territorial inventory of water. The table presents comments, as well as a description of the elementary water flows from the life cycle assessment (LCA) perspective. The highlighted rows are the categories that are addressed with particular focus in connection with the territorial inventory of water[12].

In terms of assessing the EU-27’s overall environmental impacts it is likely that water depletion will be an important indicator. Therefore water abstraction beyond safe limits, i.e. “overuse” of water, needs to be accounted for. This is also recommended in the ILCD (EC, 2011c), and implies that the accounts should be prepared at a regional level rather than at a national level (where possible). However, this is currently not feasible and even at the national level there are significant data gaps for some EU-27 countries. This preliminary version of a territorial water inventory thus focuses on Germany as a country with good data quality. The inventory further points out gaps in the currently available EU-27 data. Further analysis concentrates on the elementary flows described above and on the water exploitation index (WEI) which indicates pressure on the water resources of a country. It will need to be further developed to be applicable to the ILCD recommended method for water overuse.

WATER INVENTORY DATA FOR GERMANY

The German Federal Statistical Office publishes water data every three years. The latest available data are for 2007 for public (Destatis, 2009a) and non-public water sector (Destatis, 2009b). The statistics offer a wide range of data, e.g. data by Federal State and by watershed, which allows to derive comprehensive and consistent water balances for the country. Table 3 provides a summary on water abstraction in Germany with regard to the requirements for this territorial inventory.

Losses of water through evaporation are the second component of the inventory. The Eurostat water balance reports a single figure for losses through evaporation in Germany, amounting to 963 million m^3 in 2004. The German Federal Institute of Hydrology has been reporting on Germany’s water balances since 1990[13]; according to this source, evaporation levels were significantly lower, amounting e.g. to 183 billion m^3 in 2004, of which 4.5 billion m^3 were evaporation from water consumption and the remainder was evapotranspiration. It remains to be clarified how these data compare with the Eurostat figure.

The third component is waste water including cooling water. Table 4 provides a summary regarding waste water treatment in Germany with regard to the requirements for this territorial inventory.

[11] Eurostat environment statistics - Water (env_wat) - Water use balances in millions of cubic meters (env_watqsum): http://epp.eurostat.ec.europa.eu/portal/page/portal/environment/data/database

[12] It should be noted that these categories do not allow to derive a consistent water balance, which is also not the aim of this approach.

[13] Data available from the Federal Environment Agency (UBA)

www.umweltbundesamt-daten-zur-umwelt.de/umweltdaten/public/theme.do?nodeIdent=2303

The water exploitation index (WEI), or withdrawal ratio, in a country is defined as the mean annual total abstraction of fresh water divided by the long-term average freshwater resources[14]. By describing to what extent the total water abstraction puts pressure on water resources, the index helps identify countries with high levels of water abstraction in relation to their water resources. Countries with a high WEI are likely to be exposed to problems of water stress. The long-term average freshwater resource is derived from long-term average precipitation figures, minus long-term average evapotranspiration figures, plus the long-term average inflow from neighbouring countries.

According to Alcamo et al. (2000), the warning threshold can be defined at 20%, which distinguishes a non-stressed region from a stressed one; severe water stress can occur for a WEI above 40%, which indicates strong competition for water, but which does not necessarily trigger frequent water crises. Some experts believe that 40% is too low a threshold, and that water resources can be used much more intensely, with a WEI of up to a 60%, whereas others believe that freshwater ecosystems cannot remain healthy if the waters in a river basin are abstracted as intensely as indicated by a WEI of above 40% (Alcamo et al., 2000).

TABLE 3 TOTAL ABSTRACTION OF FRESHWATER IN GERMANY 2001, 2004 AND 2007

Total abstraction of freshwater	2001	2004	2007
1. Public water supply [milion m^3]			
TOTAL	5 409.0	5 371.7	5 127.6
Groundwater	3 502.3	3 516.1	3 157.2
Wellwater	508.4	436.8	423.5
Bank filtrate	280.4	284.4	409.7
Surface water	1 117.8	1 134.4	1 137.1
of which: lake resp. barrage	637.7	643.6	615.6
of which: river	52.9	61.3	57.7
of which: enriched groundwater	427.2	429.4	463.8
2. Non-public water supply [1000 m^3]			
TOTAL	32 597 221.0	30 185 244.0	27 173 515.0
Groundwater	2 150 150.0	2 038 628.0	2 192 624.0
Wellwater	42 914.0	41 309.0	51 267.0
River-, lake-, barrage water	29 850 425.0	27 549 019.0	24 355 514.0
Enriched groundwater	68 220.0	60 285.0	65 210.0
Bank filtrate	485 514.0	496 002.0	508 901.0
3. All territorial water supply (1+2) [milion m^3]			
TOTAL	38 006.2	35 556.9	32 301.1
Groundwater	5 652.5	5 554.7	5 349.8
Wellwater	551.3	478.1	474.8
River-, lake-, barrage water	30 541.0	28 253.9	25 028.8
Enriched groundwater	495.4	489.7	529.0
Bank filtrate	765.9	780.4	918.6

Source: Destatis (2009a and 2009b)

[14] www.eea.europa.eu/data-and-maps/indicators/water-exploitation-index

TABLE 4 WASTE WATER TREATMENT IN GERMANY 2001, 2004 AND 2007

Waste water treatment in Germany	2001	2004	2007
1. Public water supply and waste water removal [milion m^3]			
TOTAL waste water	5 331.9	5 271.3	5 274.6
to rivers	5 107.4	5 050.0	5 037.7
to coast and sea	224.5	221.3	237.1
treated in public waste water plants	5 254.3	5 204.4	5 213.4
to rivers	5 031.2	4 984.5	4 977.6
to coast and sea	223.1	219.9	235.7
treated in industrial waste water plants or abroad	27.6	27.8	31.6
to rivers	26.7	26.7	30.4
to coast and sea	0.9	1.1	1.2
effluent without treatment	49.9	39.1	29.7
to rivers	49.4	38.8	29.5
to coast and sea	0.5	0.3	0.2
2. Non-public water supply and waste water removal: direct effluent [1000 m^3]			
TOTAL waste water	31 180 729	28 910 321	25 494 848
to rivers	30 262 315	27 944 148	24 623 999
to coast and sea	918 414	966 173	870 849
untreated waste water: cooling water	28 413 761	25 945 720	22 491 772
to rivers	27 522 780	25 003 893	21 644 669
to coast and sea	890 981	941 827	847 103
untreated waste water: other water	484 568	435 037	418 661
to rivers			410 788
to coast and sea			7 873
untreated waste water: statistical difference	233 005	471 010	540 002
treated waste water	936 962	906 783	917 002
to rivers	925 289	894 731	902 619
to coast and sea	11 673	12 052	14 383
unused water	1 112 433	1 151 771	1 127 411
to rivers	1 111 911	1 151 361	1 125 953
to coast and sea	522	410	1 458
3. Non-public water supply and waste water removal: indirect effluent [1000 m^3]			
TOTAL waste water	874 409	864 541	1 291 945
untreated waste water: cooling water	377 192	370 228	776 948
untreated waste water: other water	240 806	247 304	284 082
treated waste water	177 407	175 698	161 354
unused water	4 493	4 464	5 221
statistical difference	74 511	66 847	64 340

Source: Destatis (2009a and 2009b)

TABLE 5 WATER EXPLOITATION INDEX (WEI) FOR GERMANY – DEVELOPMENT OVER TIME

	late 1990s	early 2000s	2001	2004	2005	2006	2007	2004–2006	LTAA	Source
Abstraction of freshwater:										
Total abstraction of freshwater	n/a	n/a	38,006	35,557	n/a	n/a	32,301	n/a	n/a	Destatis
Total gross abstraction of freshwater	n/a	n/a	38,006	35.557	n/a	n/a	n/a	n/a	n/a	Eurostat: env_watqsum- Water use balance_W16_1
Total freshwater abstractions	n/a	n/a	n/a	n/a	n/a	n/a	n/a	35,557	n/a	Eureau 2008
Average annual renewable freshwater resources:										
Environmental Indicators: Water: Water resources: long term annual average	n/a	n/a	n/a	n/a	n/a	n/a	188,000	n/a	n/a	UN
	n/a	n/a	n/a	174,000	151,000	150,000	n/a	n/a	188,000	Eurostat: env_watq1a- Renewable water resources
Total renewable water resources (actual = natural)	n/a	n/a	n/a	n/a	n/a	n/a	154,000	n/a	n/a	FAO Aquastat
Water exploitation index (WEI):										
WEI	n/a	n/a	n/a	n/a	n/a	n/a	n/a	19%	n/a	Eureau 2008
	23.8%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	EEA
	n/a	slightly over 20%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	OECD key environmental indicators 2008
	n/a	n/a	n/a	n/a	n/a	n/a	17.2%	n/a	n/a	calculated from Destatis and UN
	n/a	n/a	n/a	n/a	n/a	n/a	21.0%	n/a	n/a	calculated from Destatis and FAO: may be more "precise" because UN is long-term annual average
	n/a	n/a	n/a	20.4%	n/a	n/a	n/a	n/a	n/a	calculated from Eurostat data

Table 5 gives an overview of different data sources which can be used to derive the WEI for Germany. The statistics relate to freshwater abstraction and renewable freshwater resources, as well as data reported in connection with the WEI.

In general, the different data sources are relatively consistent. The WEI for Germany amounts to approximately 20%, which is near the warning threshold. While Germany's availability of water resources is generally sufficient, there are indeed some water deficient regions (with e.g. only minor usable groundwater resources, and seasonal variations of precipitation and water demand). Especially in urban regions the local water demand exceeds the local water yield[15].

WATER INVENTORY DATA FOR THE EU-27

The Eurostat database on water is incomplete and has significant gaps. Country-level data are in principle reported for each Member State for the years from 1970 to 2007. However, the country-level datasets are incomplete (i.e. they do not provide data for every country for every year)[16], and Eurostat does not present totals for the EU-27 aggregates. In order to calculate the indicator at the European level, missing data would have to be estimated. At the time of development of the life cycle indicators, only EU-27-level data could be aggregated with some limitations (e.g. data are not precisely for the same year for each country, or smaller countries are missing) for a small number of indicators where most data are available at the Member State level. In addition to the European statistics, further sources were checked for EU-27 water data.

The European Federation of National Associations of Water & Wastewater Services (EUREAU, 2009) provides country profiles based on the EUREAU's member associations data in each country. The EUREAU dataset excludes Latvia and Slovenia, as these countries do not have a EUREAU member association. Where available, publicly available data for these countries are included in the general European charts. Still, EU-27 aggregates cannot be derived from the Member States profiles data. Apart from this limitation, EUREAU presents data for water abstraction by source and by sector (by two categories: groundwater and/or springwater abstractions; surface water abstractions). For one single year, EUREAU also provides data on the WEI. Apart from the fact that consistent EU-27-level data cannot be derived, EUREAU data do not provide enough detail and coverage for the territorial inventory.

Another potential data source is the Food and Agriculture Organization Information System on Water and Agriculture (FAO AQUASTAT) for 2005. AQUASTAT is global information system on water and agriculture, developed by the Land and Water Division. The main mandate of the program is to collect, analyse and disseminate information on water resources, water uses, and agricultural water management with an emphasis on countries in Africa, Asia, Latin America and the Caribbean.

The AQUASTAT online database provides data for all EU-27 countries. The data for the natural water resources are available, but data for water withdrawal are missing. This is also the case for other countries. Furthermore, the data are available only for periods like 2003-2007 and are thus neither easily comparable across countries nor suited for monitoring year-on-year developments.

The OECD publishes data for "Total gross water abstractions" in its Environmental Data and Indicators section[17]. However, only 19 EU-27 countries are members of the OECD and the remaining European Union Member States are not covered in the OECD's data. In addition to this, the level of detail of the available water data is low and therefore insufficient for the territorial inventory.

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[15] http://www.umweltbundesamt-daten-zur-umwelt.de/umweltdaten/public/theme.do?nodeIdent=2303

[16] For instance, 2004 is a year with relatively good coverage of total gross freshwater abstraction, with data missing "only" for Ireland (for which data are there for 2005 and 2007), Italy (latest reported data are for 1998), Luxembourg, Finland and Austria (latest reported data are for 1999), Portugal (data are there for 2005), and UK (data are reported for England and Wales only).

[17] Website: http://www.oecd.org/document/57/0,3343,en_2649_34283_46478585_1_1_1_1,00.html

The United Nations statistics division publishes data on water under its Environmental Indicators named “Water resources: long term annual average”[18]. The data comprise the following parameters (in million m^3) for every country of the world:

- Precipitation
- Internal flow
- Inflow of surface and ground waters
- Renewable freshwater resources
- Renewable freshwater resources per capita.

Further, the UN reports data on water supply:

- Net freshwater delivered by water supply industry
- Net freshwater delivered by water supply industry per capita
- Population supplied by water supply industry
- Net freshwater delivered by water supply industry per capita supplied
- Net freshwater delivered by water supply industry to households
- Net freshwater delivered by water supply industry to manufacturing.

However, the data are given for the latest year available which is the same as for the Eurostat data. The UN data are valuable references for average annual freshwater resources (and are actually used by EEA for calculating the WEI) but cannot be used to provide figures for regular monitoring in connection with a territorial water inventory. There are further data available from e.g. UNEP and WRI, but these do not give any advantage to data already described before.

For the time being and due to the limited data availability the only remaining possibility is to make estimates in order to generate annual data for the territorial water inventory of the EU-27. Apart from that, data could be obtained from the Eurostat, which develops a methodology for water accounts. This development aims at preparing the data collection at Member State level, providing, e.g. tables and a compilation guide. However, the question remains if data quality can be improved at the same time as data availability.

It can be noted that water statistics for Germany offer a wide range of data (published every three years, the latest in 2007), e.g. by Federal State and watershed, which allow to derive comprehensive and consistent territorial water accounts and balances for the country as presented above.

WATER FROM THE LIFE CYCLE PERSPECTIVE

Humbert et al. (2010) have analysed existing water accounting methods, i.e. more than 30 altogether. These methods have been developed to evaluate water use in life cycle assessment (LCA). They are addressing water accounting at inventory level both in terms of data structure and content, at the index level, and at the impact level (midpoint and damage levels). Moreover, since November 2011, the recommended method for water overuse is available in ILCD handbook (EC, 2011c).

A differentiation is made between elementary flows (water flows in the ecosystem) and non-elementary flows (water flows in the technosphere). Elementary flows are identified at the inventory level. Those elementary flows that fulfil the generic needs at impact level; it allows the

[18] http://unstats.un.org/unsd/ENVIRONMENT/qindicators.htm

application of midpoint and damage level methods. Hence, the focus is on elementary flows only. The following elementary flows need to be covered in an LCA:

- Input flows: ground, fossil ground, river, lake and (desalinated) sea water and rainfall
- Output flows: water contained in the product, evapotranspiration (i.e. evaporation from soils and plants), steam, (waste-)water discharged to river, lake or sea (from various processes, such as run-off from agricultural land.

These elementary flows allow quantifying the in-stream and off-stream water use and consumption at the process level (Owens, 2002). These elementary flows can be matched with non-elementary flows[19], such as cooling water etc.

Regionalization of elementary flows is required in order to apply water accounting methods at an index and impact level. Ideally, regional information on water availability and use/consumption is to some extent available at a water shed level, based on e.g. WaterGAP2 (Alcamo et al., 2003).

Issues for the territorial inventory of water are (1) whether regional data or data on a water shed level, i.e. below the national level, need to be acquired in order to obtain a meaningful indicator; and (2) which elementary water flows need to be considered. For the time being it is assumed that with regard to (1), country level data suffice. Generally speaking only freshwater is addressed, excluding desalinated water for which the resource is saltwater.

TABLE 6 CATEGORIES FOR ENERGY RESOURCES

Resource group	Resource	Units
Solid fossil fuels	Hard coal	t; toe; TJ_NCV
	Brown coal	
	Peat	
Oil	Crude oil	t; toe; TJ_NCV
Gas	Natural gas	toe; TJ_NCV; TJ_GCV
Renewables	Solar heat	toe; TJ_NCV; TJ_GCV
	Geothermal	
	Hydro	toe; GWH; TJ_NCV
	Wind	
	Photovoltaic	

n.a. = not applicable, t = metric tonnes, toe = tonnes oil equivalents, TJ_NCV = terajoules net calorific value, TJ_GCV = terajoules gross calorific value, GWH = gigawatt hours

TABLE 7 SOURCES AND DATA FOR LULUC IN THE EU-27 AND GERMANY

LULUC	EU-27	DE
A.1. UNFCCC – National inventories	1990 - 2008; 6 classes	
A.2. CLC – CORINE land cover	2000 for EU-27; 1990 - 2000 for EU24 only	1990; 2000; 2006
LU statistical data – all classes	ESTAT (gaps)	DESTATIS (comparison with A.2 in EEA, (2006))
LU agricultural statistics – agricultural land	FAO for area, production, yield; www.organic-europe.net for total organic agricultural area EU-27 and countries 2003-2009	
LU – forestry land	Needs eventually to be further specified; check potential data sources of EFI, FAO, CIFOR, CFA	

[19] "…the elementary flows that cross the system boundary are defined as "material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation". (EC, 2010c). Non-elementary flows are thus flows within the technosphere.

2.6 ENERGY

Energy resources for the territorial inventory are grouped into categories. Table 6 provides the available units for the different energy resources considered in the territorial inventory.

Raw data are acquired as extracted mass (metric tonnes – t where applicable) and in energetic units as presented in Table 6.

Data sources for energy resources are the Eurostat online data under "energy statistics", using primary production as the relevant indicator for territorial resource extraction.

Data used include territorial energy resource data, as well as amounts of unused primary material that are extracted along with used energy materials, but which are not put to further use in the economy. The data were compiled from national studies and estimates based on the Wuppertal Institute (WI) database for material flows.

2.7 LAND USE

Land is addressed in terms of land use in a reference year with particular focus on land for agriculture, and with regard to land use changes within a reference year from one high-level category to another high-level category (e.g. from cropland to settlement).

Raw data for the territorial inventory of land are acquired with regard to land use (LU) and land use change (LUC) with the latter meaning change from one category to another category of land use or land cover[20]. In this inventory there is no strict differentiation made between land use and land cover, so the commonly used term "land use" includes both. A general overview of available data is given in Table 7.

Data sources for land use and land use change by broad categories are the national inventory reports to UNFCCC (see A.1. below). Detailed data on land use for agriculture are taken from the FAO online data base (see paragraph C below). Data for extensive use of agricultural land (organic agriculture) are taken from the FiBL-IFOAM[21] survey on organic agriculture in Europe and worldwide.

The inventory comprises net CO_2 emissions/removals and other greenhouse gases from land use, land use change and forestry as reported in the national inventory reports to UNFCCC. These comprise in detail (see prototype) (a) emissions from land use, land use change and forestry: net CO_2 emissions/removals, CH_4, N_2O, NO_x, CO, NMVOC; (b) direct N_2O emissions from N fertilization of forest land and other; (c) CO_2 emissions from agricultural lime application, and (d) biomass burning: CO_2, CH_4, N2O.

[20] Land cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures. Land use is a more complicated term. Natural scientists define land use in terms of syndromes of human activities such as agriculture, forestry and building construction that alter land surface processes including biogeochemistry, hydrology and biodiversity. Social scientists and land managers define land use more broadly to include the social and economic purposes and contexts for and within which lands are managed (or left unmanaged), such as subsistence versus commercial agriculture, rented vs. owned, or private vs. public land. While land cover may be observed directly in the field or by remote sensing, observations of land use and its changes generally require the integration of natural and social scientific methods (expert knowledge, interviews with land managers) to determine which human activities are occurring in different parts of the landscape, even when land cover appears to be the same.

[21] FiBL: Research Institute of Organic Agriculture; IFOAM: International Federation of Organic Agriculture Movements; statistics at: http://www.organic-worls.net/statistics-data-tables-excel.html#c6202

TABLE 8 LAND USE CHANGE MATRIX FOR THE EU-27 IN 2004 [1000 HA]

from / *to*	Forest land	Cropland	Grassland	Wetland	Settlements	Other land	Total rows	Conversion
Forest land	150 606	341	840	95	645	353	152 881	2 275
Cropland	1 778	110 356	10 683	70	1 202	916	125 005	14 648
Grassland	3 219	10 309	56 390	123	1 816	1 243	73 100	16 710
Wetland	402	56	73	19 934	51	150	20 666	732
Settlements	341	320	554	56	20 213	139	21 623	1 410
Other land	1 598	364	906	201	449	27 285	30 803	3 518
Total columns	157 945	121 745	69 447	20 478	24 377	30 086	424 077	39 293
Net change	5 064	-3 260	-3 653	-188	2 753	-717	0	

Source: UN (2009)

Note: shaded values are land use categories remaining the same within the given year; red are negative values (e.g. a net reduction of cropland took place as a result of conversions of other land use categories to cropland and conversion of cropland to other land use categories).

A.1. UNFCCC – NATIONAL INVENTORIES

National inventory reports (NIR)—e.g. EEA (2010b) and Federal Environment Agency (2010)—and data in the common reporting format (CRF) of all Parties included in Annex I to the Convention are found under National Inventory Submissions (UN, 2009). Data in CRF tables 5.A to 5.F are on land use and land conversion in the respective year of the data set (data are available for the EU-27 and Germany for 1990-2008), and are transferred to a simple land use change matrix. Such a matrix with 2004 data for the EU-27 is presented in Table 8.

Based on these and other data, the net CO_2 emissions/removals from LULUCF[22] as well as emissions of N_2O, CH_4, NOx, CO, NMVOC are reported in Table 5 of NIR (with calculations in Tables 5(I) to 5(V)).

The respective territorial inventory databases contain the data for the EU-27 and Germany as indicated above. They further contain land use data from FAO ResourceSTAT[23] for comparison purposes.

In addition, the net CO_2 emissions/removals from LULUCF have been included in the territorial inventory of emissions to air. A net removal of CO_2 emissions (negative value) signifies an intake of CO_2 (sink). Net emissions have been accounted as biogenic CO_2 emissions.

Although the data is highly aggregated by land use types, NIRs provide valuable information.

A.2. CLC – CORINE LAND COVER

CORINE[24] land cover is a European Commission Program aimed at gathering information relating to land use and land cover, for which the European Environment Agency (EEA) carries responsibility to

[22] It should be noted that this refers to direct land use change effects only. Indirect land use change effects are not addressed but rather subject to ongoing research (for example, in case existing cropland is used for biofuels crops instead of crops for nutrition, the cultivation of the latter may be shifted to another piece of land which e.g. may have been natural ecosystems land before).

[23] http://faostat.fao.org/site/377/default.aspx#ancor

[24] CORINE: Coordinated Information on the European Environment.

provide information. The CORINE land cover[25] (CLC) classification comprises three levels and 45 classes at the highest level of detail (3-digits) as presented in Annex 1 in Table 24.

EU-27 data are not available for 1990 (no CLC 1990 for CY, MT, SE (EEA, 2006)), but only for 2000 for the time being. Data on land cover changes between 1990 and 2004 is only available for an EU-24 aggregate (EEA, 2006). In general, CORINE land data are available for 1990, 2000 and 2006. They include information for Germany (Keil et al., 2005 and 2010). In addition to information on the areal extents of the 45 land cover classes differentiated by CORINE, the reports for Germany also cover dominant land cover changes. While for example the most obvious land cover change between 1990 and 2000 was from CLC 211 to 231, it was from CLC 312 to 324 between 2000 and 2006. The authors (Keil et al., 2005) interpreted the change from CLC 211 (arable land) to 231 (pastures) as extensification of agriculture, and the change from CLC 312 (coniferous forest) to 324 (transitional woodland shrub) as loss of forest area. In turn, the change from CLC 211 to 231 was only of minor importance in the period between 2000 and 2006, when the trend was in the opposite direction: the change from CLC 231 to 211 was much more pronounced and ranked second among all changes. The authors interpreted this as intensification in agriculture. Keil et al. (2005) provide an overview of general possible interpretations of CLC changes (Table 9) and allocated these to each type of change (from one 3-digit CLC to another).

A decision is outstanding whether CLC data are deemed to be useful for the development of the inventory indicators. Therefore, detailed data have been acquired for neither the EU-27, nor for Germany—and in fact, there is no data available on land cover changes at the EU-27 level. When evaluating the data made available through CORINE, it needs to be considered that these data are snapshots over longer time periods and therefore not as useful for monitoring environmental changes as annually reported data. Regarding the consistency with LCI data it should be noted that the ILCD reference elementary flows refer to an extended and further differentiated land classification system (EC, 2010b).

B) LAND USE STATISTICS

Eurostat provides land use data in its data base “env_la_luq1-Land use by main category”. This data base covers in principle all 27 EU Member States for the years 1950, 1970, 1980, 1985, 1990, 1995, 2000. Recent and up to date information is hence not available. In addition, the data display many gaps (e.g. built-up and related land). They are thus not appropriate for use in this project. For the EU-27, the UNFCCC data (see A.1) seem to be the best currently available statistics on comprehensive coverage of land use.

FOR GERMANY, THE FEDERAL STATISTICAL OFFICE OF GERMANY PROVIDES DETAILED LAND USE DATA FROM CADASTRAL SURVEY AS PRESENTED IN

Table 10 (shaded cells provide details for agricultural land; categories marked with asterisk (*) are sub-categories of built-up and related land).

C) AGRICULTURAL LAND USE STATISTICS

There are two data sets of the FAO on land use in agriculture which are referred to in this project:

- “ResourceSTAT Land” for aggregated level data, and
- “Production Crops” for detailed data on primary crops

ResourceSTAT Land[26] contains land use data with the EU-27 breakdown presented in Table 11. These data are also available for each Member State of the EU-27.

[25] http://www.eea.europa.eu/publications/COR0-landcover

Production Crops[27] contains data for all primary crops with reference to the following parameters:

- Area Harvested
- Yield
- Production Quantity
- Seed

These data are available for the EU-27, as well as for each Member State. All relevant data have been acquired. The data has been evaluated by experts and is considered to be of high quality.

The Research Institute of Organic Agriculture FiBL provides data on organic agriculture (including in-conversion) in the EU-27 and Member Countries for the years 2003 to 2009[28]. The survey on organic farming in Europe is carried out annually by the Research Institute of Organic Agriculture FiBL (Frick, Switzerland) as part of the global survey on organic agriculture. The global survey is carried out in cooperation with the International Federation of Organic Agriculture Movements (IFOAM). The information is based on statistics provided by national ministries, Eurostat, NGOs or the private organic sector.

D) FORESTRY LAND USE STATISTICS

Land use for forestry purposes has been addressed above in connection with the data sources discussed with regard to LU and LUC. However, the question what kind of raw data shall be used for the inventory remains open. Depending on the answer to this question, specific sources for data and information may be referred to. Possible sources include e.g.:

- The European Forest Institute (EFI): www.efi.int/portal
- The Center for International Forestry Research (CIFOR): www.cifor.cgiar.org
- The Commonwealth Forestry Association (CFA): www.cfa-international.org

TABLE 9 RESULTS FOR LAND USE AND LAND COVER CHANGES ACCORDING TO CORINE

In German	In English
Intensivierung in der Landwirtschaft	Intensification of agriculture
Extensivierung in der Landwirtschaft	Extensification of agriculture
Aufforstung	Forestation
Flächen mit Waldverlust	Areas with loss of forest
Urbanisierung/ Zunahme der Versiegelung	Urbanisation/Increase of built-up area
Neue Abbaufläche	New area for mineral resource extraction
Rekultivierung von Abbauflächen	Rehabilitation of mining areas
Neue Wasserfläche	New water areas
Sonstige Änderung	Other changes

Note: The original terms in German are provided since the English translations are not official

[26] http://faostat.fao.org/site/377/default.aspx#ancor

[27] http://faostat.fao.org/site/567/default.aspx#ancor

[28] http://www.organic-world.net/statistics-europe-production.html

TABLE 10 LAND USE STATISTICS DATA FOR GERMANY [km^2]

Land use	2000	2004	2005	2006
Total area	**357 023**	**357 058**	**357 058**	**357 058**
Buildings*	23 081	23 938	24 047	24 260
Production sites	2 528	2 518	2 588	2 586
of which: area for extraction of minerals	1 796	1 764	1 813	1 804
Recreation*	2 659	3 131	3 338	3 368
Traffic*	17 118	17 446	17 538	17 693
Agriculture	192 490	191 124	190 720	190 400
Agricultural used area	170 680	170 205	170 351	169 510
of which: arable land and permanent crops	120 200	121 071	121 062	120 693
of which: arable land and permanent crops: organic farming	2 865	4 029	4 236	4 392
of which: arable land and permanent crops: area for ecological compensation	0	0	0	0
of which: permanent crops	2 160	2 084	2 029	2 032
of which: set-aside land (excluding use for materials)	0	0	7 938	7 390
of which: pastures	50 480	49 134	49 289	48 817
of which: pastures: organic farming	2 596	3 650	3 838	3 988
Non-agricultural used agriculture area	21 810	20 919	20 369	20 890
Forest area	105 017	105 398	105 398	105 398
Water area	6 653	6 758	6 785	6 811
Areas for other use	7 478	6 744	6 643	6 542
of which: cemetery*	350	352	353	356
Total built-up and related area*	43 940	45 621	46 050	46 458
Production sites excluding areas for minerals extraction*	732	754	775	782
Organic farming as % of agricultural used area	3.2%	4.5%	4.7%	4.9%

TABLE 11 FAO LAND USE STATISTICS DATA FOR THE EU-27

Item (1000 ha)	2004	2005	2006	2007	2008	2009
Country area	432 892	432 894	432 923	432 921	432 922	432 925
Land area	418 243	418 417	418 146	418 139	418 082	418 174
Agricultural area	192 432	187 980	191 608	186 504	190 130	188 406
Agricultural area organic, total	4 557	6 039	5 418	7 030	6 327	6 906
Agricultural area certified organic	3 233	4 300	3 486	5 041	4 242	4 873
Agricultural area in conversion to organic	1 068	1 505	1 461	1 466	1 549	1 661
Arable land and Permanent crops	122 941	121 806	121 972	120 409	121 237	120 856
Arable land	110 599	109 406	109 671	108 217	109 112	108 833
Arable land organic, total	270	340	441	552	721	2 081
Arable land area certified organic	182	218	269	342	527	640
Arable land area in conversion to organic	68	101	150	179	160	230
Permanent crops	12 342	12 400	12 301	12 193	12 125	12 023
Permanent crops organic, total	7	14	12	16	19	23
Permanent crops area certified organic	3	6	5	7	11	13
Permanent crops area in conversion to organic	3	7	6	7	5	6
Permanent meadows and pastures	69 491	66 174	69 636	66 095	68 893	67 550
Permanent meadows and pastures organic, total	829	756	827	975	1 086	1139
Permanent meadows and pastures area certified organic	520	449	463	566	650	668
Permanent meadows and pastures area in conversion to organic	74	97	133	151	154	142
Forest area	153 812	154 342	154 846	155 351	155 856	156 361
Other land	71 999	76 095	71 691	76 283	72 097	73 407
Inland water	14 649	14 477	14 777	14 782	14 838	14 752
Total area equipped for irrigation	18 473	18 542	18 377	18 246	18 255	213

3 IMPORTED AND EXPORTED PRODUCT GROUPS AND REPRESENTATIVE PRODUCTS

3.1 BACKGROUND

In order to assess the environmental impacts of trade, 15 major import and export product groups were selected. In a second step, one representative product was selected for each product group. For each selected imported product, the three most relevant export countries were identified and considered in the further analysis. Life cycle inventory (LCI) data regarding the production and transport were then used to calculate the inventory (emissions and resource extraction) associated with the import or export of each product.

3.2 SELECTION OF IMPORT AND EXPORT GROUPS AND REPRESENTATIVES

For the selection of relevant import and export product groups, the 2-digit (HS2) level of the HS-CN classification of the external trade database was used (ComExt[29] (Eurostat, 2010)). The selection of the product groups was based on a pre-selection of the 50 most important product groups by mass, and a final selection based on life cycle inventory (LCI) data on important products within these 50 product groups. More information can be found in the EC report (2012a).

Table 12 presents the selected product groups for imports and Table 13 summarises the selected product groups for exports. Based on the CN8 statistics, representative products were identified for the selected product groups. The criteria for selecting the most appropriate representative product for each group were their relevance by mass and relevance by value (EC, 2012a); selection by mass only will not lead to a meaningful results. In order to consider both criteria in a consistent way, scaling factors are calculated by dividing the total mass or value of the HS2 group by the mass or value of a possible representative. The selected representative of each HS2 group/cluster has the smallest sum of both scaling factors (mass and value) compared with the other products in the group. The following exceptions were made:

- Waste and metal scrap cannot be seen as meaningful representatives of their product groups. Even though they achieved the smallest sum of the two scaling factors, neither waste nor metal scrap was selected as representative products.
- Group CN8 is not sufficiently homogenous to find an appropriate representative product (e.g. *84733090 parts and accessories for automatic data-processing machines*).

In both cases the product with the next smallest scaling factor was used as representative.

In this first stage of the indicator development only one representative for each import and export group was used, the only exception being HS2 group 84. The HS2 group 84 was divided into two groups due to the wide range of products covered (laptops vs. excavators). HS 84b was therefore defined to cover the HS groups 8470 to 8474 (automatic data-processing machines and parts therefore), and HS 84a all other HS4 groups. Furthermore it is be noted here that about 50% of the HS2 groups 61, 62 and 63 are cotton textiles and the most important representative in terms of mass is the CN8 group 61091000 cotton t-shirts. For this reason, group 52 cotton fabrics and yarn was merged with the groups 61, 62 and 63.

[29] http://epp.eurostat.ec.europa.eu/portal/page/portal/external_trade/data/database

TABLE 12 PRIMARY IMPORT TO THE EU-27, INCLUDING THE TOP 3 SOURCE COUNTRIES

#	HS2 code	Product groups	Representative	CN8 code	Source country of imports		
					1.	2.	3.
1	27	Mineral fuels	crude oil	27090090	RU	NO	SA
2	72&73	Iron & Steel	non alloyed steel slaps or coils	72071210	RU	UA	MX
3	76	Aluminium	unwrought aluminium	76011000	RU	MZ	NO
4	61/62/ 63/52	Textiles/Cotton	t-shirts (Cotton)	61091000	BD	TR	CN
5	87	Road vehicles	passenger car	87032319	JP	KR	TR
6	39	Plastics	polyethylene bags	39232100	CN	MY	TH
7	84a	Machinery	air conditioning	84158190 (from 2006 84158100)	CN	TH	JP
	84b	Machinery	computer/laptop	84713000			
8	85	Electrical machinery	video recording or reproducing apparatus	85219000	CN	ID	TR
9	26	Ores	iron ore	26011100	BR	AU	MR
10	28	Inorganic chemicals	aluminium oxide	28182000	JM	SR	BA
11	31	Fertilizers	urea	31021010	RU	EG	HR
12	29	Organic Chemicals	methanol	29051100	CL	RU	LY
13	17	Sugar	cane sugar	17011110	BR	MU	FJ
14	23	Residues and waste from the food industry	soya oil cake	23040000	AR	BR	
15	02	Meat	bovine meat boneless	02013000	BR	AR	UY

Note: AR – Argentina, AU – Australia, BA – Bosnia and Herzegovina, BD – Bangladesh, BR – Brazil, CL – Chile, CN – China, DE – Germany, EG – Egypt, HR – Croatia, ID – Indonesia, JM – Jamaica, JP – Japan, KR – Republic of Korea, MR – Mauritania, MU – Mauritius, MX – Mexico, MY – Malaysia, MZ – Mozambique, NO – Norway, RU – Russian Federation, SA – Saudi Arabia, SR – Suriname, TH – Thailand, TR – Turkey, UA – Ukraine, UY – Uruguay

TABLE 13 PRIMARY EU-27 EXPORT

#	HS2 code	Product groups	Representative	CN8 code
1	72&73	Iron and steel	Hot rolled non-alloyed steel	72085120
2	27	Mineral fuels	Crude oil	27090090
3	87	Road vehicles	Passenger cars	87032319
4	39	Plastics	Propylene	39021000
5	84a	Machinery	Self-propelled excavators	84295210
	84b	Machinery	Data processing machines	84714990 (from 2006 84714900)
6	76	Aluminium	Alloyed aluminium sheets	76061291
7	47&48	Pulp and paper	Paper and paperboard	48101990
8	85	Electrical machinery	Electric motor parts	85030099
9	31	Fertilizers	NPK fertilizer	31052010
10	17	Sugar	White sugar	17019910
11	4	Dairy	Milk and cream in solid forms	04021019
12	2	Meat	Frozen boneless swine meat	02032955
13	28	Inorganic chemicals	Aluminium oxide	28182000
14	29	Organic chemicals	Caprolactam	29337100
15	25	Minerals	Portland cement	25232900

A challenge for the updating of the resource indicators might result from regrouping of products into other CN8 product groups over time. For instance, since 2006 representative product 'air conditioner' (listed in Table 12) has been accounted for under CN 84158190. However, until 2005 it was accounted under CN 84158100. An annual updating of the indicators therefore has to be preceded by a check of possible changes in the HS-CN classification.

After the selection of the representative products (based on the 8 digit code), the three most important export countries were identified for each imported product group representative, based on trade statistics.

It was not possible to identify three export countries for each representative product. For example for product group 23 'Residues and waste from the food industry', approximately 99% of the representative product soya oil cake is imported from Argentina and Brazil. The third largest exporter, Norway, accounted for only 0.5%.In this case, for example, only two export countries (Argentina and Brazil) were selected.

For the identification of the 15 primary EU-27 exports (product groups and the representative products) the same approach was taken as for the identification of the 15 primary EU-27 imports. The product groups and the selected representative products are presented in Table 12 for imports and Table 13 for EU-27 exports. Table 12 further lists the three primary source countries of the imported products.

3.3 EMISSION AND RESOURCE EXTRACTION INVENTORY FOR IMPORTS AND EXPORTS

The inventory of emission releases and resource extraction associated with the production and transport of imports and exports is calculated based on life cycle inventory (LCI) data sets. These are referred to for all identified representative products of the EU-27's imports and exports. The following steps were taken to calculate the entire inventory for the EU-27's imports:

- A calculation was performed for each representative product (e.g. passenger car): For each of the 3 primary source countries (for passenger cars: JP, KR and TR) the imported quantities were multiplied with the applicable LCI data set for the production of one tonne of this product in the relevant country.
- The emissions as well as the resource extraction associated with the imports from the three primary source countries were added up for each product representative individually. These sums were then extrapolated to reflect the overall impact associated with the EU-27 imports (e.g. when the three main source countries provided 80% of the imported quantities by mass, the emissions and resource extraction was multiplied with 1.25).
- The impacts associated with each product group were then extrapolated based on the impacts calculated for the group's representative product (i.e. if the representative product of CN8 stands for 10% of the HS2 group by mass, the emissions and resource extraction of the representative product were multiplied by 10 to calculate the impacts of the entire CN8 group).
- In a next step, the emissions and resource extraction associated with all 15 product groups were added together.
- Finally a third extrapolation was performed to evaluate the overall impacts associated with the EU-27's imports, based on the results for the 15 selected product groups (i.e. if the selected product groups represent 85% of the total imports by mass, the totalled emissions of the 15 product groups are multiplied by 1.18).

The same procedure was used for calculating the inventory for the EU-27's exports. The only exception is that just one LCI data set was required per representative product (only EU-27 or Germany as export country).

TABLE 14 SCALING FACTORS USED TO CALCULATE THE INVENTORY OF THE IMPORTS

#	Code (HS2)	Product groups	Representative	Code CN8	Scaling factor 3 countries to complete CN8 by mass	Scaling factor CN8 to HS2 by mass
1	27	Mineral fuels	crude oil	27090090	1.6	2.0
2	72&73	Iron & Steel	non alloyed steel slaps or coils	72071210	1.1	14.5
3	76	Aluminium	unwrought aluminium	76011000	1.5	2.4
4	61/62/ 63/52	Textiles/Cotton	t-shirts (Cotton)	61091000	1.6	15.6
5	87	Road vehicles	passenger car	87032319	1.1	6.6
6	39	Plastics	polyethylene bags	39232100	1.2	16.5
7	84a	Machinery	air conditioning	84158190 (from 2006 84158100)	1.1	39.4
	84b	Machinery	computer/laptop	84713000		25.9
8	85	Electrical machinery	video recording or reproducing apparatus	85219000	1.1	38.1
9	26	Ores	iron ore	26011100	1.5	1.5
10	28	Inorganic chemicals	aluminium oxide	28182000	1.1	7.6
11	31	Fertilizers	urea	31021010	1.2	4.7
12	29	Organic Chemicals	methanol	29051100	1.9	3.6
13	17	Sugar	cane sugar	17011110	1.8	2.3
14	23	Residues and waste from the food industry	soya oil cake	23040000	1.0	2.6
15	02	Meat	bovine meat boneless	02013000	1.2	7.0

TABLE 15 SCALING FACTORS USED TO CALCULATE THE INVENTORY OF THE EXPORTS

#	Code (HS2)	Product groups	Representative	Scaling factor CN8 to HS2 by mass
1	72&73	Iron and steel	Hot rolled non-alloyed steel	29.3
2	27	Mineral fuels	Crude oil	6.0
3	87	Road vehicles	Passenger cars	4.8
4	39	Plastics	Propylene	16.3
5	84a	Machinery	Self-propelled excavators	61.9
	84b	Machinery	Data processing machines	19.2
6	76	Aluminium	Alloyed aluminium sheets	9.1
7	47&48	Pulp and paper	Paper and paperboard	14.9
8	85	Electrical machinery	Electric motor parts	31.0
9	31	Fertilizers	NPK fertilizer	8.8
10	17	Sugar	White sugar	1.2
11	4	Dairy	Milk and cream in solid forms	9.7
12	2	Meat	Frozen boneless swine meat	5.9
13	28	Inorganic chemicals	Aluminium oxide	8.0
14	29	Organic chemicals	Caprolactam	36.4
15	25	Minerals	Portland cement	4.9

To generate the results, the extrapolation was done by mass, but the extrapolation by value is also possible. However, the only good that cannot be scaled by mass is electricity. For some countries in the EU-27 a substantial share of their electricity is imported or exported. Therefore, the emissions and resource extraction associated with the generation of electricity were calculated separately and added to the inventory in an additional step. Electricity figures were taken from energy statistics (in GWh) provided by Eurostat[30].

Table 14 and Table 15 present all relevant scaling factors by mass for the 15 import and export product groups. The 15 representative products (CN8) cover in total 40% of the imported goods by mass for the EU-27 indicators within the investigated period. The 15 product groups (HS2) cover in total around 79% of the imports. For exports, the representative products (CN8) cover 8%, and the 15 product groups (HS2) cover 65% by mass. The coverage of all representatives (CN8) is markedly lower for Germany (27% share of all imports and 4% share of all exports by mass), as the selection of the representatives was not specific to a particular Member State.

3.4 TOURISM

BACKGROUND

In addition to the territorial emissions and resource use and imported and exported goods, environmental impacts associated with services that cross national borders should be taken into account. Initially, the service industry tourism was considered for inclusion. It was intended to also include business trips, but the available data did not support this[31]. The approach was proposed and it can later be refined—as for goods—to include further product groups. However, due to insufficient data coverage, it was not possible to include tourism in preliminary calculations.

METHODOLOGICAL APPROACH

The approach to account for environmental impacts of tourism (and business trips) is outlined in the life cycle indicators framework (EC, 2012a). The approach for tourism can be summarised as follows:

- First, compare the number of person-days spent outside the reference region (e.g. EU-27 residents) with the number of person-days foreigners (non-residents) spent within the reference region,
- Calculate the life cycle inventory (resource consumption/emissions) per person-day within the reference region,
- Calculate the inventory from the tourism balance as:
  - number of person-days per holiday x life cycle inventory intensity of the residents outside the reference region, minus
  - number of person-days per holiday x life cycle inventory intensity of foreigners spending their vacation in the reference region,
- Combine LCI data for different passenger transport options (passenger transport to holiday region) with statistics on holiday destinations, number of passengers and a convention on the transport mode (mix) (of course only required for holidays of EU-27 citizen).

[30] http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database

[31] The Eurostat Tourism statistics (http://epp.eurostat.ec.europa.eu/portal/page/portal/tourism/data/database) report in this case only data for outbound business trips. Furthermore, there is no data for EU-27, but for Germany.

It is assumed that the impact intensity is independent of the reference region.

INVENTORY FOR TOURISM

There are two parts of the tourism inventory, one for person-days and the other for passenger transport to the holiday region. Table 16 gives an overview of the statistical data sets of the Eurostat Tourism Statistics that provide suitable raw data for the tourism inventory.

Table 17 and Table 18 present the available data on person-days for holidays of EU-27 resp. German citizens outside their region (item 1.1 in the table) versus person-days of non-residents within the region (item 2.1 in the table). Data coverage for both the EU-27 and Germany is given only for 2007. It is questionable whether estimates allow for valid data to fill the existing gaps. Estimations appear problematic when observing trends such as the declining number of person-days German citizens spent outside their country between 2004-2007, which is countered by an increase in numbers in 2008. Another uncertainty is given by the cut-off criterion of x plus nights which is 4 plus nights for the EU-27 but 1 plus nights for Germany.

The impacts (emissions and resources) for the person-days are calculated based on the energy consumption associated for the operation of a hotel room for one day (including all overheads, such as floors, lobby, kitchen etc.).

TABLE 16 EUROSTAT DATA SOURCES FOR THE TOURISM INVENTORY

	Residents	Non-residents	Eurostat Data Set
Number of nights - Domestic		X	Nights spent by non-residents in tourist accommodation establishments - world geographical breakdown - annual data (tour_occ_ninraw)
Number of nights - Outbound	X		Number of tourism nights - by main mode of transport used - annual data (tour_dem_tntr)
			Number of tourism nights - geographical breakdown - annual data (tour_dem_tnw)
Destination	X		Number of tourism nights - geographical breakdown - annual data (tour_dem_tnw)
Transport mode	X		Number of tourism nights - by main mode of transport used - annual data (tour_dem_tntr)
Number of passengers – Outbound (=No of nights outbound/average No of nights per person)	X		Number of tourism nights - by main mode of transport used - annual data (tour_dem_tntr)
			Number of tourism nights - geographical breakdown - annual data (tour_dem_tnw)
			Number of tourism nights - by length of stay - annual data (tour_dem_tnls)

TABLE 17 TOURISM PERSON-DAYS FOR EU-27

#	Item	2007	2008
1	Number of person days of residents outside reference region	n/a	n/a
1.1	Holidays - Outbound (4 plus nights)	2 139 121 163	n/a
2	Number of person days of non-residents within reference region	n/a	n/a
2.1	Nights spent by non-residents in tourist accommodation establishments	226 833 649	219 706 752

TABLE 18 TOURISM PERSON-DAYS FOR GERMANY

#	Item	2004	2005	2006	2007	2008
1	Number of person days of residents outside reference region	n/a	n/a	n/a	n/a	n/a
1.1	Holidays - Outbound (1 plus nights)	820 291 000	763 049 724	748 809 043	640 406 891	658 410 126
2	Number of person days of non-residents within reference region	n/a	n/a	n/a	n/a	n/a
2.1	Nights spent by non-residents in tourist accommodation establishments	n/a	n/a	n/a	54 485 379	56 247 039

Data for the passenger transport to the holiday region are available for Germany only; there are no data for the EU-27. For Germany the impact associated with holiday-related passenger transport is calculated as follows:

- The number of the German residents' trips to destinations outside the reference region (by destination country) is taken from Eurostat statistics (Holidays – Outbound – 1 plus nights);
- Distances from Frankfurt/Main to the respective capitals of the destination countries are used as approximations for the travelled distances. Frankfurt/Main is at the centre of Germany and has the largest international airport of the country.[32]
- The share of transport modes (car, rail, plane) is modelled according to the simple assumptions given above;
- The passenger-km are calculated for each transport mode (assuming two passengers per car on average[33]);
- The impacts (emissions and resources) for the three different transport modes are calculated based on LCI data and the following assumptions:
    - Travel by car: medium size passenger car, Euro4, 50% diesel and 50% gasoline;
    - Travel by train: intercity train with a load factor of 39% and a electricity consumption of 0.029 kwh/seatkm (IFEU, 2008)
    - Travel by plane: Boeing 747 as an average for all flights, as long distance flights are dominant (>90%).

[32] Distances (flights) are taken from http://www.flugzeugposter.de/cgi-fp/shop.cgi?fra_entfernung=1

[33] This reflects the average person number per household in Germany in 2006, as no specific data were found.

4 CALCULATION OF RESOURCE INDICATORS

4.1 DESCRIPTION OF CALCULATION PROCEDURE

The resource life cycle indicators are calculated in several steps. The first step is to calculate the inventory of resource extraction (minerals, metals, fuels, water etc.), emissions (into air, water, soil) and land use for the apparent consumption over time for the EU-27 territory and single Member State. In a second step an impact assessment is performed based on impact assessment methodologies (EC, 2011c and 2012a). In a third step the resource impact indicators and sub-indicators are calculated following life cycle assessment (LCA) methodology (EC, 2012a). The results are calculated at three different levels:

- at inventory level (e.g. air emissions like CO_2, SO_x, NO_x, resource extraction like crude oil, natural gas, minerals, water, land use, etc.),
- at impact categories level (e.g. climate change, acidification, euthrophication, etc.—either individually calculated or optionally normalized, weighted and aggregated to an intended single indicator of the overall environmental impact), and
- at resource impact indicator level (i.e. to demonstrate a potential of decoupling of economic growth and productivity from environmental impacts).

TABLE 19 IMPACT CATEGORIES AND THEIR UNITS

Impact categories[34]	Unit
Climate change midpoint	kg CO_2 eq.
Ozone depletion midpoint	kg CFC11 eq.
Human toxicity midpoint, cancer effects	CTUh
Human toxicity midpoint, non-cancer effects	CTUh
Particulate matter/Respiratory inorganics midpoint	kg PM2.5 eq.
Ionizing radiation midpoint, human health	kg U235 eq.
Ionizing radiation midpoint, ecosystems	CTUe = PAF*m3*year
Photochemical ozone formation midpoint, human health	kg C_2H_4 eq.
Acidification midpoint	mol H+
Eutrophication terrestrial midpoint	kg N eq.
Eutrophication freshwater midpoint	kg P eq.
Eutrophication marine midpoint	kg N eq.
Ecotoxicity freshwater midpoint	CTUe = PAF*m3*year
Land use midpoint	kgCdeficit*year
Resource depletion water, midpoint	Environmental Load (EL)
Resource depletion, mineral, fossils and renewables, midpoint	Person Reserve (PR)

[34] For land use and resource depletion water no impacts have been calculated due to missing consistent life cycle inventory (LCI) data.

TABLE 20 SECTIONS OF THE PROTOTYPE

Prototype section	Worksheet	Content
0.1. References	0.1 List of references	List of used references for domestic inventory
1 Domestic Inventory	1.1.1 Domestic Air Inventory	Inventory of emissions to air, water and soil for the EU-27 territory. Reference years 2004-2006 (minimum). Nomenclature as taken from the relevant literature
	1.2. Domestic Water Inventory	
	1.4.1 Domestic Land Use and Land Use Change (LULUC)	Inventory of land use and land use change for the EU-27 territory. Reference years 2004-2006 (minimum). Nomenclature as taken from the relevant literature
	1.4.2 Domestic Land Use Agriculture	
	1.4.3 LULUCF GHG	
	1.5 Domestic Water Use	Inventory of resource extraction for the EU-27 territory for energy carriers, water, biomass, metals and non-metallic minerals. Reference years 2004-2006 (minimum). Nomenclature as taken from the relevant literature
	1.6 Domestic Energy	
	1.7.1 Domestic biomass	
	1.7.2 Domestic metals	
	1.7.3 Domestic non-metallic minerals	
	1.8 Mapping domestic inventory	Summary of all inventory data from 1.1 to 1.7 in measurement units as indicated
2 Imports and exports	2.0. LCI data import	LCI (per functional unit) of the data sets used to cover products imported to the EU-27 territory and exported from the EU-27 territory. LCI flow nomenclature as used in LCA software GaBi
	2.1. LCI data	LCI (per functional unit) of the used data sets mapped to the ILCD nomenclature/ILCD reference elementary flow list
	2.2.1 Import Inventory 2004	LCI of the entire imports combining the LCI data in 2.1 and trade statistics for the relevant reference years
	2.2.2 Import Inventory 2005	
	2.2.3 Import Inventory 2006	
	2.3.1 Export Air Inventory 2004	LCI of the entire exports combining the LCI data in 2.1 and trade statistics for the relevant reference years
	2.3.2 Export Air Inventory 2005	
	2.3.3 Export Air Inventory 2006	
3 Apparent consumption	3.1 LCI inventory apparent consumption	LCI of the domestic inventory plus imports minus exports for the relevant reference years
	3.2 Characterization factors	Characterization factors for the selected impact categories and LCIA methodologies
	3.3.1 – 3.3.16 LCIA total inventory	LCIA results of the selected impact categories for the total inventory (domestic inventory plus imports minus exports)
4 Results	4.1 Results	Time series of selected LCI and LCIA results; time series for resource impact indicators (all eco-efficiency indicators, as well as selected resource productivity and resource specific impacts indicators). Normalized results for resource impact indicators
	4.2 Normalization and weighting data	Diagrams for normalized resource impact indicators
	4.3.1 Diagrams LCI	Diagrams for selected results on inventory level
	4.3.2 Diagrams LCI Split up	Diagrams presenting main contributors (elementary flows) for selected impact categories
	4.3.3 Diagrams LCIA	Diagrams presenting resource indicators for all assessed impact categories
	4.3.4 Diagrams Eco-efficiency	Diagrams presenting eco-efficiency indicators for all selected resource indicators

For this development, the results were calculated for the years 2004, 2005 and 2006. The results shall be updated annually to monitor the development of economic growth and productivity in relation to associated environmental impacts. The results for all three levels are separately displayed for the EU-27/Member State territory, for the imports and exports, and for the apparent consumption, in order to enable an enhanced analysis of possible changes. In addition, the results for imports and exports can be further disaggregated to present the relative significance and contribution of individual import and export product groups (HS2 level) at inventory level or impact assessment level. The impact categories (Table 19) selected follow the recommendation of the ILCD Handbook (EC, 2010c), as do impact assessment methods (EC, 2011c).

4.2 STRUCTURE OF THE CALCULATION PROTOTYPE

The prototype is structured in five sections. Table 20 presents the content of the different sections of the calculation prototype (for the EU-27; the same structure is used for Germany).

4.3 FUNCTIONALITY OF THE PROTOTYPE

DOMESTIC INVENTORY

The first section of the prototype contains the domestic inventory of all elementary flows for which data was available or gaps could be filled with appropriate estimates. The domestic inventory is structured into different types of resource extraction (water, energy, metals etc.), land use and land use change, and emissions into the environmental media air, water and soil. For emissions, resource extractions and land use covered in the domestic inventory, the original nomenclature of the literature source/data base is used, and the original unit of the data is provided.

IMPORTS AND EXPORTS

Section 2 covers the life cycle inventory (LCI) of the imports and exports. The first worksheet contains the LCI per functional unit[35] of all required LCI data sets (15 imported products from three to four different export countries/region, 15 exported products). In these preliminary calculations, the life cycle data were extracted from the LCA software GaBi 4 (PE International, 2007), however, for the future calculation the life cycle data will be obtained from wider sources[36]. The worksheet 2.1 is required for mapping the LCI of the data sets with the ILCD reference elementary flows (EC, 2010b and 2010d).

In worksheets 2.2.1-2.2.3 the inventory (resource extraction and emissions) for the products imported into the EU-27 territory is calculated. Each worksheet contains the calculation for one reference year. For each of the 15 selected product groups the mass and value of the entire HS2 group (e.g. HS2 27 mineral fuels), the entire CN8 group (e.g. CN8 product group 27090090 crude oil) and the three main export countries from where the product is imported are displayed in the upper section of the prototype. To calculate the inventory the following calculations are made for each product group:

- The total mass of the imported product is determined for the three (or four, for the specific Member State indicators) principal source countries. This mass is then multiplied by the corresponding LCI data set (e.g. mass of exported crude oil from Russia multiplied by the LCI data set ‘RU: crude oil’).
- The inventories for each of the three source countries are added together to one inventory for the imported product (e.g. inventory for the amount of imported crude oil from the three principal source countries Russia, Norway and Saudi Arabia). In a next step, this inventory is multiplied by a scaling factor to extrapolate the result in accordance with the total imports of the product (e.g. inventory for imported crude oil from Russia, Norway and Saudi Arabia extrapolated to reflect the impacts associated with total crude oil imports to the EU-27/Member State, i.e. including imports from other source countries). The same procedure is done for the additional product group covering imported electricity.
- A second extrapolation is done to estimate the overall inventory for each of the 15 identified HS2 product groups (e.g. HS2 27 mineral fuels). For this extrapolation, the inventory of the imported product (e.g. CN8 27090090 crude oil) is multiplied by a second scaling factor (e.g. quotient of HS 27 mineral fuels and CN (27090090 crude oil).

[35] ISO 14044 (2006) defines the functional unit as ´quantified performance of a product system for use as a reference unit. …. The scope of an LCA shall clearly specify the functions (performance characteristics) of the system being studied. The functional unit shall be consistent with the goal and scope of the study. One of the primary purposes of a functional unit is to provide a reference to which the input and output data are normalized (in a mathematical sense).´

[36]

- The inventory of all 15 product groups is added together and a third scaling is done to estimate the total inventory for all identified product groups ('99 HS2 groups'). Finally, the inventory for imported electricity is added.
- All scaling factors are presented in the prototype and can be used either on a mass or value basis. For this initial development phase, all results are presented with a mass scaling.

In worksheets 2.3.1-2.3.3 the inventory (resource extraction and emissions) for the export of products from the EU-27 territory to trade partners is calculated as outlined in chapter 3. The calculation in the prototype is done in a similar way as for the imports; however, the first two steps are not necessary.

APPARENT CONSUMPTION

In section 3 of the prototype the inventory of the apparent consumption is calculated (domestic inventory plus inventory of imports minus inventory of exports). Worksheet 3.2 contains the characterization factors for all elementary flows covered in the domestic inventory and the inventories of the imports and exports. The following 12 worksheets display the impact assessment results of the domestic inventory, imports, exports and apparent consumption. To calculate results for one impact category (e.g. climate change) the elementary flows that are covered (e.g. for the domestic inventory) are multiplied by the corresponding characterization factors (e.g. carbon dioxide = 1, methane = 25, nitrous dioxide = 298, etc.). The sum of all multiplications is the result of the impact category in the corresponding unit (e.g. kg of CO_2-equivalents) for the domestic inventory, imports, exports and apparent consumption.

RESULTS

Section 4 of the prototype provides time series at an inventory level for selected elementary flows (e.g. carbon dioxide emission into air over time), time series at an impact assessment level (e.g. climate change over time), as well as the resource impact indicators over time. The prototype allows adding further elementary flows.

The eco-efficiency indicators are calculated by dividing the region's or country's GDP by the individual results of the different impact categories of the impact assessment (e.g. GDP/climate change) for the apparent consumption. For visualizing the development of the eco-efficiency indicator, the GDP and the impact category indicator over time in one diagram, a normalisation of the data is necessary. This can be achieved for a specific impact indicator by defining e.g. the 2004 value of both the GDP and the impact category indicator as one ('1'). The relative development over time can then be illustrated in one diagram for both indicators as well as the eco-efficiency indicator.

4.4 UPDATE OF THE PROTOTYPE

The prototype allows to individually exchange the life cycle inventory (LCI) data that was used for the calculation of the import and export inventory. Therefore it is not bound to a single source of data. The ILCD data network[37] is foreseen to feed into future development of life cycle indicators.

[37] http://lct.jrc.ec.europa.eu/assessment/assessment/data

5 RESULTS OF RESOURCE INDICATORS

5.1 OVERVIEW

The selected results for resource life cycle indicators are demonstrated at the inventory level and at the impact assessment level, as well as for the eco-efficiency indicator. The results are generated for both the EU-27 and Germany. The diagrams illustrating the results at an inventory level (single emissions or resources) and impact assessment level (impact categories) present trends over time. Emissions, resource extraction or impacts are presented individually for the domestic inventory, imports, exports and the apparent consumption. Additional results are presented in the Annexes 2 and 3.

The basic idea for demonstrating results at the inventory basis is to get a better understanding of the share of emissions domestically released or resources domestically extracted, versus emissions and resource extractions associated with the import and export of goods. Related developments over time can be observed for the EU-27 territory or Member States. But the monitoring of the domestically released emissions alone does not give a complete picture of the environmental impacts of the EU-27 or one Member State respectively. The transfer of high polluting heavy industry sectors from EU-27 Member States to emerging markets reduces emission releases and resource extraction within the EU-27 territory. However, the manufactured goods from these industry sectors are still in demand and therefore imported into the EU-27, together with commonly imported raw and semi-finished materials. Usually, the overall impact of the industry sector therefore increases because the average production in emerging economies from where the products are imported is less clean and energy-efficient than in Europe.

The aggregation of several emissions contributing to the same impact category—such as carbon dioxide and methane in the context of climate change—enables the monitoring of possible shifts between these emissions (e.g. outsourcing of production in the EU-27 territory and therefore reduction of carbon dioxide emissions vs. higher amount of methane emissions and same level of carbon dioxide emissions associated with the imported goods).

5.2 RESOURCE INDICATORS FOR THE EU-27

5.2.1 INVENTORY LEVEL

Figure 3 presents fossil carbon dioxide emissions released within the EU-27 territory, the emissions associated with imports as well as exports, and the total emissions associated with the EU-27's apparent consumption. The graph illustrates that the emissions for the domestic inventory remain stable between 2004 and 2006, with only a slight decrease of one percent between 2004 and 2005, which is partly already compensated in 2006. Both, imports and exports increased between 2004 and 2006. Carbon dioxide emissions associated with imports, however, are significantly higher than emissions associated with exports (i.e. around 30-40%). Hence, the emissions associated with the EU-27's apparent consumption are higher than to for the domestic inventory (around 5%).

Methane, carbon monoxide, nitrogen oxides and sulphur dioxide emissions all have the same type of trend: the emissions are higher for imports than for exports, and the emissions associated with the imports increase more significantly between 2004 and 20006. The diagrams for the emissions of carbon monoxide, methane and nitrogen oxides are presented in the Annex 2.

Figure 4 demonstrates that for sulphur dioxide emissions, the amount of imported emissions is high compared to the emissions associated with exports, and also relative to domestic emissions.

Emissions associated with the apparent consumption of the EU-27 are therefore significantly higher than domestic emissions, with an increasing trend between 2004 and 2006.

Figure 5 presents the domestic crude oil extraction, the crude oil extraction associated with imports and exports (import of crude oil and crude oil used as feedstock or energy carrier to produce other imported goods). The results demonstrate the EU-27's extreme import dependency with regard to crude oil. Some of the imported crude oil is re-exported which leads to the fact that exports are higher than the domestic extraction, and the apparent consumption is lower than the imports. A continuous increase in consumption levels can be observed between 2004 and 2006.

Figure 6 presents the extraction of all fossil fuels (crude oil, coal, natural gas, peat, uranium). Again, the EU-27 is reliant on imports. However, the domestic extraction includes coal and natural gas produced within the EU-27, and exceeds exports. Consequently, the apparent consumption is higher than the imports.

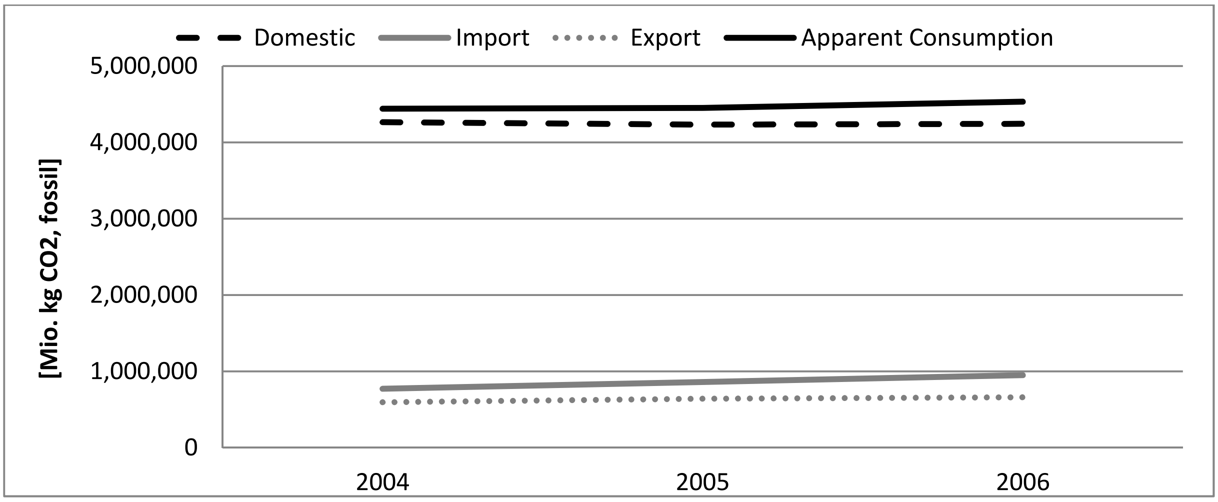

FIGURE 3 CARBON DIOXIDE EMISSIONS (FOSSIL FUELS)[38] (EU-27)

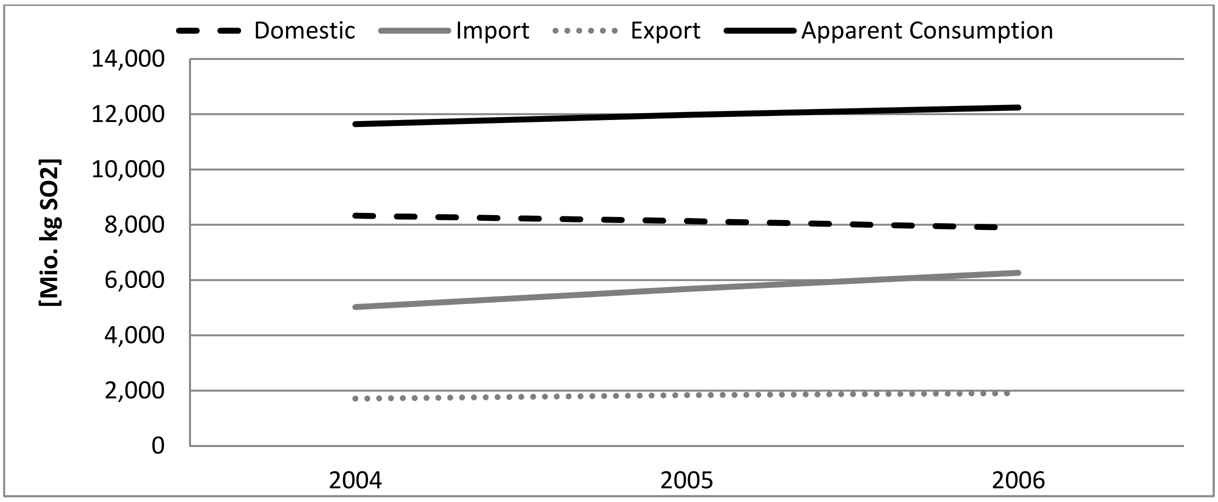

FIGURE 4 SULPHUR DIOXIDE EMISSIONS (EU-27)

[38] The intake of carbon dioxide by biomass, biogenic emissions and carbon dioxide emissions due to land use changes are not considered in this diagram.

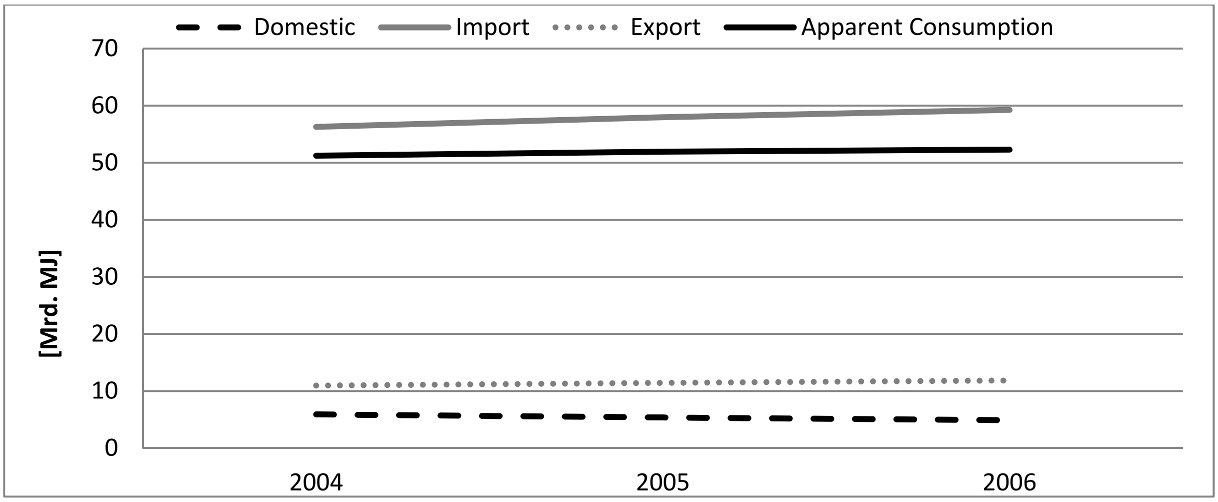

FIGURE 5 CRUDE OIL EXTRACTION (EU-27)

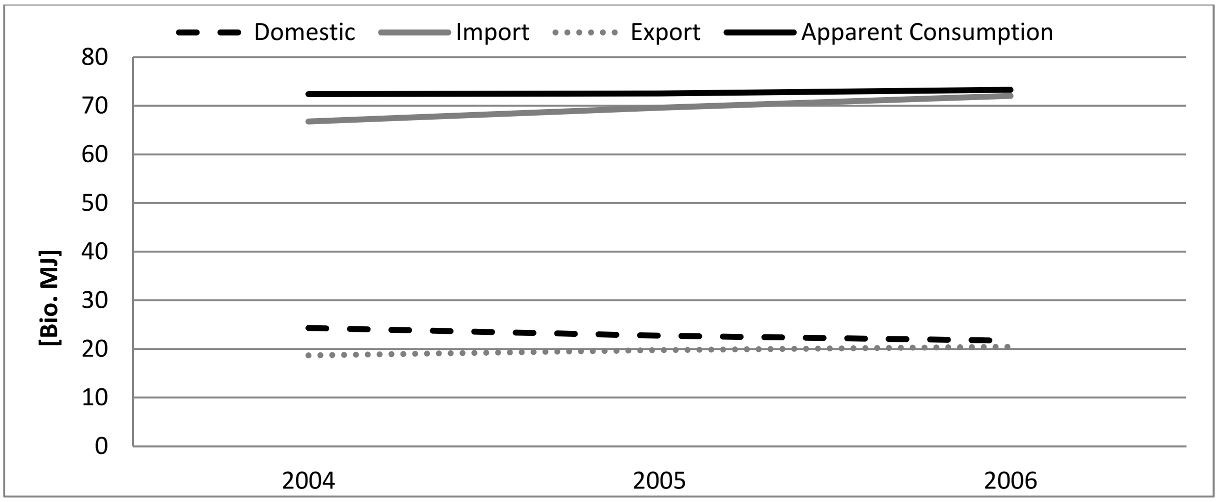

FIGURE 6 FOSSIL FUEL EXTRACTION (EU-27)

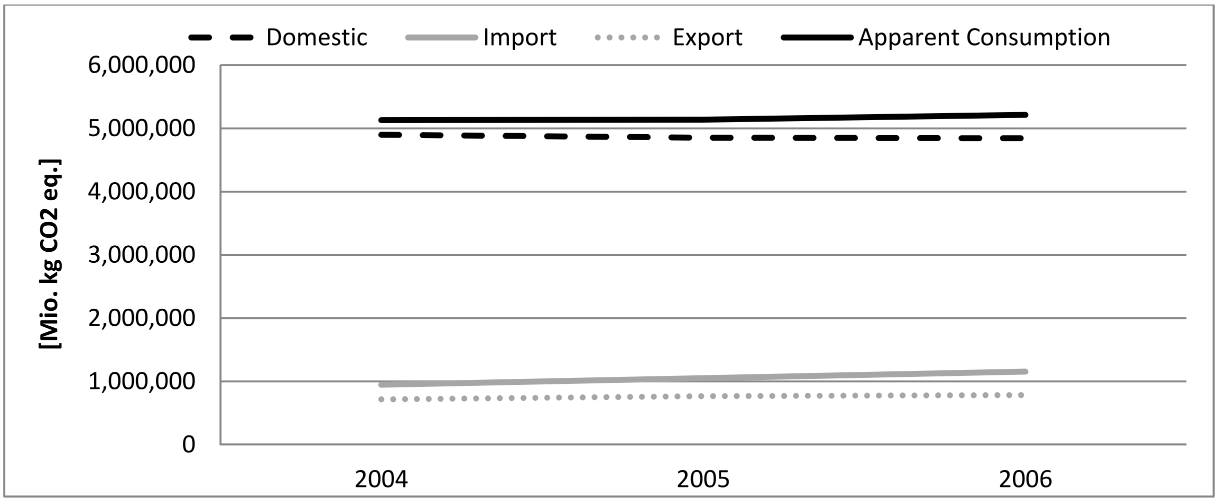

FIGURE 7 CLIMATE CHANGE (EU-27)

5.2.2 IMPACT ASSESSMENT LEVEL

Figure 7 presents the EU-27 results for the impact category climate change. The trends at the domestic level, as well as for imports, exports and apparent consumption are very similar to the results for fossil carbon dioxide emissions. In 2004, the impacts associated with imports were about 30% higher than for exports; and the gap between imports and exports is increasing further. Overall there is a slight increase in CO_2-eq. emissions from apparent consumption. The vast majority of emissions occur domestically.

Figure 8 provides a breakdown of the results for EU-27's climate change impact in 2004, differentiating the main contributing substances. Fossil carbon dioxide emissions were the main contributor to climate change for domestic, import and exports. Fossil carbon dioxide emissions were followed by biogenic carbon dioxide emissions, methane and nitrous oxide. Biogenic carbon dioxide emissions (which have the same characterization factors as fossil carbon dioxide emissions) were largely compensated through the intake of carbon dioxide by biomass.

The characteristics and trends presented for the impact category climate change (for domestic, imports, exports and apparent consumption) can be observed in a similar way for the following impact categories: particulate matter/respiratory inorganics (Figure 9), photochemical ozone formation (Figure 10), acidification (Figure 11), eutrophication terrestrial (Figure 12), eutrophication freshwater (Figure 13), eutrophication marine (Figure 14), and ecotoxicity freshwater (Figure 15).

Figure 16 presents the results for ozone depletion. The impacts from domestic releases of ozone-depleting substances (ODs) are not included, since information on the release of relevant ODS with a sufficient reliability was not available. The observed ozone depletion for the apparent consumption was therefore mainly influenced by the variation in imports, since export levels were relatively stable between 2004 and 2006.

The human toxicity (cancer effects) impacts for the domestic inventory remained stable between 2004 and 2006 (Figure 17). Domestic emissions were low compared to those associated with the EU-27's imports and exports. Therefore, the impacts associated with the apparent consumption were mainly driven by imports.

The human toxicity (non-cancer effects) impacts for the domestic inventory and those associated with imports and exports are relatively constant between 2004 and 2006 (Figure 18). Compared with the other relatively stable impact categories (such as climate change or acidification), a noticeable difference lies in the fact that the human toxicity (non-cancer effects) impacts associated with imports are lower than those associated with exports. Therefore, the impacts for the apparent consumption were lower than those at the domestic level.

The results were very similar for ionizing radiation (human health) and ionizing radiation (ecosystems) impacts in connection with the EU-27's apparent consumption. . In both categories, domestic impacts were dominant. The impacts associated with imports and exports had no significant impact on the apparent consumption, as illustrated in Figure 19 and Figure 20.

For land use, illustrated in Figure 21, only domestic impacts were considered, i.e. apparent consumption and domestic are the same. The domestic impacts describe a relatively strong linear decrease between 2004 and 2006 (-60%). This decrease is related to the impact assessment method and not the inventory data itself (see chapter 2 for more information).

Figure 22 presents the results for the resource depletion over time. The impacts from domestic extraction are lower than the impacts from imports, illustrating the EU-27's high dependency on resource imports. A high increase of the impacts associated with imports and exports is noticeable between 2004 and 2006. This increase translates into a continuous increase in the impacts associated with the EU-27's apparent consumption.

Figure 23 disaggregates the impacts associated with resource depletion into minerals and fossil fuels. The domestic extraction is mainly influenced by the extraction of strontium and, to a lower extent, by zinc, silver and lead extraction. For imports and exports the picture is more divers, precious metals have a high impact, but chromium, mercury and crude oil are also noticeable.

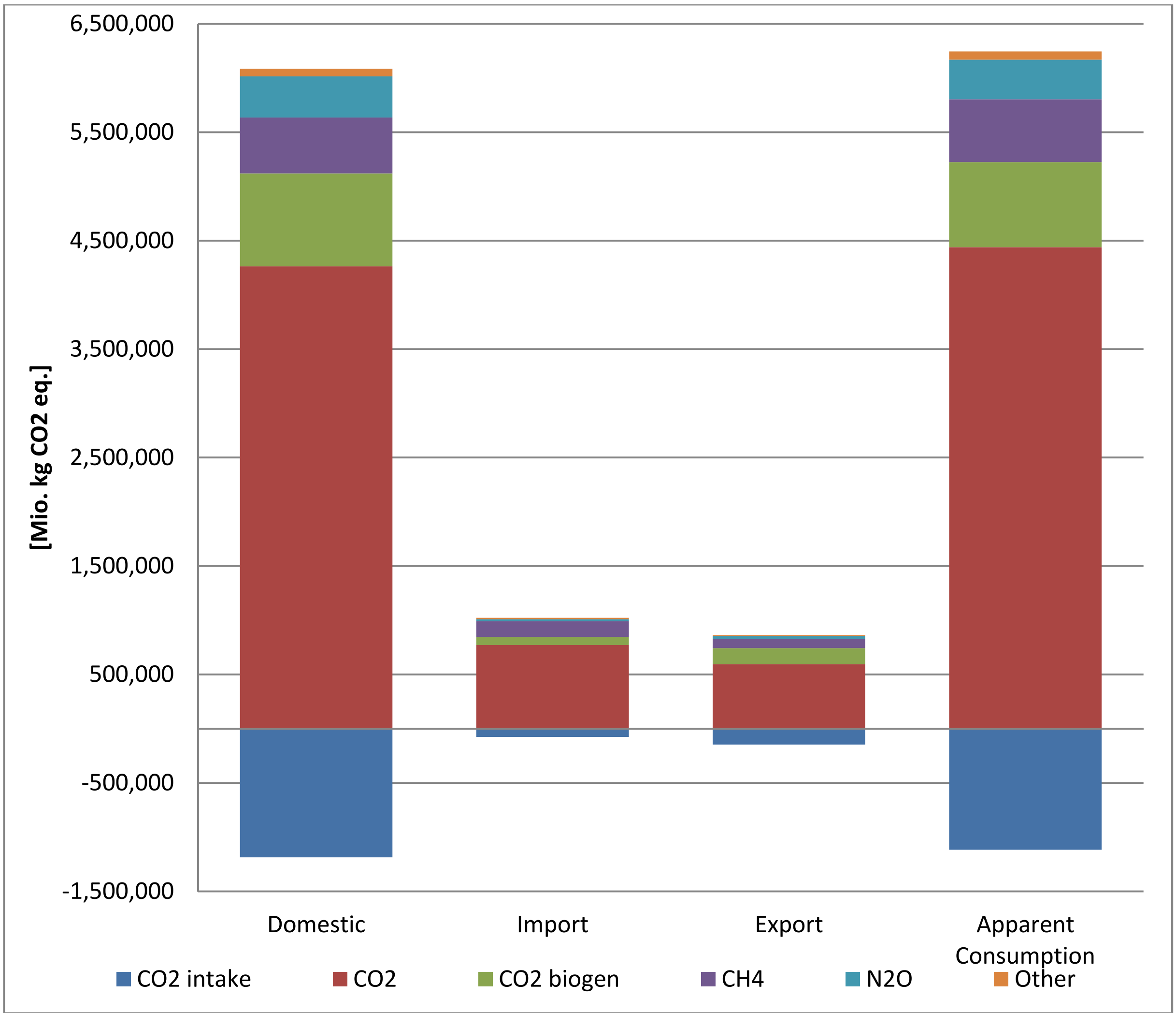

FIGURE 8 CLIMATE CHANGE IMPACT CATEGORY STRUCTURE (EU-27, 2004)

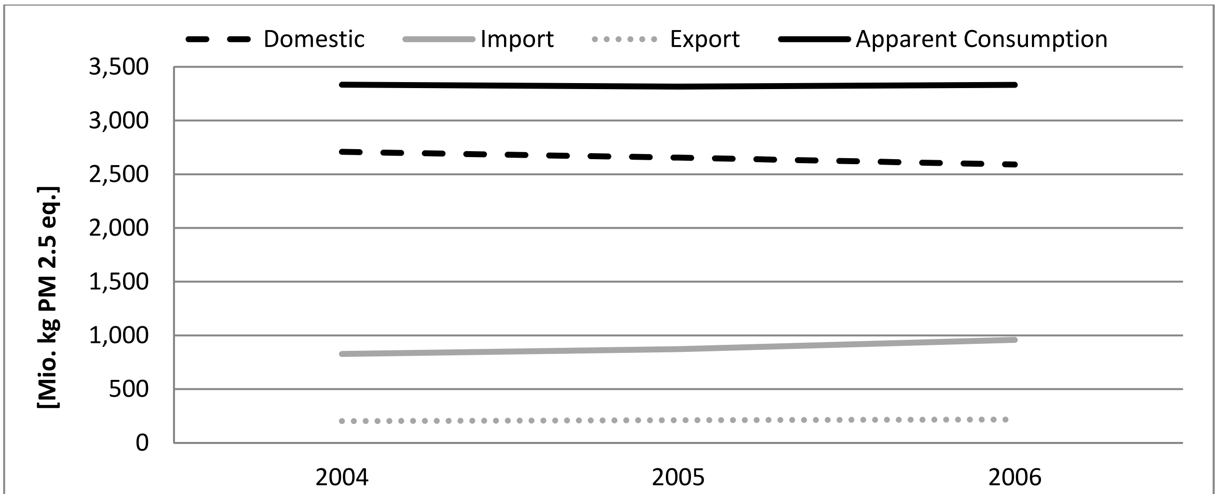

FIGURE 9 PARTICULATE MATTER/RESPIRATORY INORGANICS (EU-27)

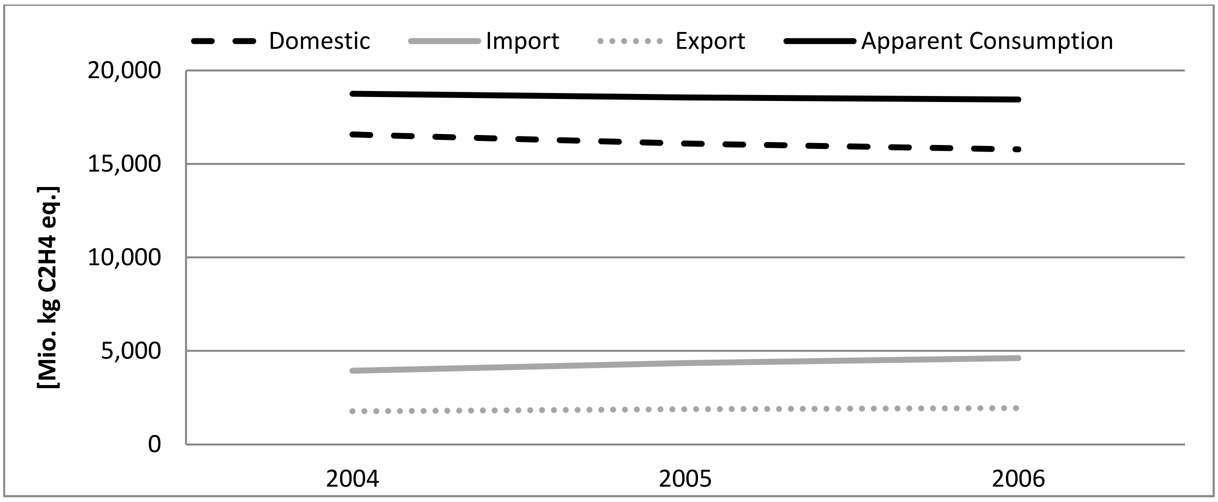

FIGURE 10 PHOTOCHEMICAL OZONE FORMATION (EU-27)

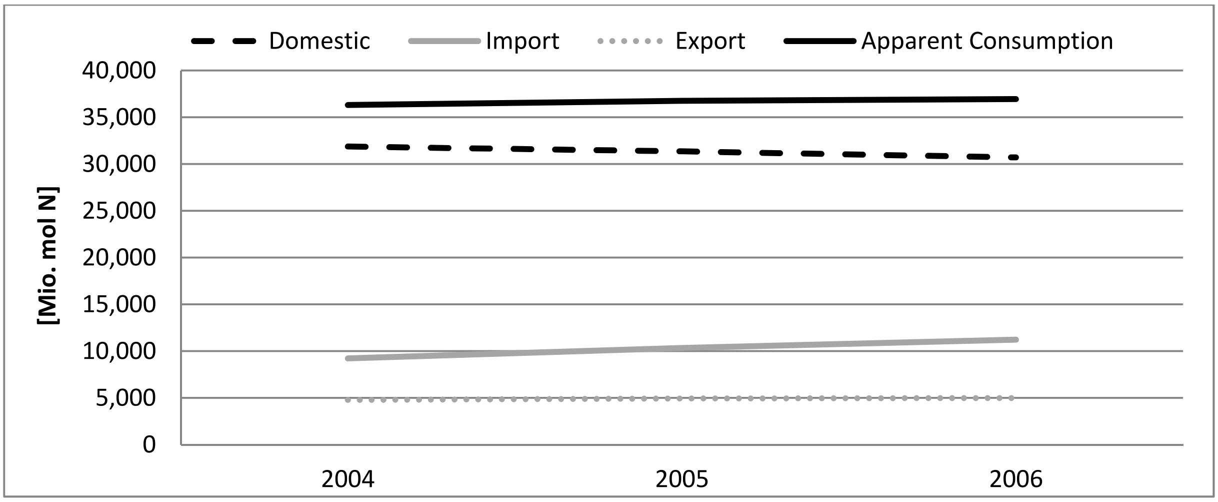

FIGURE 11 ACIDIFICATION (EU-27)

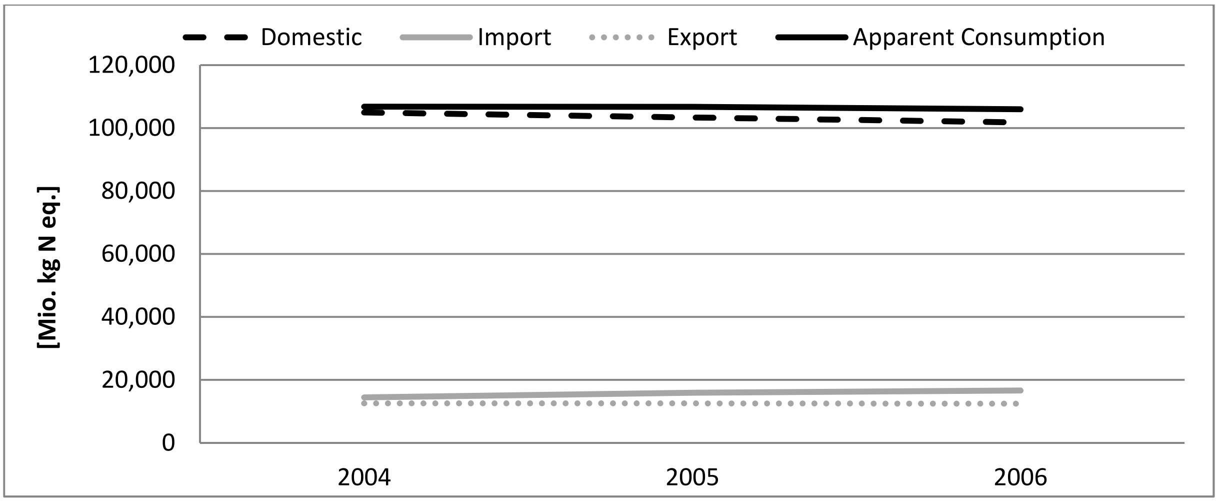

FIGURE 12 EUTROPHICATION TERRESTRIAL (EU-27)

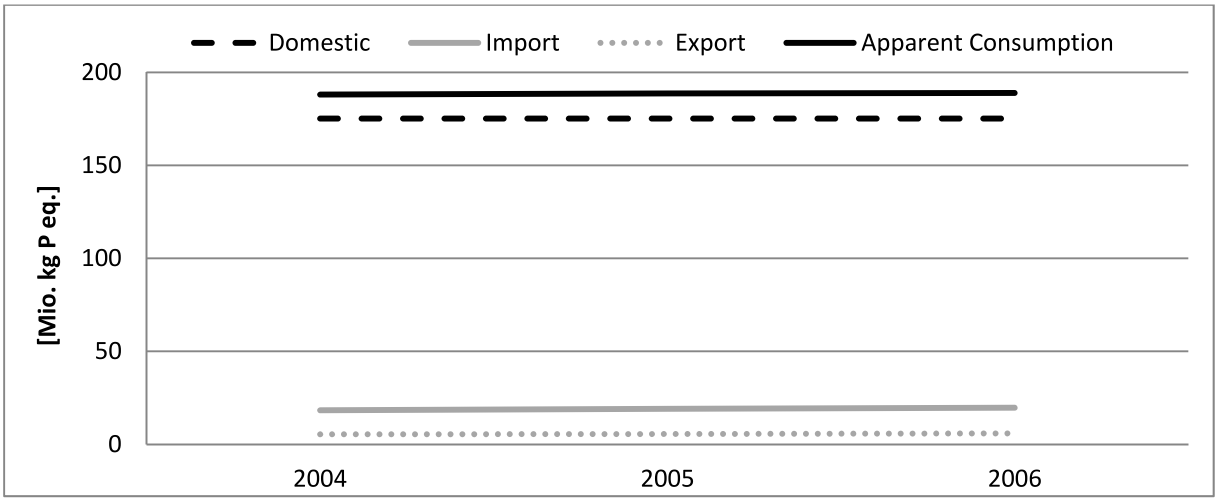

FIGURE 13 EUTROPHICATION FRESHWATER (EU-27)

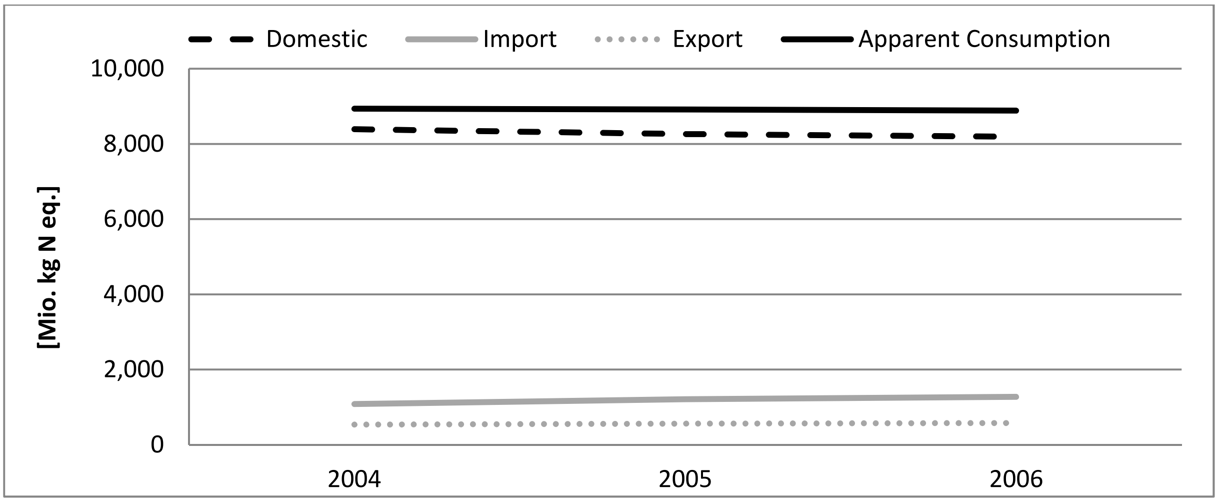

FIGURE 14 EUTROPHICATION MARINE (EU-27)

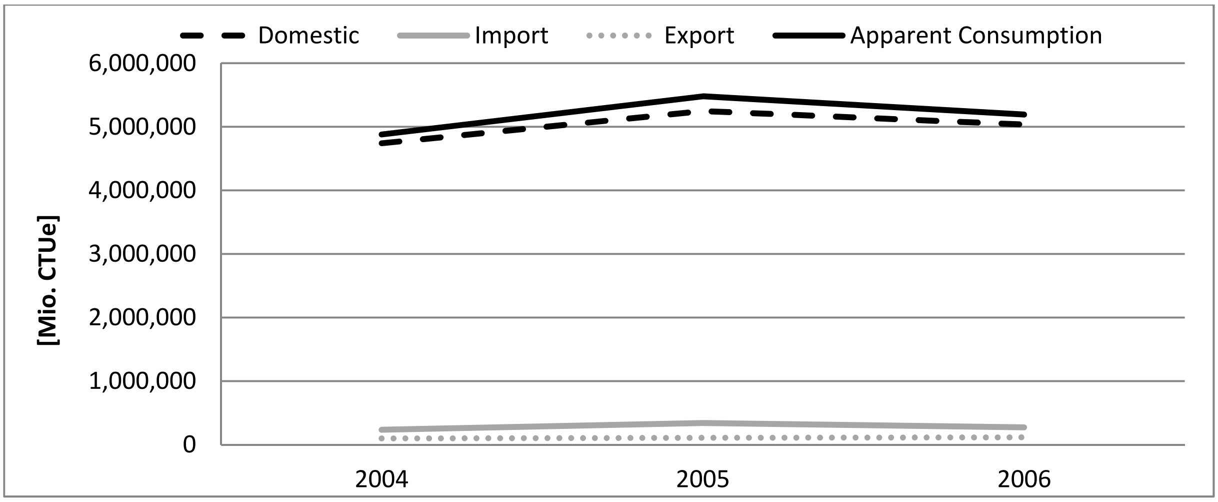

FIGURE 15 ECOTOXICITY FRESHWATER (EU-27)

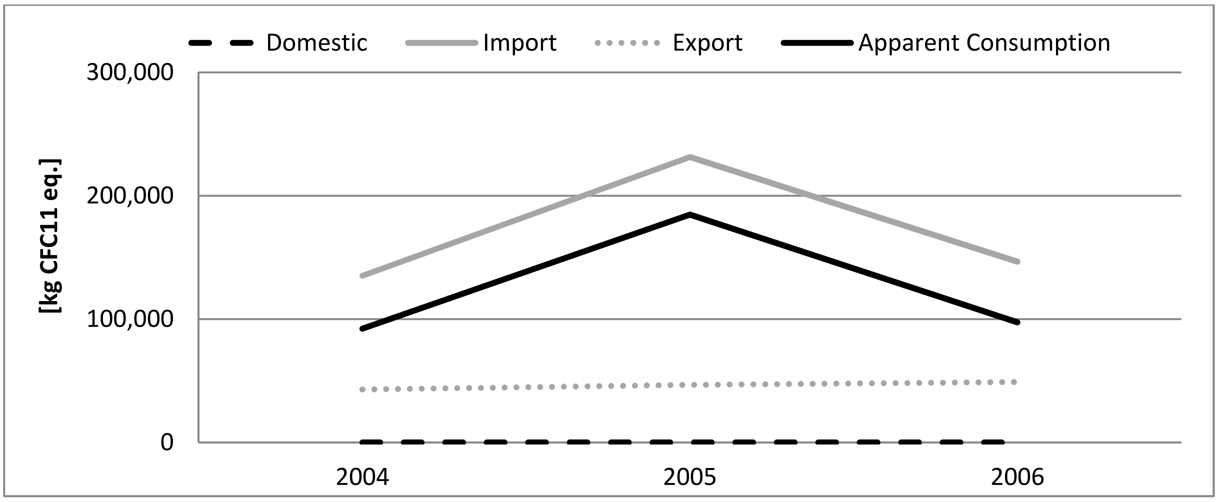

FIGURE 16 OZONE DEPLETION (EU-27)

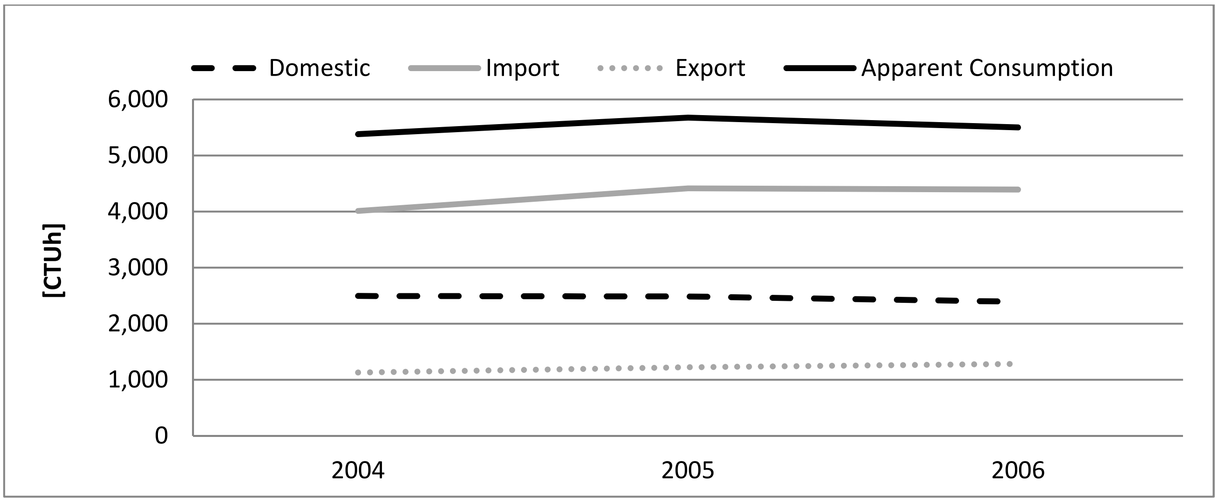

FIGURE 17 HUMAN TOXICITY (CANCER EFFECTS) (EU-27)

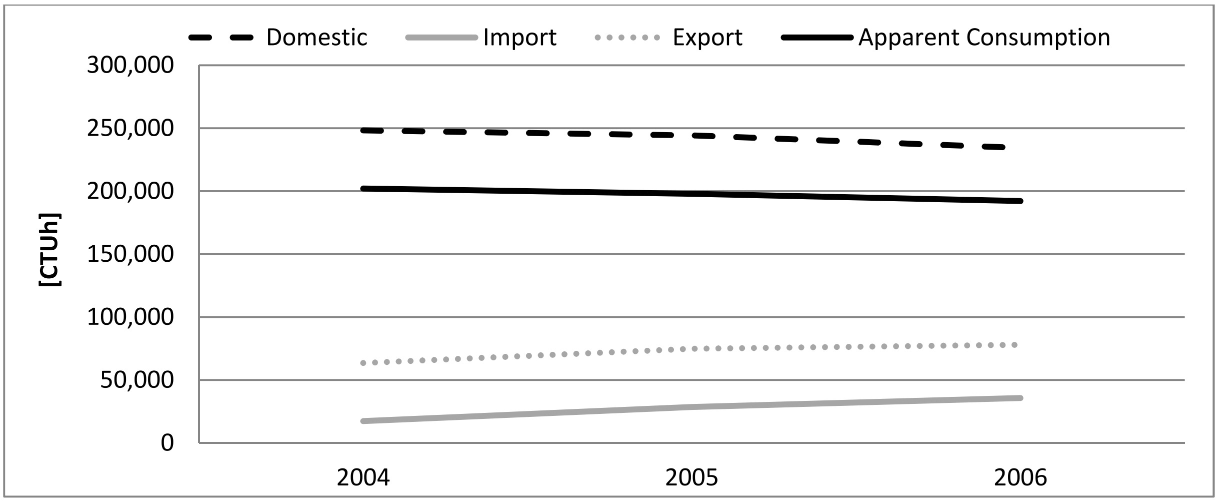

FIGURE 18 HUMAN TOXICITY (NON-CANCER EFFECTS) (EU-27)

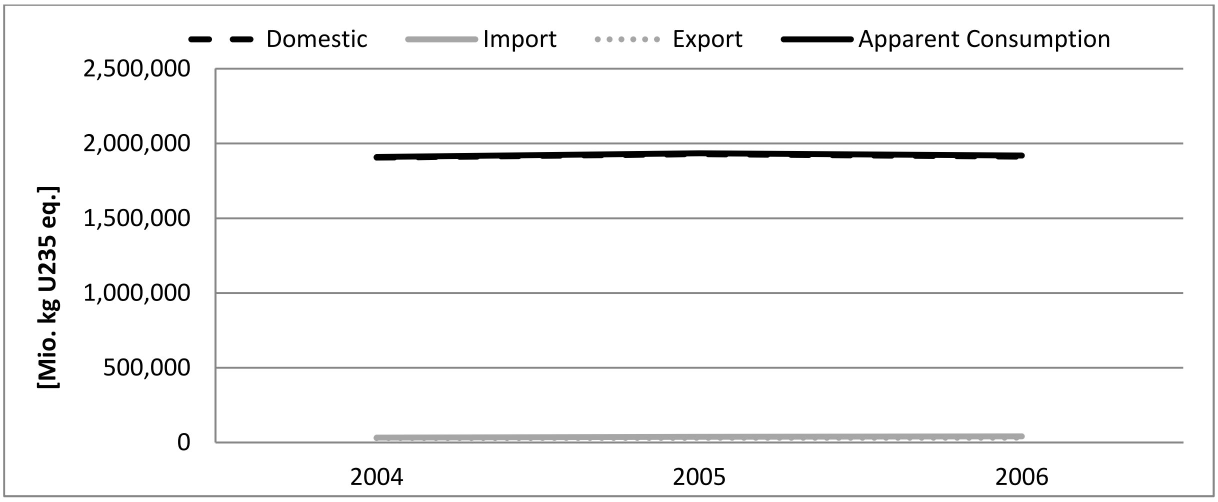

FIGURE 19 IONIZING RADIATION (HUMAN HEALTH) (EU-27)

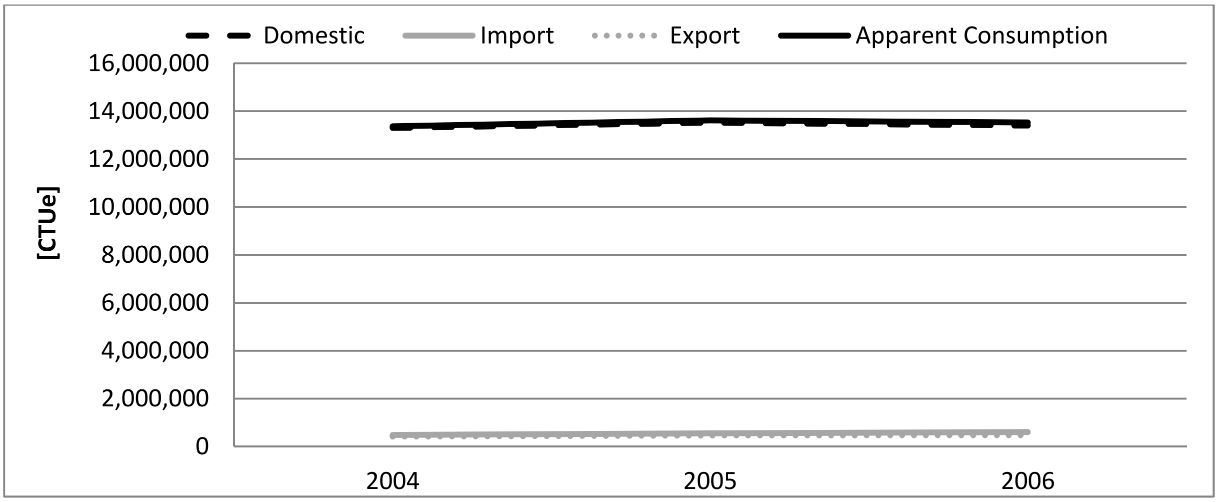

FIGURE 20 IONIZING RADIATION (ECOSYSTEMS) (EU-27)

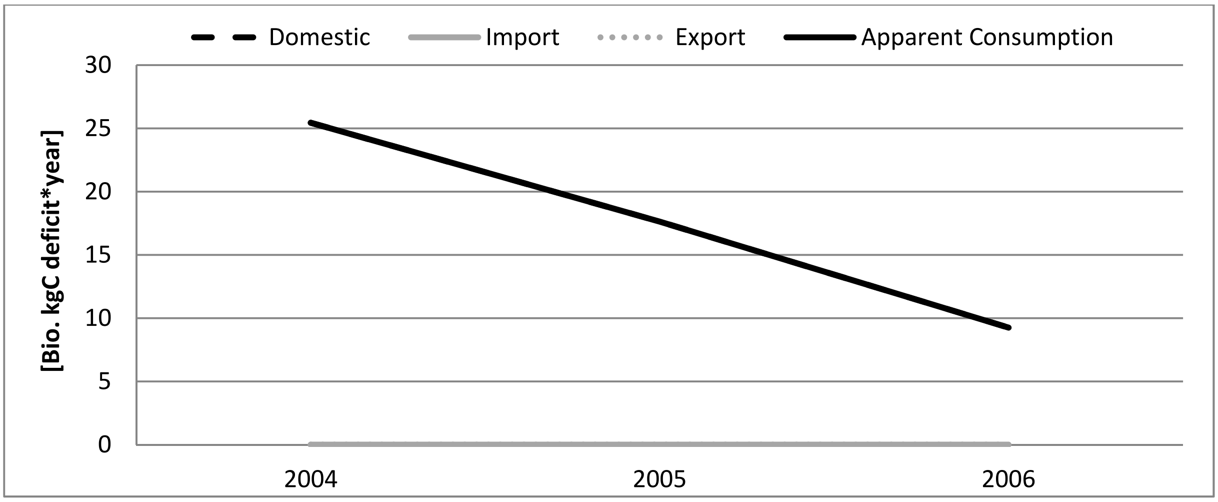

FIGURE 21 LAND USE (EU-27)

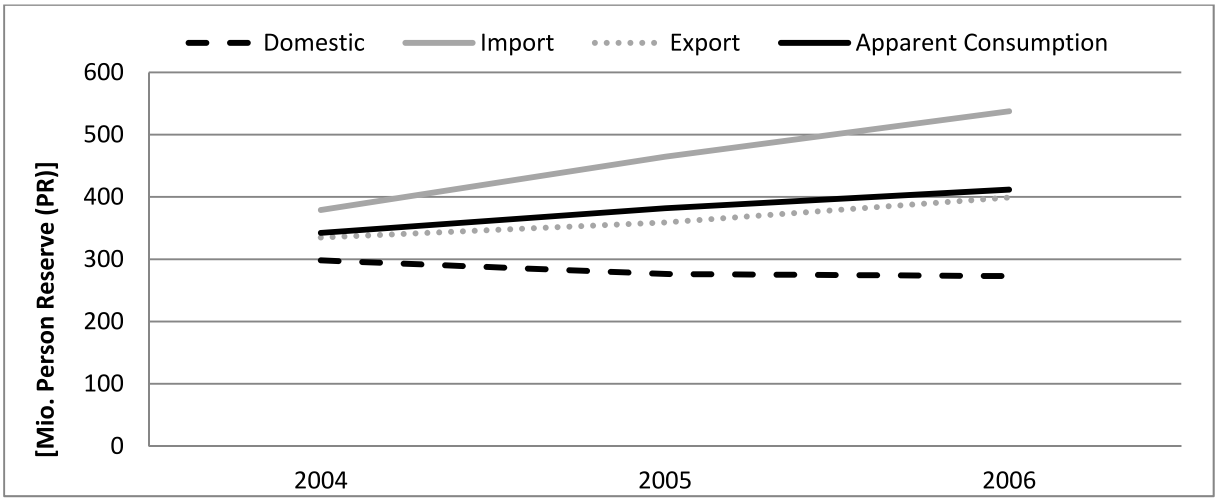

FIGURE 22 RESOURCE DEPLETION MINERAL AND FOSSILS (EU-27)

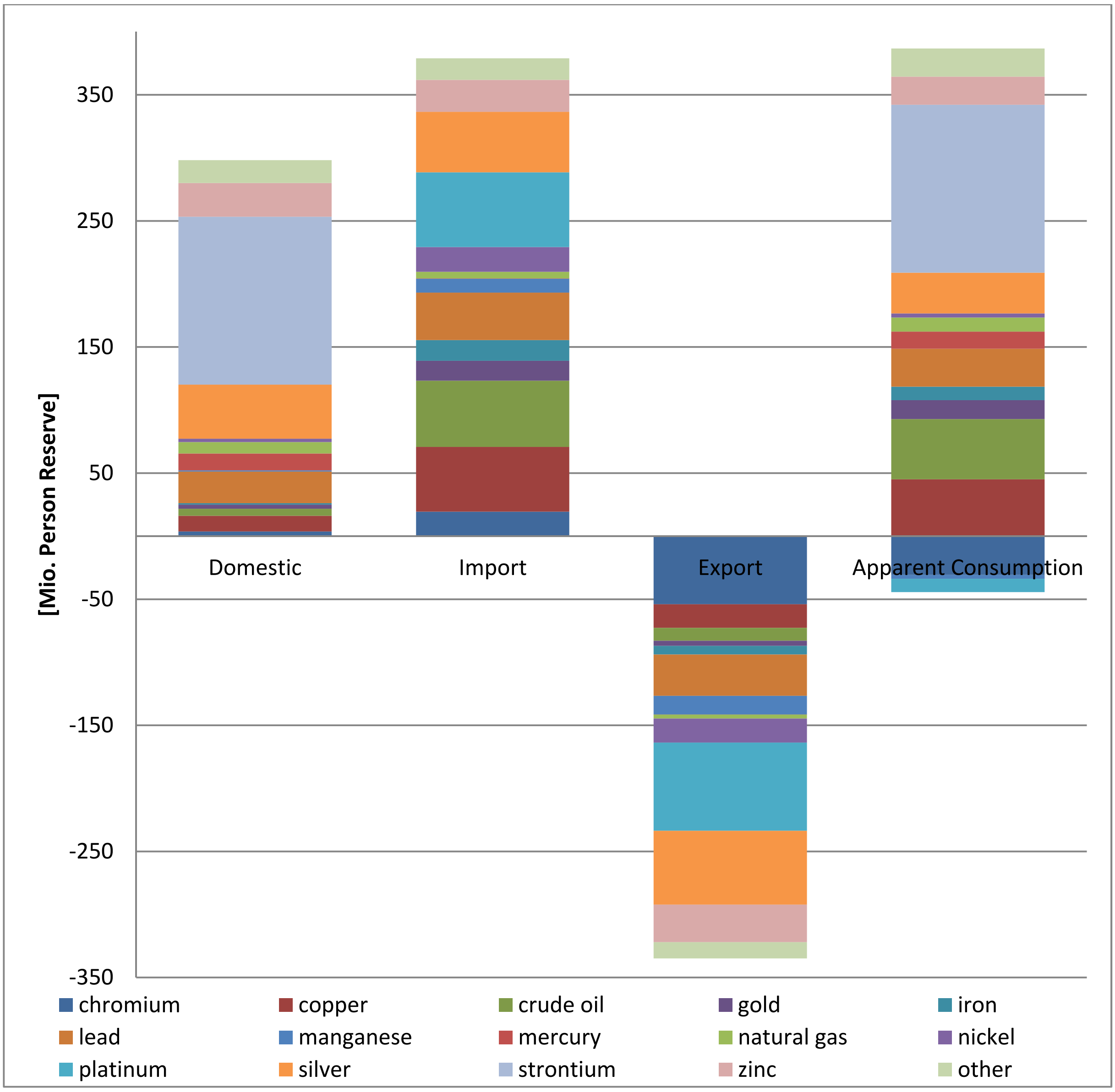

FIGURE 23 RESOURCE DEPLETION MINERALS AND FOSSIL (EU-27, 2004)

5.2.3 ECO-EFFICIENCY INDICATORS

Figure 24 presents the eco-efficiency indicator for climate change, expressed as the quotient of the gross domestic product (GDP) and the climate change impacts (apparent consumption) for the EU-27. The unit is EUR/kg CO_2-equivalents. The results describe the development of how many EUR were on average generated per kg of released CO_2-equivalents between 2004 and 2006. The result is a small increase from 1.93 to 1.99 EUR/kg CO_2-equivalents.

The results for all other eco-efficiency indicators are presented in Table 26 in the Annex 2. Besides the eco-efficiency indicator data for climate change presented in Figure 24 and the summary table in the Annex 2, normalized data provide the opportunity to compare the relative changes of GDP and different impact categories over time. Figure 25 presents normalized data for the impact categories climate change, acidification and photochemical ozone formation. The year 2004 was selected as reference year, i.e. the GDP and the impact category values for 2004 were set to 1.

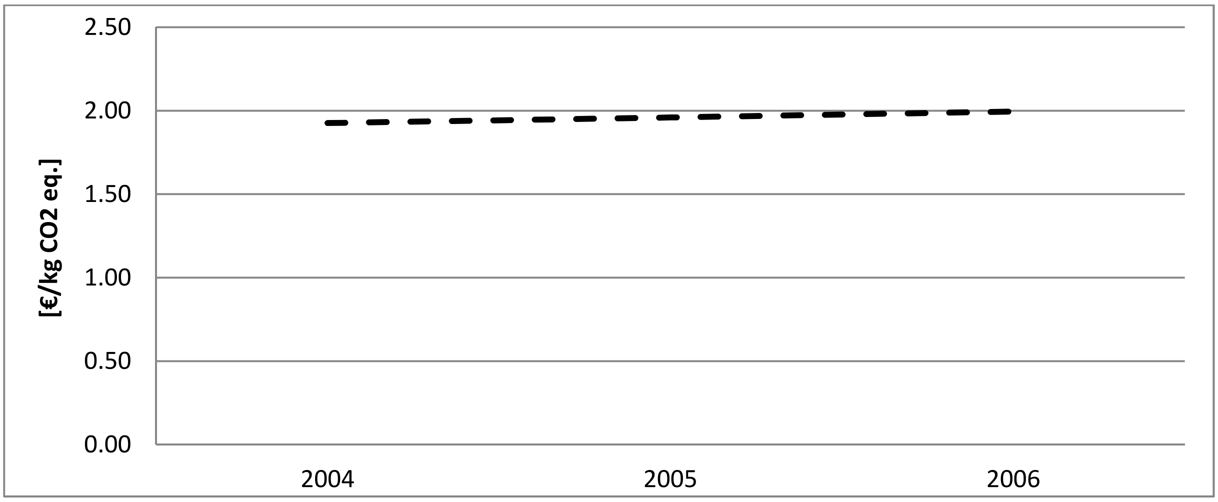

FIGURE 24 ECO-EFFICIENCY INDICATOR – CLIMATE CHANGE (EU-27)

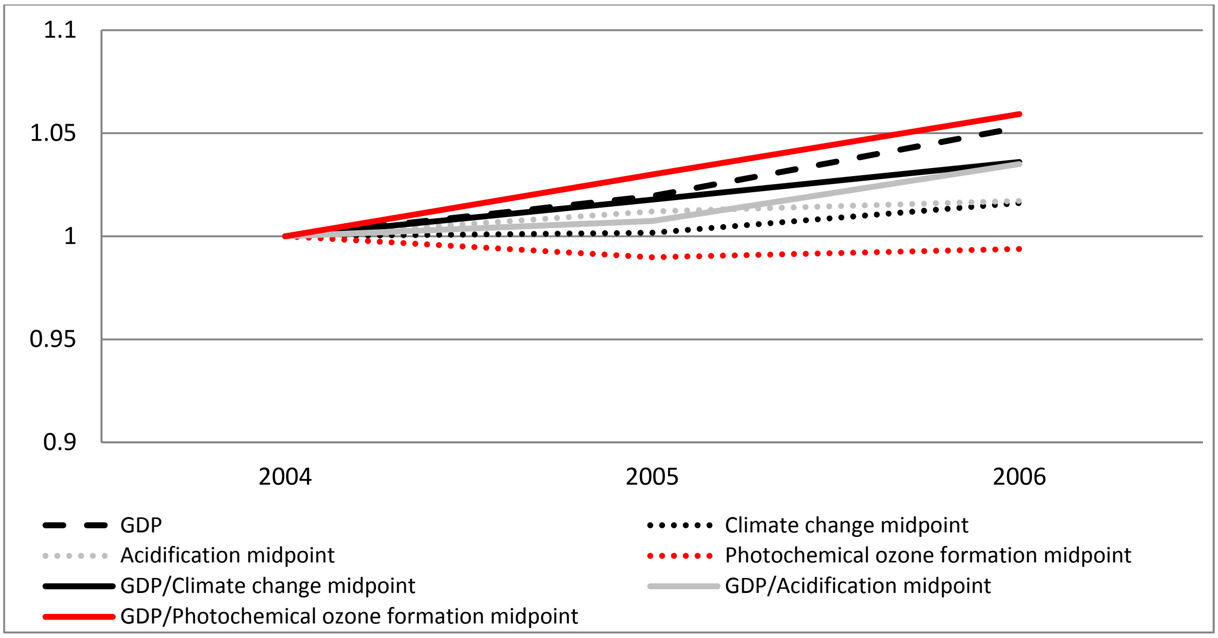

FIGURE 25 NORMALIZED ECO-EFFICIENCY INDICATOR (EU-27, 2004 = 1)

5.3 RESOURCE INDICATORS FOR GERMANY

5.3.1 INVENTORY LEVEL

Figure 26 presents the fossil carbon dioxide emissions released within Germany (domestic), the emissions associated with imports and exports, as well as the total emissions for the apparent consumption. The main difference to the EU-27 results is that the emissions related to exports are higher than for the imports. This result in lower emissions associated with the apparent consumption compared to domestic emissions.

The dominant factor for Germany's sulphur dioxide emissions are emissions associated with imports and exports (see Figure 27). The emissions associated with exports are significantly higher than Germany's domestic emissions. On the export side, the main contributors are vehicles, machinery, steel and aluminium. With regard to imports, mineral fuels, machinery, aluminium, and plastics are most significant in connection with sulphur dioxide emissions.

The crude oil extraction data in Figure 28 highlights Germany´s lack of crude oil. The apparent consumption is therefore entirely driven by the import and re-export of crude oil.

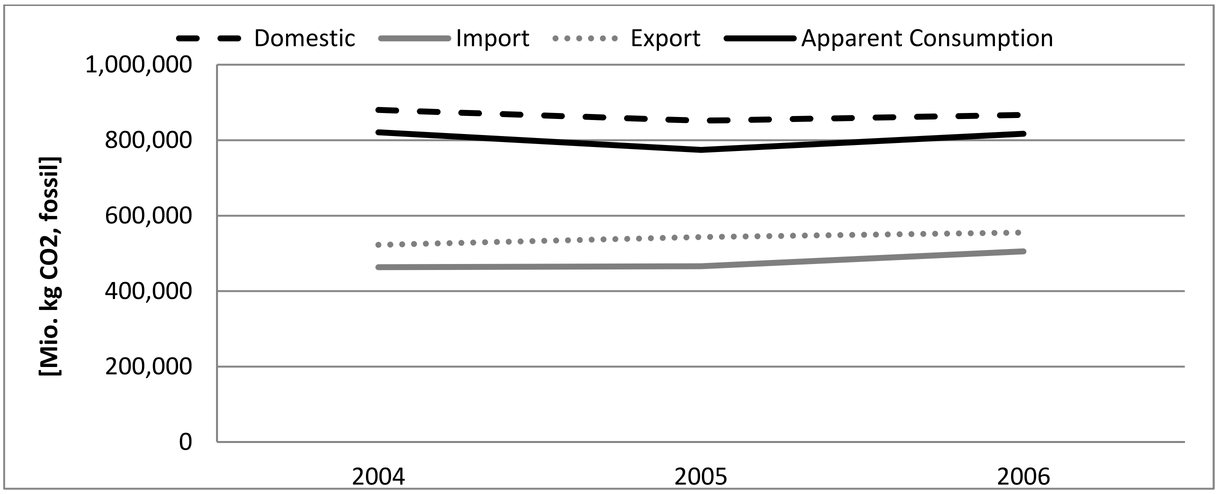

FIGURE 26 FOSSIL[39] CARBON DIOXIDE EMISSIONS (DE)

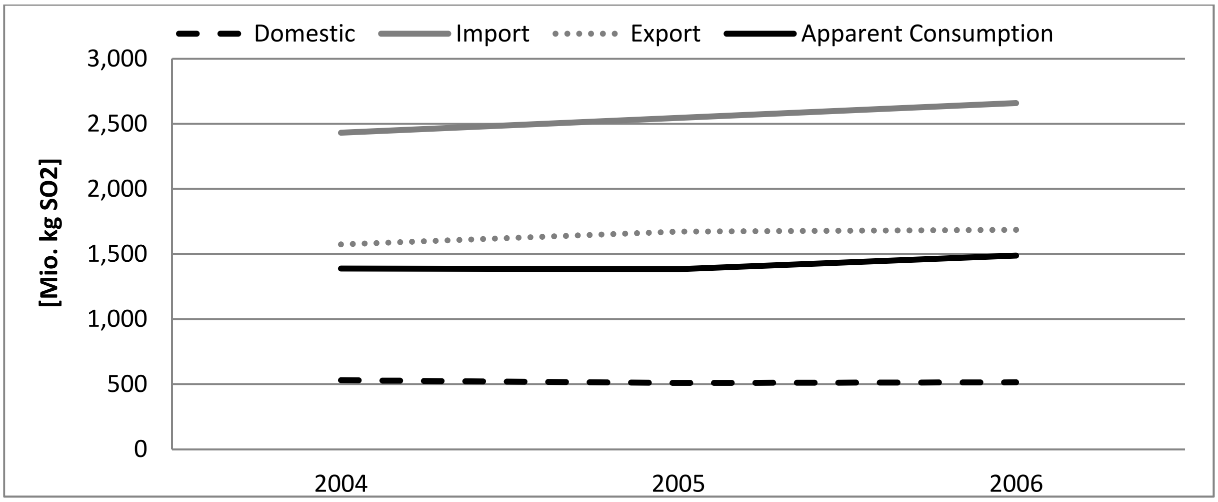

FIGURE 27 SULPHUR DIOXIDE EMISSIONS (DE)

[39] The intake of carbon dioxide through biomass, the biogenic emissions as well as carbon dioxide emissions due to land use changes are not shown in this diagram.

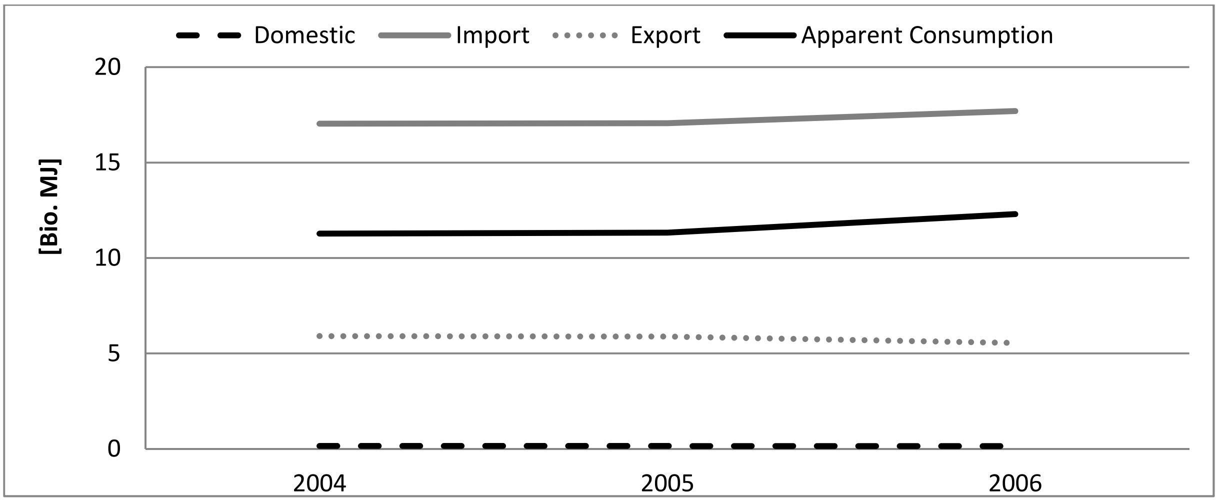

FIGURE 28 CRUDE OIL EXTRACTION (DE)

5.3.2 IMPACT ASSESSMENT LEVEL

Domestic emissions are the main driver for Germany's climate change impacts as in the case of the EU-27. The main difference is that the impacts related to imports and exports are more significant for Germany. Domestic impacts and imports decrease from 2004 to 2005. However, this decrease was counterbalanced in 2006.

Figure 29 presents Germany's impacts for resource depletion of mineral and fossils. The impacts related to the domestic extraction are almost zero. Impacts associated with exports are significantly higher than those from imports, hence resulting in negative apparent consumption. The results of all other impact categories are presented in the Annex 3.

5.3.3 ECO-EFFICIENCY INDICATORS

The eco-efficiency indicators for Germany are calculated in the same way as for the EU. The eco-efficiency indicator for climate change indicates a higher level of eco-efficiency for Germany compared to the EU-27 (2.24 EUR/kg CO2-eq. for DE in 2004 compared to 1.93 for the EU-27). The German eco-efficiency increased from 2004 to 2005 and decreased to the 2004 level in 2006 (see Figure 31). Further results can be seen in Table 27 in the Annex 3.

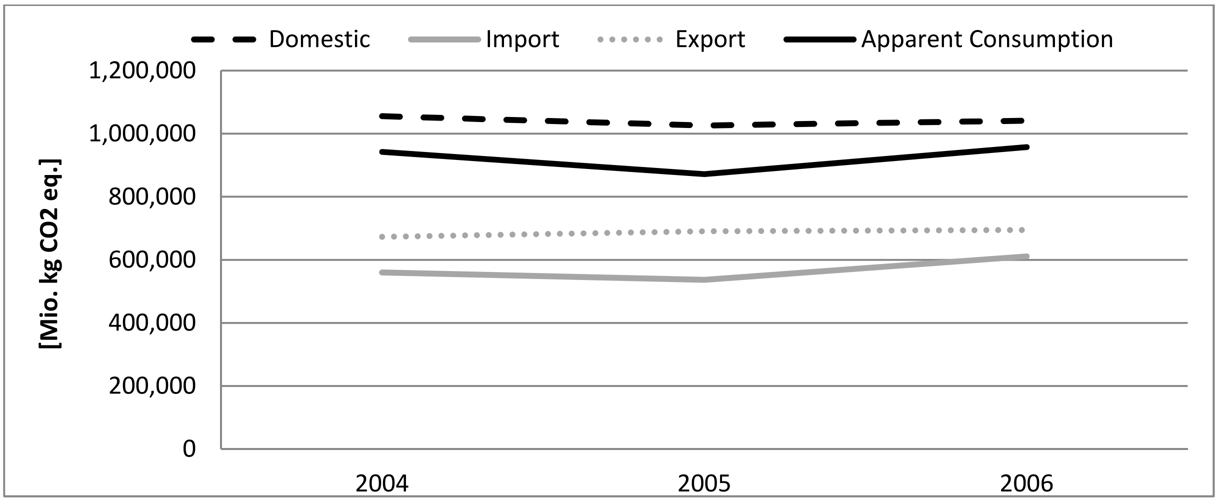

FIGURE 29 CLIMATE CHANGE (DE)

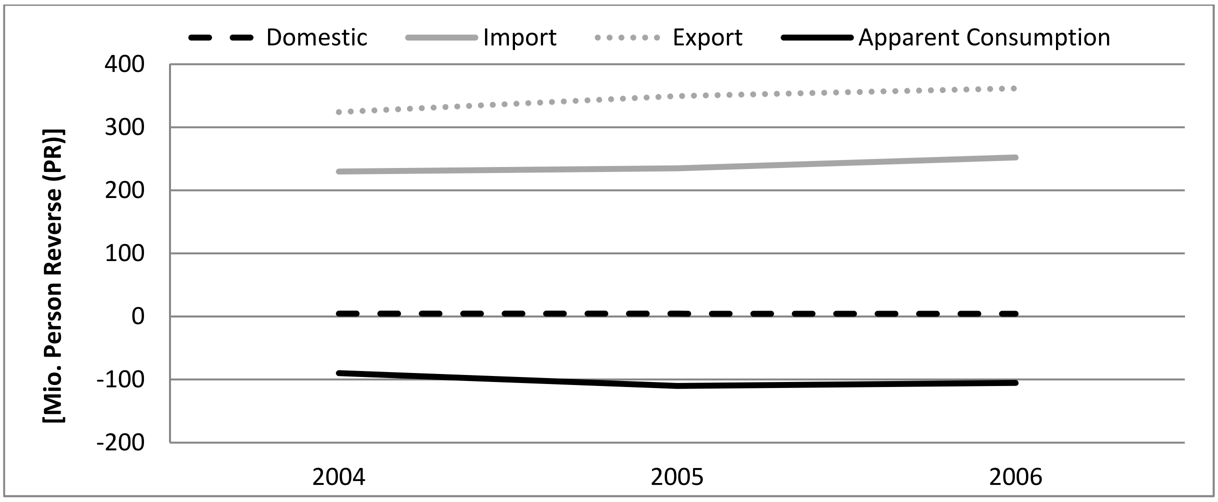

FIGURE 30 RESOURCE DEPLETION MINERAL AND FOSSILS (DE)

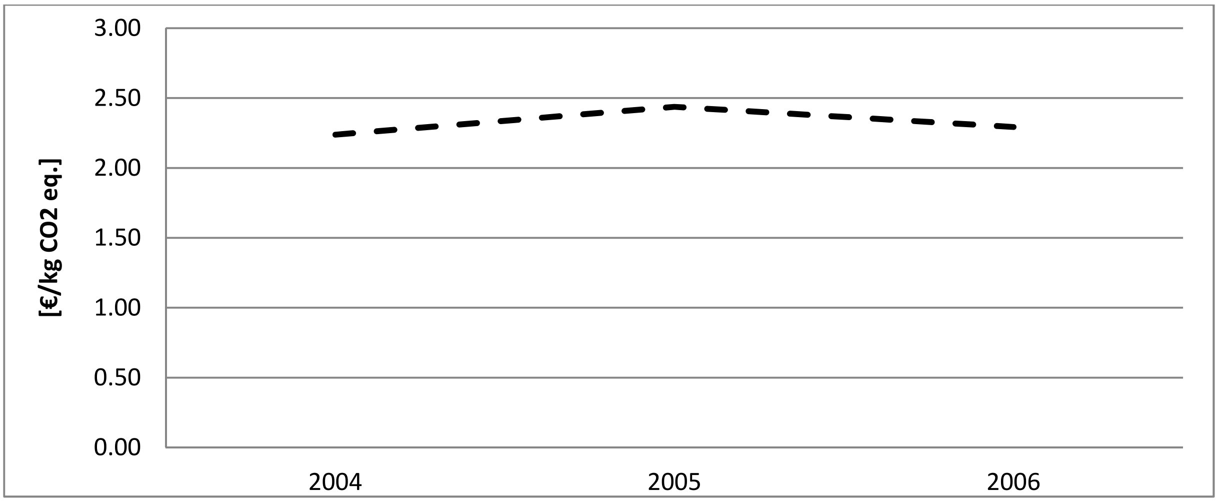

FIGURE 31 ECO-EFFICIENCY INDICATOR – CLIMATE CHANGE (DE)

6 INTERPRETATION

6.1 RESOURCE INDICATORS FOR THE EU-27

6.1.1 INVENTORY LEVEL

The results presented at the inventory level[40] demonstrate that emissions and impacts associated with imports and exports have an important effect on the emissions and impacts associated with the EU-27's apparent consumption.

Changes in individual emissions or resource extraction related to imports and exports were observed between 2004 and 2006. These changes were primarily related to variations in trade volumes for the 15 selected product groups, variations in the total trade volume in mass, as well as changes in the amount of international electricity trading. Overall, the influence of imported and exported electricity was minor for the EU-27 indicators (below 1%). Only for radioactive emissions and uranium resource extraction the imports of electricity have a noticeable influence on the impacts associated with the EU-27's total imports (10-20%).

Variations of fossil carbon dioxide emissions as well as methane, nitrogen oxides and sulphur dioxide emissions related to imports can be mostly attributed to changes in the imported volume of particular product groups. Especially the increase of imports of iron & steel (+30%, HS2 group 72 & 73), aluminium (+10% HS, group 76), vehicles (+20%, HS2 group 87), machinery (+9%, HS group 84) and finally mineral fuels (+5%, HS2 group 27) lead to the observed increase of impacts associated with imports.

Carbon monoxide emissions from imports are mainly driven by steel & iron and sugar imports (combustion of bagasse). The higher emissions associated with increased imports of steel & iron products between 2004 and 2006 are compensated by lower sugar imports.

The high relevance of sulphur dioxide emissions associated with the apparent consumption (Figure 4) is mainly driven by energy imports (crude oil extraction), as well as imports of apparel and machinery. The high sulphur dioxide emissions associated with imports of energy and apparel reflect differences in emission standards between the EU-27 and the source countries; they are further an indication of a high sulphur-intensity of the fuel combustion and electricity generation in the source countries. Actual levels of sulphur dioxide emissions associated with imports could be even higher as no country specific consumption mixes were available for the materials used during the production of machinery, vehicles and steel & iron.

The crude oil extraction and the fossil fuel extraction presented in Figure 5 and Figure 6 are mainly influenced by the energy import dependency of the EU-27. The high share of imported crude oil relative to all other fossil fuels needs to be interpreted with caution (e.g. compare import levels in Figure 5 and Figure 6). In this initial development only one representative product (crude oil) was used to calculate the impacts associated with the imports of mineral fuels (HS2 group 27). Hence, the entire amount of imported mineral fuels was represented by LCI data sets for crude oil production. The crude oil imports (CN 27090090) represent, however, only around 50% of the imported mineral fuels, plus 15% of refined oil products which are based on crude oil. The remainder is coal (20%) and natural gas & condensates (15%). Consequently, the high relevance of oil imports[41] is affected by an overestimation of the direct crude oil imports. This problem affects

[40] E.g. emissions, such as carbon dioxide, carbon monoxide, sulphur dioxide, methane or nitrogen oxides.

[41] I.e. direct import of crude, refined oil products, as feedstock in products or consumed as energy carrier to produce/extract the imported goods

also the fossil fuel extraction presented in Figure 6, but not in the same magnitude, because coal has a significantly lower calorific value than crude oil.

6.1.2 IMPACT ASSESSMENT LEVEL

CLIMATE CHANGE

The interpretation of the climate change results is similar to the interpretation for the fossil carbon dioxide emissions in the previous chapter. The fossil carbon dioxide emissions associated with imports are mainly driven by the import of mineral fuels, steel, aluminium and machinery. The methane emissions are determined by the import of mineral fuels (around 60%) and meat (10%), while nitrous oxide emissions are mainly influenced by the import of apparel (45%) and meat (13%). It should be noted that the representative product for the product group apparel (HS groups 52, 61, 62 and 63) is a cotton shirt as more than 50% of the imported apparel is made of cotton, and the cotton shirt was the most relevant CN8 group. This could lead to an overestimation of the nitrous oxide emissions associated with imports. The climate change impact from exports is characterized by the impacts associated with exported steel, vehicles, machinery and organic chemicals. Export-related methane emissions are strongly linked to the export of dairy products (45% of the methane emissions associated with exports).

As stated above, the biogenic carbon dioxide emissions are mainly compensated by the intake of carbon dioxide by biomass. The climate change impact from land use, land use changes and forests (LULUCF) is accounted as biogenic carbon dioxide emissions. The LULUCF impacts for the EU-27 were negative between 2004 and 2006 (sink of emissions), reducing the impacts by around 400.000 kt of CO_2 equivalent. The inclusion of the LULUCF impacts reduces the results for the climate change impact category by 8% for the domestic inventory. A minor difference occurs with regard to the import and export of products that contain biogenic carbon (such as food or fodder). The places of intake and the release of the biogenic carbon dioxide later on are different. The influence on the results is below 1% for climate change.

OZONE DEPLETION

The results for ozone depletion need to be interpreted with care as the impacts of the domestic inventory are not accounted for. The impacts associated with imports were mainly driven by CFC 114 (1,2-dichloro-1,1,2,2-tetrafluoroethane) emissions to air caused by the production of refrigerants used in imported air-conditioning devices. The large increase of the impacts in 2005 is directly linked to a doubling of the trade volumes for imported air conditioners from 2004 to 2005, and a bisection of the imports in 2006 compared to 2005. Hence, the data gaps for the domestic inventory and the limited number of selected representatives for the product groups do not allow for a comprehensive overview to generate a reliable result with regard to imports and exports. In conclusion, the results for the ozone depletion are not seen as reliable.

HUMAN TOXICITY, CANCER EFFECTS

The relatively low domestic impacts compared to the impacts associated with imports and exports for the impact category human toxicity (cancer effects) can be explained by the fact that not all emissions covered by the LCI data are also included by the domestic impacts. The domestic impacts are mainly driven by chromium emissions to water and air, as well as mercury emissions. For the imports, the chromium emissions to water only represent around 10%, the majority is caused by dioxin emissions to air, formaldehyde emissions to air, chromium emission to soil and other releases. Dioxin and formaldehyde emissions to air as well as chromium emissions to soil are not covered within the domestic inventory. This leads to a certain distortion due to a different selection of the covered emissions. It is therefore not possible to draw a direct conclusion as to potential differences in emission standards between the EU-27 and the source countries of the imports.

HUMAN TOXICITY, NON-CANCER EFFECTS

The domestic impacts with regard to human toxicity (non-cancer effects) are primarily related to heavy metal emissions to air (lead, mercury, zinc and cadmium). The domestic inventory and imports and exports cover mainly the same relevant emissions. Heavy metal emissions to soil, however, are an exception. High impacts of exports compared to those associated to imports are explainable by negative emissions for the imports caused by agricultural products. The incorporation of zinc by cotton (cotton shirt as representative for apparel) and soya oil cake (representative for HS2 group 23) as micronutrients reduces the overall impacts associated with imports. Without this incorporation the impacts for imports would be even higher than for the exports. The results suffer therefore from dissimilar system boundaries for the domestic inventory on the one hand, and LCI data for imports and exports on the other hand (consideration of micronutrition intake for biomass within LCI data).

PARTICULATE MATTER/RESPIRATORY INORGANICS

The domestic impacts with regard to particulate matter/respiratory inorganics are mainly determined by dust emissions to air (70%) and sulphur dioxide emissions to air (19%). The remaining impacts are related to ammonia, carbon monoxide and nitrogen oxide emissions to air. The main driver from the imports are dust emissions from the product group sugar (HS 17) related to the combustion of bagassse (representing around 35% of the entire impacts), as well together with sulphur dioxide and dust emissions from apparel (high electricity consumption) and machinery, as well as sulphur dioxide emissions associated with the supply of mineral fuels.

IONIZING RADIATION, HUMAN HEALTH AND ECOSYSTEMS

For both ionizing radiation impact categories (human health and ecosystems) the domestic impacts are by far dominant and almost completely influenced by carbon 14 emissions to air (around 99% of the domestic impacts). However, the reliability of the data suffers from the fact that cesium, cobalt and tritium emissions to water are not covered by the domestic inventory for the category human health (ecosystems).

PHOTOCHEMICAL OZONE FORMATION

The characteristics of the impacts in the category photochemical ozone formation over time are similar to those for climate change and other impact categories (see chapter 2). The main contributors for the domestic inventory are nitrogen oxides (70%), volatile organic compounds (14%) and carbon monoxide (9%). For imports and exports, a similar split between the main contributors can be observed. Around 67% of the impacts in 2004 were due to nitrogen oxide emissions to air, 5% due to unspecified non-methane volatile organic compound (NMVOC) emissions to air, plus 12% related to specific VOC to air, such as propane, toluene or ethane. Carbon monoxide represents around 6% of relevant import related impacts, only sulphur dioxide is of higher importance, i.e. 10%. A possible explanation for the higher share of sulphur dioxide emissions might be higher emissions associated with the electricity and thermal energy supply used during the production of the imported goods.

ACIDIFICATION

The domestic impacts are dominated by ammonia, nitrogen oxide and sulphur dioxide emissions to air.[42] The net balance between imports and exports has a considerable impact on the apparent consumption. Sulphur dioxide emissions are of greater importance for the impacts associated with the imports compared to the domestic impacts, i.e. ~71% in 2004. The product group mineral fuels (HS27) is the main contributor for sulphur dioxide emissions on the import side (sour gas treatment, diesel aggregates etc.). In addition, sulphur dioxide emissions associated with the import of apparel and machinery are significant. As already observed for other impact categories before, this might be related to higher emissions associated with the electricity and thermal energy supply used during the production of the imported goods. On the export side, ammonia emissions from dairy products contribute 30% of the acidification impacts.

EUTROPHICATION TERRESTRIAL

The eutrophication terrestrial impacts are related to ammonia and nitrogen oxide emissions to air. In terms of domestic impacts, both types of emissions are each responsible for around 50% of the impacts. The impacts associated with imports and those associated to exports balance each other. Hence, impacts for domestic and apparent consumption are congruent.

EUTROPHICATION FRESHWATER

The eutrophication freshwater impacts are completely determined by phosphate emissions to fresh water. The constant value for the domestic inventory between 2004 and 2006 is due to the fact that data was only available for 2005 (Bouraoui et al., 2011). For 2004 and 2006 the 2005 data for phosphate emissions was used.

EUTROPHICATION MARINE

Similar to the eutrophication terrestrial impacts, the EU-27's eutrophication marine impacts are influenced by ammonia and nitrogen oxide emissions to air. One difference is the distinctly high relevance of nitrogen oxide emissions (>90%).

ECOTOXICITY FRESHWATER

The impacts with regard to ecotoxicity are related to more than 100 different emissions to different environmental media. The impacts associated with the domestic inventory are predominantly driven by pesticide emissions. Emissions of endosulfan to air (30% in 2004), cyhalothrin to water (26% in 2004) and alpha-cypermethrin to water (21% in 2004) together make up more than 75% of the domestic impacts. However, there are large differences in the characterization factors of the different emissions. As an example, 27.137 tonnes of endosulfan emissions to air have a similar impact as 8 tonnes of cyhalothrin emissions to water.

The increase of the domestic impacts between 2004 and 2005 (around 10%) and the decrease between 2005 and 2006 (around 5%) are directly linked to pesticide emissions: Higher endosulfan emissions were calculated for 2005 compared to 2004, and lower pesticide emissions (cyyhalothrin and alpha-cypermethrin) for 2006 compared to 2005. The models that were applied for the calculation of the pesticide emissions (Birkved and Hauschild, 2006) are the cause for the observed changes.

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[42] In 2004: ammonia 38%, nitrogen oxide 27%, sulphur dioxide 34%.

As only some agriculture products are covered within the imports and exports, pesticide emissions play a less significant role for the impacts of imports and exports. Important contributors are copper and vanadium emissions to air, as well as copper emissions to water. There are negative impacts from zinc emissions to agricultural soil, as already discussed for the impact category human toxicity (non-cancer effects). The withdrawal of micronutrients via biomass is not covered in the domestic inventory. Apart from the possible uncertainties related to the pesticide emissions, the emissions covered by the domestic inventory and imports and exports differ.

LAND USE

Impacts from land use are only covered for the domestic land use. The high decrease of the impacts by 60% from 2004 to 2006 is at first difficult to understand as the inventory data for the land use changed very little. The underlying reason for the decrease is related to the fact that the negative impacts are mainly compensated by beneficial effects. The impacts from the transformation of land into "other land use", "arable land" or settlements are compensated by the transformation of "other land use" or settlements into forests or grassland. As the values for impacts (positive) and the values for benefits (negative) are very high, the prominent variation of the balance is not necessarily linked to high variations with regard to the actual land use.

RESOURCE DEPLETION MINERALS AND FOSSIL FUELS

In order to understand the results for the impact category resource depletion minerals and fossil fuels, there are two aspects that have to be kept in mind:

- First of all the assessment of the resource depletions reflects the scarcity of the extracted minerals and fossil fuels. It is not a summation by mass of all resources covered in this impact category. The applied characterization factor for strontium[43] is 2,300 times higher than the characterization factor for crude oil or natural gas (per kilogram). This explains why, with reference to the applied assessment methodology, the domestically extracted fossil fuels have no relevant influence for the domestic resource depletion. The same holds true for imports. While the import of mineral fuels is a main contributor to a multitude of emissions and impact categories, it is only of minor significance for the resource depletion impacts associated with imports or exports.
- The second aspect is the selection of the representative products for the 15 considered product groups. The majority of resources with high characterization factors are not covered directly. For example, chromium is not covered directly (e.g. via direct import of ferrochrome, or via high alloyed semi-finished steel products such as coils, or slabs profiles of stainless steel); only imports of final products such as vehicles or machinery include these minerals which are relatively scarce.

Therefore, the high increase of the resource depletion for imports and exports is influenced by an increase of trade volumes for steel, vehicles and machinery. Nonetheless it can be assumed that the impacts associated with the EU-27's imports are underestimated, as some types of mineral extractions and semi-finished products which might have a high potential impact based on their characterization factor, are not directly covered under imports.

[43] Characterization factor per kg: strontium 0.941, crude oil 0.000039, natural gas 0.000042

6.1.3 ECO-EFFICIENCY INDICATORS

The increase of the value for the climate change eco-efficiency indicator (Figure 24) suggests a decoupling of economic growth from climate change impacts for the investigated time period 2004-2006.

The normalized data further indicates an increase in the decoupling for the eco-efficiency indicator climate change over time (Figure 25). This increase means that the decoupling is due to a stronger growth of the GDP compared to the absolute increase of climate change emissions. The same holds true for the acidification indicator. In contrast, the photochemical ozone formation decreases between 2004 and 2006 (the value goes down to below 1), resulting in the highest increase in the decoupling between economic growth and impacts.

CURRENTLY INSUFFICIENTLY ROBUST IMPACT CATEGORIES

For some impact categories, such as ozone depletion, human toxicity (non-cancer), ionizing radiation, land use, as well as resource depletion minerals and fossil fuels a meaningful interpretation of the respective eco-efficiency indicators is not possible. The reasons are described in the relevant paragraphs of chapter 6.1.2 and can be summarised as follows:

- Distortion due to a differing number of elementary flows (emissions or resources) covered at the domestic level, as well as for imports and exports in one impact category.
- Different system boundaries for the domestic inventory and LCI data for imports and exports (e.g. consideration of micronutrition intake for biomass within LCI data).
- Impacts not covered at all at the domestic level or for imports and exports within one impact category.
- The number of selected representative products for the product groups is not sufficient to generate a reliable result to realistically characterize impacts associated with imports and exports. This is especially the case for the impact category resource depletion minerals and fossil fuels.
- Missing information with regard to country-specific LCI data of certain materials used for imported (or exported) goods, i.e. the applicable consumption mix for the source countries of imports are not available (e.g. where does the steel or aluminium used for the production of cars in e.g. Turkey actually come from?).

6.2 RESOURCE indicators FOR GERMANY

The majority of the resource indicators for Germany can be interpreted in the same way as the EU-27 indicators. The interpretation chapter for Germany focuses therefore on the differences between the results for EU-27 and Germany.

6.2.1 INVENTORY LEVEL

Fossil carbon dioxide emissions associated with exports are higher than for imported goods. A reason for this might be the large amounts of manufactured goods exported from Germany, such as machinery or passenger cars.

The relatively low sulphur dioxide emissions within the domestic inventory compared to the sulphur dioxide emissions associated with exports and imports might refer to the relative high emissions standards in Germany. Further explanations (especially for the circumstance that the emissions associated with the exports are higher than for the domestic inventory) are as follows:

- A major part of the virtually imported sulphur dioxide emissions are re-exported. A selection of the exported manufactured goods, such as vehicles or machinery are made with imported semi-finished products, e.g. steel, aluminium, plastics, machinery components.
- The applied life cycle inventory (LCI) data sets for the 15 representative products of exported goods are the same as for the EU-27 indicators. For semi-finished products with high energy demand, such as aluminium, the differing energy supply routes and emissions standards within the EU-27 could lead to an overestimation of the impacts for the exported goods.

As already described for the EU-27 indicator above, the entire amount of imported mineral fuels is represented as crude oil production by the LCI data sets (as explained above). This leads to an overestimation of the crude oil imports presented in Figure 28.

6.2.2 IMPACT ASSESSMENT LEVEL

The climate change impacts for Germany display a higher influence of imported and exported goods compared to the EU-27 indicator. The explanations given for the inventory level in chapter 6.2.1 also apply for climate change and for other impact categories included in the Annex 3.

The relatively low domestic impacts for the impact category resource depletion mineral and fossil fuels are influenced by two factors. Firstly, Germany does not have any significant metal extraction. Moreover, resources which are extracted in Germany (predominantly coal, natural gas and non-metallic minerals) have a relative low characterization factor compared to other metallic resources, such as chromium or copper. The fact that the impacts for imported resource depletion are lower than for the exported, despite the high import dependency of Germany, can only be explained – as before for the EU-27 indicator – by a distortion of the selected imports and exports (see chapter 6.1.2).

The higher variation for some impact categories compared to the EU-27 indicator is related to the fact that the selection of product groups and representative products was made from an EU-27 perspective (see also chapter 6.1.3 for further explanation). One consequence is that some goods are not imported or exported in the same relevant amounts as for the EU-27. This results in a higher sensitivity for certain product groups on the results for German indicators.

6.2.3 ECO-EFFICIENCY INDICATORS

For Germany, the eco-efficiency indicator climate change ranges between 2.2 and 2.5 EUR/kg CO_2-eq. between 2004 and 2006.

As described above at the impact assessment level, some of the impact categories, such as ecotoxicity freshwater, eutrophication freshwater or human toxicity, have relatively high fluctuations with regard to the impacts associated with exports and especially with imports. The reasons have already been discussed in chapters 6.1.3, 6.2.1 and 6.2.2.

7 OVERALL ENVIRONMENTAL IMPACT INDICATOR

The EU Thematic Strategy on the Sustainable Use of Natural Resources (EC, 2005a) establishes a policy context for weighting based upon three sets of resource indicators. A weighting procedure is usually required across a comprehensive set of environmental impact categories in order to derive at an overall environmental impact across the EU-27; in the case of Germany (or any other Member State) normalisation and weighting would be required.

In ISO 14044 (2006:47) weighting is defined as [...] *converting and possibly aggregating indicator results across impact categories using numerical factors based on value-choices´ (p. 45) and ´Weighting is the process of converting indicator results of different impact categories by using numerical factors based on value-choices. It may include aggregation of the weighted indicator results. Weighting is an optional element with two possible procedures, either to convert the indicator results or normalized results with selected weighting factors, or to aggregate these converted indicator results or normalized results across impact categories. Weighting steps are based on value-choices and are not scientifically based. Different individuals, organizations and societies may have different preferences; therefore it is possible that different parties will reach different weighting results based on the same indicator results or normalized indicator results. In an LCA it may be desirable to use several different weighting factors and weighting methods, and to conduct sensitivity analysis to assess the consequences on the LCIA results of different value-choices and weighting methods [...].*

To calculate the overall environmental impact indicator, the weighting procedure has been developed for life cycle indicators (Huppes and van Oers, 2011).

7.1 NORMALISATION

7.1.1 GENERAL ASPECTS

The normalisation step within life cycle assessment (LCA) is done to gain a better understanding of the relative magnitude for each indicator result (ISO, 2006). It is required before indicators can be weighted and aggregated into one overall environmental impact score. Within the normalisation step, the result for a specific impact category is divided by the total impact for the same impact category within a reference region and reference year. The result is a dimensionless that can be compared to other normalised impact indicators.

The relevant normalisation factors for the reference regions EU-27 and Germany are obtained from calculation of the resource indicators within this project. The normalisation factors presented in Table 21 represent the impacts for the domestic inventory in 2004 for EU-27 and Germany.

Some of the impact categories are excluded from the normalisation and weighting step for various reasons: The impact categories ozone depletion and resource depletion (water) cannot be assessed in the domestic inventory of the resource indicators. The domestic inventory results of the resource indicators use are not considered to be robust enough for normalisation and weighting for human toxicity (cancer effects), ecotoxicity (freshwater) and land use.

TABLE 21 NORMALISATION FACTORS DERIVED FROM THE DOMESTIC INVENTORY OF THE RESOURCE INDICATORS

Impact category (midpoint)	Unit	EU-27	DE
Climate change	kg CO_2 eq.	4 897 798 498 804	1 055 285 757 898
Ozone depletion	kg CFC11 eq.	0	0
Human toxicity, cancer effects	CTUh	2 496	214
Human toxicity, non-cancer effects	CTUh	248 184	34 017
Particulate matter/Respiratory inorganics	kg PM2.5 eq.	2 707 507 805	246 669 829
Ionizing radiation, human health	kg U235 eq.	1 905 100 000 105	287 020 505 243
Ionizing radiation, ecosystems	CTUe = PAF*m^3*year	13 299 396	2 003 674
Photochemical ozone formation, human health	kg C_2H_4 eq.	16 581 055 979	2 048 353 851
Acidification	mol H+	31 878 744 303	3 669 929 073
Eutrophication terrestrial	kg N eq.	104 907 336 164	14 689 864 624
Eutrophication freshwater	kg P eq.	175 105 845	11 876 780
Eutrophication marine	kg N eq.	8 389 304 517	967 785 382
Ecotoxicity freshwater	CTUe = PAF*m^3*year	4 742 069 627 752	194 145 476 275
Land use	kgCdeficit*year	25 438 570 822 185	-5 525 447 750 900
Resource depletion water	Environmental Load (EL)	0	0
Resource depletion, mineral, fossils and renewables	Person Reserve (PR)	298 196 201	4 421 246

7.1.2 NORMALISED RESULTS

Figure 32 and Figure 33 illustrate the normalised results of the domestic inventory for EU-27 and Germany. The normalised results are same because the impact category values for the 2004 domestic inventory and the normalisation data are identical.

An increase over time (higher than one) represents an increase for the domestic inventory of the relevant impact category and vice versa.[44]

The overall, aggregated environmental impact indicator is calculated based on the normalised results of the apparent consumption of each impact category considered. Figure 34 and Figure 35 present the normalised impact category results for the apparent consumption for EU-27 and Germany respectively.

2004 results that are unequal to one occur if imports (or exports) of goods lead to an overall net import (or export) of environmental impacts for selected impact categories. 2004 figures below one represent lower impacts for the apparent consumption than for the domestic inventory. Hence, net impacts are exported outside the reference region. A 2004 result higher than one represents that net impacts are imported and the impacts for the apparent consumption are higher than for the domestic inventory.

A rising normalised impact over time reflects an increase of the impacts for the apparent consumption. Most of the impact categories are relatively stable over time, with the exception of resource depletion (fossils and minerals). The reason therefore is the increasing impact associated with imports of goods. Further explanations for the development over time are given in the interpretation Chapter (6.1.2 and 6.2.2).

[44] Please refer to the interpretation chapter (6.1.2 and 6.2.2) for explanations about the development of the impact categories over time.

In Germany the variations are higher compared to EU-27 due to the fact that the representatives for the imports and exports were not directly selected for Germany. Another important aspect is the result for resource depletion (fossils and minerals). A negative normalized value is obtained when the apparent consumption is negative. The reason for this negative apparent consumption is a distortion of selected representatives for the imports and exports and the fact that Germany has a very small domestic inventory for resource depletion (fossil and minerals; see also Chapter 6.2.2 for further explanation); resulting in a normalized impact of -20 to -25 for resource depletion (fossil and minerals). Therefore, the overall environmental impact indicator is not calculated for Germany, as the results are not considered to be reliable enough.

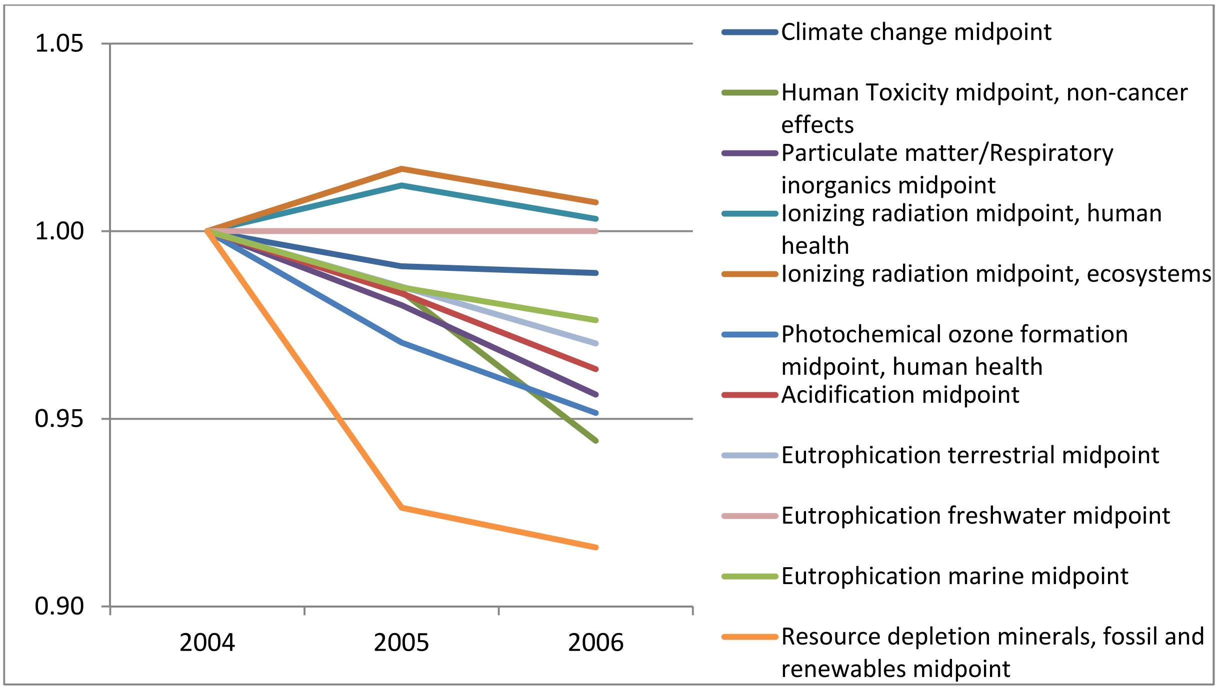

FIGURE 32 NORMALISED IMPACT CATEGORIES – DOMESTIC INVENTORY (EU-27, 2004 = 1)

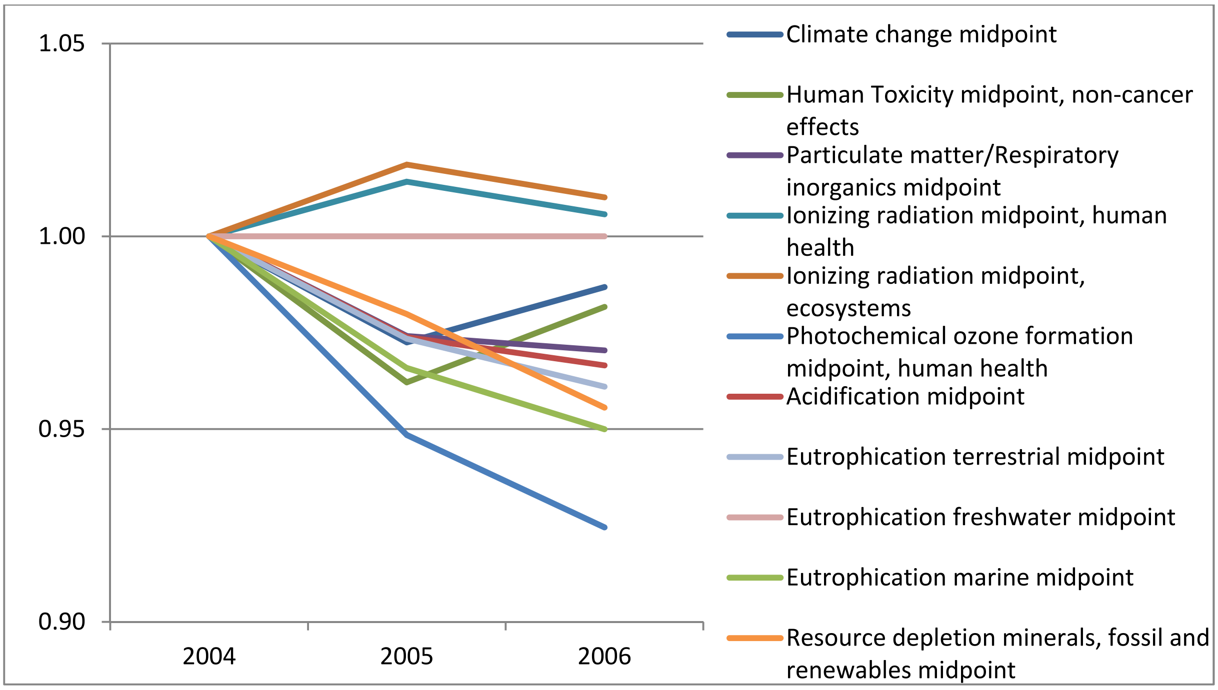

FIGURE 33 NORMALISED IMPACT CATEGORIES – DOMESTIC INVENTORY (DE, 2004 = 1)

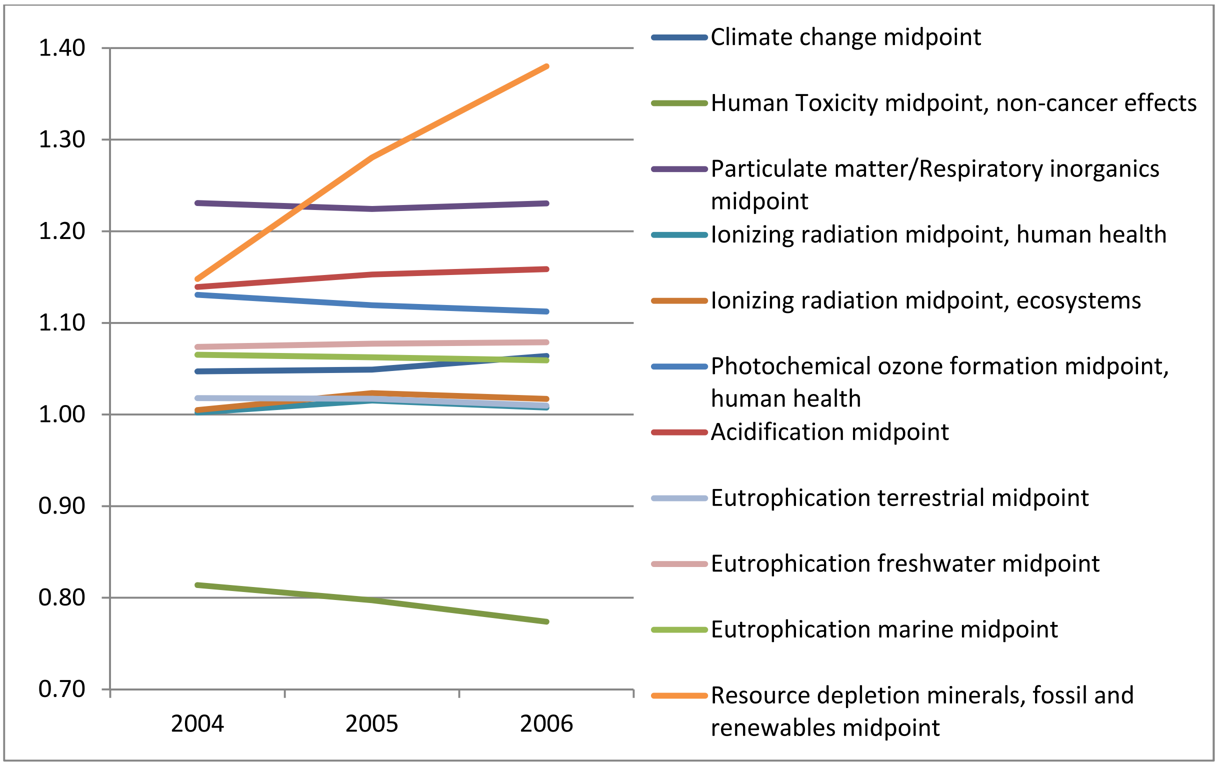

FIGURE 34 NORMALISED IMPACT CATEGORIES – APPARENT CONSUMPTION (EU-27, 2004 = 1)

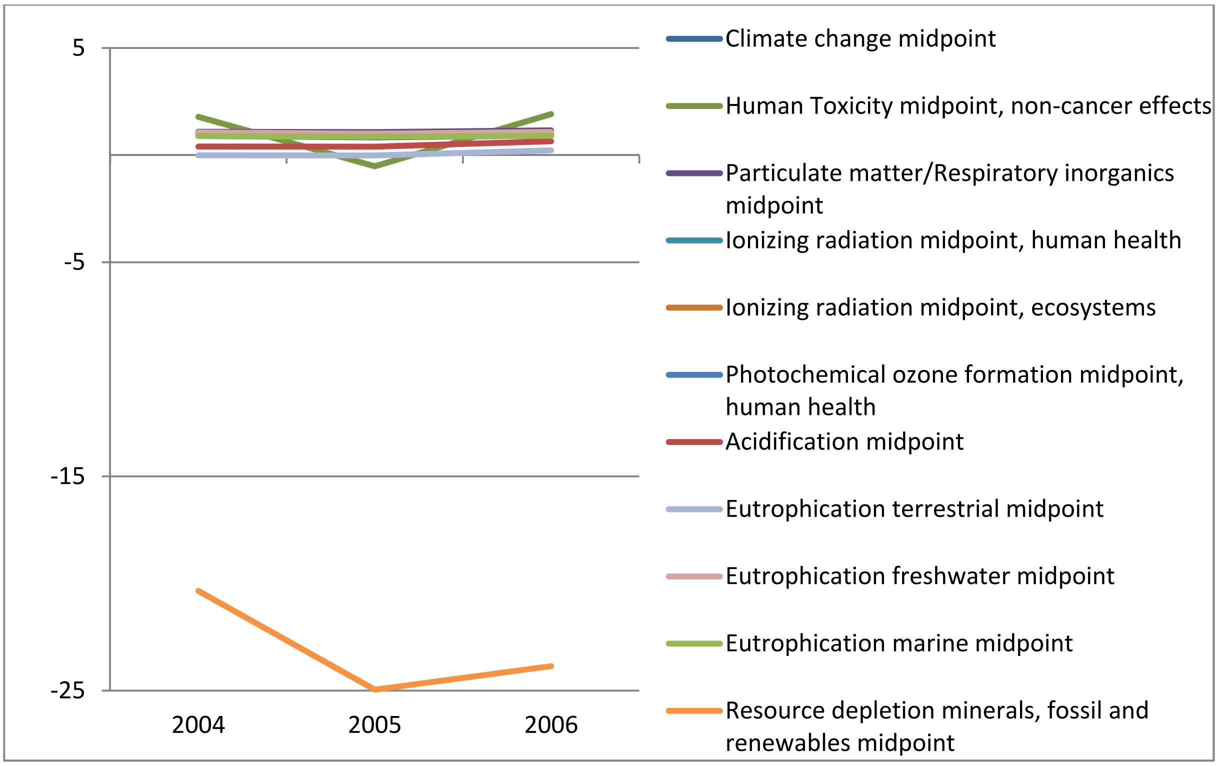

FIGURE 35 NORMALISED IMPACT CATEGORIES – APPARENT CONSUMPTION (DE)

7.2 WEIGHTING

7.2.1 GENERAL ASPECTS

The list of recommended environmental impact categories is provided by the ILCD Handbook (EC, 2011c). The ILCD Handbook also gives recommendations on environmental impact assessment models and factors for LCA, which constitute the starting point for the development of the weighting scheme.

Arriving at an overall eco-efficiency indicator starts with a large number of environmental interventions, covering emissions, extraction of resources and land use. These correspond to the life cycle inventory (LCI) results (or flows) of a life cycle assessment (LCA).

Next, relatively simple and stable models link this large number of flows to a much smaller number of midpoint effects, like radiative forcing in the context of climate change, primary resource depletion or acidification. Ultimately, there are effects which are directly important for judgment: health effects, effects on the natural environment, and effects on human welfare. These ultimate endpoint effects are much more difficult to model.

The weighting methods methodologies can be grouped into three main categories: midpoint methods, endpoint methods, and integrated methods. Integrated methodologies include both midpoints and endpoints.

There are several operational weighting methods available which apply to these three main approaches. In this report, an average weighting set for midpoint assessment has been used. It has been adapted from the weighting factors of three panel weighting sets (EPA Science Advisory Board, BEES Stakeholder Panel and NOGEPA). The weighting scheme used (Table 22) is described in detail in the report Huppes and van Oers (2011).

In this development, not all impact categories recommended by the ILCD Handbook have been included in the weighting procedure (see Table 22 which summarises the reasons for exclusion). For the categories that are included in the aggregation process, the Simple Additive Weighting scheme is applied. This calculates the sum-product by multiplying the normalised impact category scores with their respective weights (see Hwang and Yoon, 1981 and Yoon and Hwang, 1995).

It should be noted that the weighting step and calculation of a single environmental impact score is only done for demonstration purposes and should not be considered a recommendation or official weighting set endorsed by the European Commission.

7.2.2 WEIGHTED RESULTS

The overall environmental impact indicator for EU-27 presented in Figure 36 include all impact categories in a single score indicator based on the weighting factors in Table 22. The value for the domestic inventory in 2004 is one, as all normalised impact category values of the domestic inventory are one for 2004. The small decrease (-3% between 2004 and 2006) over time for the domestic inventory reflects the overall decreasing tendency for all impact categories considered.

In contrast, the apparent consumption describes an increase over time (+10% between 2004 and 2006), mainly influenced by the high increase of resource depletion impacts (fossil and minerals) associated with imports.

TABLE 22 AVERAGE AND ADJUSTED WEIGHTING SCHEME

Impact category (midpoint)	Weight	Adjusted weighting set for selected impact categories	Reasons for exclusion
Climate change	23.21%	36.37%	
Ozone depletion	3.62%	0.00%	Data availability and quality for domestic emissions are poor
Human toxicity, cancer effects	6.49%	0.00%	Emissions incomplete for domestic inventory
Human toxicity, non-cancer effects	4.05%	6.35%	
Particulate matter/Respiratory inorganics	6.56%	10.29%	
Ionizing radiation, human health	3.23%	5.06%	
Ionizing radiation, ecosystems	3.23%	5.06%	
Photochemical ozone formation, human health	5.38%	8.44%	
Acidification	4.21%	6.59%	
Eutrophication terrestrial	2.33%	3.66%	
Eutrophication freshwater	2.33%	3.66%	
Eutrophication marine	2.33%	3.66%	
Ecotoxicity freshwater	10.87%	0.00%	Highest impacts from pesticide emissions which were calculated using the PEST LCI model; PEST was originally developed to conduct LCA of specific agricultural products and not macro-scale analysis of the entire agriculture industry
Land use	10.15%	0.00%	High variations for domestic inventory due to impact assessment methodology; not included in imports and exports
Resource depletion water	5.08%	0.00%	Not covered in domestic inventory; country-specific information not available within LCI data used for import and export
Resource depletion, mineral, fossils and renewables	6.92%	10.85%	

Source: Based on Huppes and van Oers (2011)

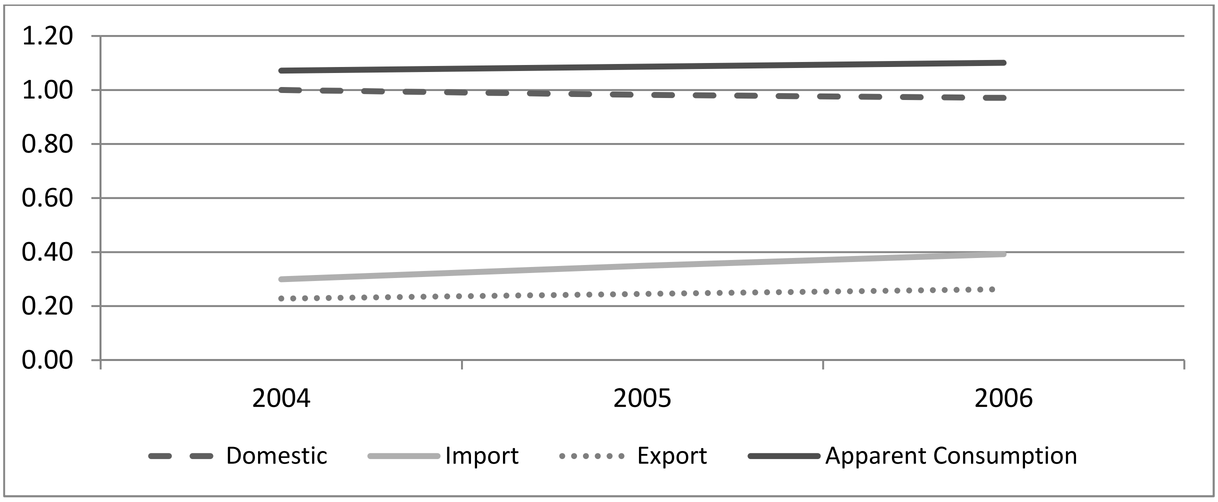

FIGURE 36 OVERALL ENVIRONMENTAL IMPACT INDICATOR (EU-27)

8 CONCLUSIONS AND WAY FORWARD

The development of the resource life cycle indicators is a significant improvement in the measurement of environmental impacts for entire economies and regions. The consideration of domestic impacts alone does not take into account a possible outsourcing of heavy industries outside of the domestic territory or the import dependency of economies. The proposed indicators provide a useful tool to assess the decoupling of economic growth and environmental impacts for several important impact categories.

The results and interpretation illustrate that, especially for the EU-27, the indicators provide reliable and meaningful results for different impact categories such as: climate change; particulate matter/respiratory inorganics; photochemical ozone formation; acidification; eutrophication terrestrial; and marine as well as ecotoxicity freshwater.

The remaining impact categories are affected by certain distortions as described in chapter 6. The following suggestions are made to improve the reliability of the results for these impact categories:

- For certain product groups, the number of selected representatives should be increased. This is especially the case for imported mineral fuels, ores and semi-finished metal products. Increasing the number of the considered representative products will improve the reliability of the resource depletion indicator.
- The number of product groups covered in the analysis should be increased. This is especially important for the application of the indicators at a Member State level. Since the selection was made from the EU-27 perspective, some imports and exports might not be relevant for specific Member States.
- Data gaps within the domestic inventory should be reduced.
- The elementary flows of life cycle inventory (LCI) data and the domestic inventory should be harmonized.
- Currently differing system boundaries of the domestic inventory and LCI data for imports and exports should be aligned (e.g. consideration of micronutrition intake for biomass within LCI data).
- Ideally, the LCI data should include the consumption mixes for cradle-to-gate data as used for the production of manufactured goods in the relevant exporting countries.
- LCI data sets for exported products should ideally be country specific if the indicators are applied at the Member State level.
- In terms of statistical data, especially domestic data on a number of emission types and on water use need to be collected.
- As an alternative approach to develop the domestic data, a bottom-up calculation by expanding and adjusting the separate basket-of-products indicator could be considered.

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ANNEX 1 REFERENCE DATA

TABLE 23 LAND USE CATEGORIES OF ENVIRONMENT STATISTICS OF EUROSTAT

Code	Label	Data
LA_1	Total agricultural land	1
LA_1_1	Arable land	2
LA_1_2	Land under permanent crops	3
LA_1_3	Land under permanent meadows and pasture	4
LA_1_4	Other agricultural land	5
LA_2	Total land under forest and other wooded land	6
LA_2_1	Predominantly coniferous	7
LA_2_2	Predominantly broadleaved	8
LA_2_3	Predominantly other	9
LA_2_4	Mixed forest	10
LA_2_5	Other wooded land	11
LA_3	Built-up and related land	12
LA_3_1	Residential land	13
LA_3_2	Industrial land	14
LA_3_3	Land used for quarries, pits, mines, etc.	15
LA_3_4	Commercial land	16
LA_3_5	Land used for public services, excluding transport, communication and technical infrastructure	17
LA_3_6	Land of mixed use	18
LA_3_7	Land used for transport and communication	19
LA_3_8	Land used for technical infrastructure	20
LA_3_9	Recreational and other open land	21
LA_4	Wet open lands	22
LA_4_1	Mires	23
LA_4_2	Wet tundra	24
LA_4_3	Other wet open lands	25
LA_5	Total dry open lands	26
LA_5_1	Dry open land with special vegetation cover	27
LA_5_1_1	Heathland	28
LA_5_1_2	Dry tundra	29
LA_5_1_3	Mountainous grassland	30
LA_5_1_4	Other dry open land with special vegetation cover	31
LA_5_2	Dry open land without, or with insignificant vegetation cover	32
LA_5_2_1	Bare rocks, glaciers and perpetual snow	33
LA_5_2_2	Sand beaches, dunes and other sandy lands	34
LA_5_2_3	Other dry open land without, or with insignificant vegetation cover	35
LA_6	Waters	36
LA_6_1	Inland waters	37
LA_6_2	Tidal waters	38
LA_7	Land area	39
LA_8	Total area	40

TABLE 24 LAND USE CATEGORIES OF CORINE LAND COVER

Categories
1. Artificial surfaces
1.1 Urban fabric
111 Continuous urban fabric
112 Discontinuous urban fabric
1.2 Industrial, commercial and transport units
121 Industrial or commercial units
122 Road and rail networks and associated land
123 Port areas
124 Airports
1.3 Mines, dump and construction sites
131 Mineral extraction sites
132 Dump sites
133 Construction sites
1.4 Artificial non-agricultural vegetated areas
141 Green urban areas
142 Sport and leisure facilities
2 Agricultural areas
2.1 Arable land
211 Non-irrigated arable land
212 Permanently irrigated land
213 Rice fields
2.2 Permanent crops
221 Vineyards
222 Fruit trees and berry plantations
223 Olive groves
2.3 Pastures
231 Pastures
2.4 Heterogeneous agricultural areas
241 Annual crops associated with permanent crops
242 Complex cultivation patterns
243 Agriculture and significant natural vegetation mosaics
244 Agro-forestry areas
3 Forests and semi-natural areas
3.1 Forests
311 Broad-leaved forest
312 Coniferous forest
313 Mixed forest
3.2 Shrub and/or herbaceous vegetation associations
321 Natural grassland
322 Moors and heathland
323 Sclerophyllous vegetation

Categories
324 Transitional woodland shrub
3.3 Open spaces with little or no vegetation
331 Beaches, dunes and sand plains
332 Bare rock
333 Sparsely vegetated areas
334 Burnt areas
335 Glaciers and perpetual snow
4 Wetlands
4.1 Inland wetlands
411 Inland marshes
412 Peatbogs
4.2 Coastal wetlands
421 Salt marshes
422 Salines
423 Intertidal flats
5 Water bodies
5.1 Inland waters
511 Water courses
512 Water bodies (lakes and reservoirs)
5.2 Coastal waters
521 Coastal lagoons
522 Estuaries
523 Sea and ocean

TABLE 25 PRIMARY CROPS LIST FROM FAOSTAT WITH HARVESTED AREA IN EU-27 [kha]

Item	Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agave Fibres Nes	800	n/a									
Alfalfa for forage and silage	641	2313.7	2140.0	2179.2	2172.2	2008.3	2107.6	2095.7	2025.2	2054.7	2040.4
Almonds, with shell	221	844.8	831.9	802.7	793.8	771.7	772.7	723.9	706.8	706.0	788.4
Anise, badian, fennel, corian.	711	35.6	37.6	47.6	49.1	50.3	45.3	36.7	37.3	39.1	40.7
Apples	515	736.6	692.1	664.9	606.1	620.4	614.1	574.3	577.8	561.3	560.1
Apricots	526	86.0	75.2	76.2	81.2	79.5	79.0	75.3	75.0	83.1	82.9
Arecanuts	226	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Artichokes	366	85.0	83.2	84.4	82.6	81.6	82.2	81.6	80.3	77.7	79.5
Asparagus	367	54.9	56.9	55.6	55.3	55.4	56.8	57.0	54.9	52.3	52.2
Avocados	572	19.2	19.0	19.5	20.0	20.1	20.3	21.2	21.9	22.0	22.5
Bambara beans	203	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bananas	486	10.6	10.9	10.9	11.4	11.4	11.2	11.3	11.2	10.8	11.6
Barley	44	14202.0	14330.2	14269.4	14027.7	13704.8	13828.9	13760.0	13698.7	14521.1	13944.0
Beans, dry	176	144.0	114.0	114.2	112.9	126.6	134.0	131.0	107.4	90.9	84.4
Beans, green	414	97.4	92.4	92.2	97.1	96.0	94.8	96.1	91.8	85.7	81.9
Beets for Fodder	647	105.3	82.6	72.5	68.3	66.4	63.2	61.2	60.1	60.9	60.8
Berries Nes	558	5.9	5.6	5.9	15.2	14.9	21.1	20.5	22.2	23.4	23.6
Blueberries	552	9.4	10.2	10.7	10.5	10.1	12.9	14.0	14.6	12.5	11.1

Item	Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Brazil nuts, with shell	216	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Broad beans, horse beans, dry	181	175.1	184.9	233.8	264.8	251.4	286.2	256.0	221.7	226.8	253.8
Buckwheat	89	103.3	109.1	94.4	96.8	123.4	146.6	160.2	141.0	139.2	141.3
Cabbage for Fodder	644	66.0	50.5	54.0	51.4	50.1	47.4	46.6	46.3	46.3	46.3
Cabbages and other brassicas	358	232.3	226.0	208.3	220.8	205.6	220.7	203.7	199.5	194.8	201.4
Canary seed	101	20.1	5.7	9.0	15.6	11.7	10.3	8.1	6.3	6.4	6.8
Carobs	461	107.3	96.2	93.4	87.1	86.1	86.2	63.5	62.0	70.1	74.6
Carrots and turnips	426	142.1	141.6	138.7	153.5	159.2	160.6	158.9	142.4	138.4	141.3
Carrots for Fodder	648	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Cashew nuts, with shell	217	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cashewapple	591	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cassava	125	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Castor oil seed	265	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cauliflowers and broccoli	393	138.7	131.8	130.5	140.4	131.6	131.6	135.4	133.9	129.7	130.4
Cereals, nes	108	23.6	24.1	25.3	50.3	44.3	36.3	48.6	64.1	61.9	71.0
Cherries	531	159.4	161.8	138.9	132.8	131.2	126.2	126.5	126.9	125.2	129.5
Chestnuts	220	74.4	73.9	75.9	81.4	76.8	77.0	76.9	80.4	83.6	81.9
Chick peas	191	89.9	94.7	102.6	98.2	97.3	71.8	36.0	43.0	34.0	37.6
Chicory roots	459	20.9	19.7	18.1	19.8	20.4	20.4	11.7	12.1	11.9	11.9
Chillies and peppers, dry	689	44.6	45.4	44.6	44.9	44.7	44.1	40.5	38.4	37.2	37.7
Chillies and peppers, green	401	93.2	84.6	84.7	86.6	81.1	75.3	84.0	76.0	67.1	70.3
Cinnamon (canella)	693	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Citrus fruit, nes	512	2.17	2.36	2.91	2.43	4.21	5.43	6.47	5.57	3.97	4.73
Clover for forage and silage	640	1058.3	1017.1	964.0	947.1	819.5	996.0	1066.2	1011.6	1003.7	1004.1
Cloves	698	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cocoa beans	661	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coconuts	249	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coffee, green	656	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cow peas, dry	195	0.07	0.07	0.07	0.08	0.08	0.10	0.09	0.09	0.12	0.12
Cranberries	554	1.70	2.60	1.00	1.02	0.90	0.80	0.80	0.80	0.80	0.80
Cucumbers and gherkins	397	73.8	68.8	63.4	64.2	62.8	59.6	66.5	60.4	58.4	58.3
Currants	550	72.6	74.1	81.1	79.2	81.0	88.0	62.8	64.6	62.0	61.5
Dates	577	0.75	0.86	0.76	0.76	0.87	0.89	0.87	0.95	0.84	0.85
Eggplants (aubergines)	399	25.9	25.7	24.8	32.0	31.2	30.0	31.6	31.8	29.4	27.6
Fibre Crops Nes	821	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Figs	569	129.6	125.5	125.7	116.2	116.4	116.3	110.1	109.9	107.3	106.2
Flax fibre and tow	773	138.8	143.4	133.0	152.2	144.4	141.1	119.1	114.2	110.6	109.4
Fonio	94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
forage Products	651	1158.6	1138.9	1134.2	1132.8	1131.6	1144.1	1141.8	1140.3	1150.8	1150.8
Fruit Fresh Nes	619	74.3	59.9	59.5	71.8	69.3	73.0	73.9	78.7	80.2	81.3
Fruit, tropical fresh nes	603	3.08	3.08	3.08	3.09	3.09	2.89	2.89	2.89	2.89	2.89

Item	Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Garlic	406	59.7	60.2	52.6	49.8	42.9	42.2	40.8	39.0	39.6	39.6
Ginger	720	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gooseberries	549	21.7	21.6	19.2	19.1	19.1	13.9	13.7	13.8	13.7	14.0
Grapefruit (inc. pomelos)	507	3.01	2.90	3.04	2.60	2.77	2.68	2.76	2.70	2.92	2.81
Grapes	560	3920.2	3876.9	3871.8	3860.0	3788.5	3748.7	3739.0	3649.3	3597.7	3622.9
Grasses Nes for forage;Sil	639	2397.8	2288.8	2386.4	2402.7	2410.8	2457.2	2404.6	2423.5	2415.4	2417.7
Green Oilseeds for Silage	642	2819.6	2828.6	2827.7	2828.5	2828.4	2826.7	2827.0	2828.0	2828.0	2828.0
Groundnuts, with shell	242	11.0	11.0	10.9	10.8	9.8	10.8	10.9	10.6	10.6	10.6
Hazelnuts, with shell	225	96.9	95.3	95.3	95.7	94.1	95.2	96.7	97.2	94.9	92.6
Hemp Tow Waste	777	6.2	1.8	2.3	3.5	6.5	7.5	3.6	2.8	2.8	2.8
Hempseed	336	8.6	7.3	9.5	8.5	11.0	10.2	10.2	10.2	10.2	10.5
Hops	677	33.8	34.6	35.4	31.5	30.9	30.6	30.7	31.1	32.1	32.1
Jute	780	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Karite Nuts (Sheanuts)	263	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kiwi fruit	592	27.9	28.8	30.2	30.2	31.9	32.8	32.7	33.3	34.0	35.4
Kolanuts	224	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leeks, other alliaceous veg	407	34.5	31.8	30.0	31.6	31.5	31.2	31.6	31.1	29.8	30.4
Leguminous for Silage	643	2089.5	2071.1	2070.2	2056.9	2077.9	2106.8	2103.5	2103.5	2103.5	2103.5
Leguminous vegetables, nes	420	35.8	34.4	33.9	33.2	35.1	36.8	38.5	38.3	37.6	38.8
Lemons and limes	497	94.1	95.5	93.7	90.5	89.2	86.6	83.5	81.5	88.6	83.0
Lentils	201	38.2	36.3	39.2	42.5	48.8	52.7	35.5	31.6	30.1	39.4
Lettuce and chicory	372	144.7	143.1	140.4	142.0	144.2	143.0	146.1	137.8	135.5	135.4
Linseed	333	314.5	200.1	152.8	198.9	184.6	208.2	186.0	138.1	121.4	119.0
Lupins	210	49.8	45.5	41.2	86.0	78.5	96.7	92.1	94.6	69.6	79.4
Maize	56	9337.5	9619.0	9263.0	9737.6	10059.9	8991.7	8555.9	8033.6	8808.4	8349.4
Maize for forage and silage	636	4473.3	4538.4	4459.4	4788.2	4705.9	4685.3	4778.0	4952.7	5112.9	5220.5
Maize, green	446	48.6	52.3	65.8	73.1	61.8	55.8	60.7	62.7	60.8	57.4
Mangoes, mangosteens, guavas	571	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manila Fibre (Abaca)	809	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maté	671	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melonseed	299	1.90	1.70	1.70	1.70	1.70	1.70	1.70	1.80	1.80	1.80
Millet	79	18.2	17.8	22.9	30.4	37.2	30.9	34.2	32.9	32.6	34.3
Mixed grain	103	1714.6	1675.1	1570.1	1689.7	1685.4	1636.6	1766.1	1704.5	1618.9	1526.8
Mushrooms and truffles	449	0.47	0.46	0.48	0.45	0.45	0.42	0.48	0.45	0.42	0.41
Mustard seed	292	36.9	48.8	68.3	134.0	78.8	45.0	42.6	44.7	59.4	88.1
Natural rubber	836	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nutmeg, mace and cardamoms	702	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nuts, nes	234	19.2	25.0	13.6	22.0	21.9	6.7	6.6	5.9	5.9	5.9

Item	Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Oats	75	3063.2	3055.2	3240.9	3178.9	2912.4	2880.3	2925.9	2972.5	2992.4	2876.2
Oil palm fruit	254	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oilseeds, Nes	339	48.2	52.7	59.6	66.5	68.0	64.9	53.7	57.3	55.5	64.5
Okra	430	0.07	0.07	0.07	0.09	0.08	0.08	0.09	0.09	0.09	0.09
Olives	260	4635.2	4714.8	4751.7	4772.2	4830.9	4827.7	4862.4	4838.1	4841.8	4871.5
Onions (inc. shallots), green	402	10.5	10.7	10.4	12.0	10.8	10.5	11.7	11.4	11.7	11.8
Onions, dry	403	202.3	188.8	182.0	194.9	194.2	184.7	187.0	187.0	192.6	187.7
Oranges	490	305.4	307.1	291.9	306.9	305.2	307.0	306.2	310.8	317.9	310.3
Other Bastfibres	782	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other melons (inc.cantaloupes)	568	98.1	97.0	96.8	98.3	95.3	100.4	99.6	96.2	93.0	86.0
Papayas	600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peaches and nectarines	534	265.0	267.1	259.2	262.8	262.6	258.0	253.3	252.7	239.6	245.2
Pears	521	164.3	156.5	145.5	149.7	147.6	142.7	138.9	138.0	136.8	132.2
Peas, dry	187	943.2	977.7	898.4	905.0	902.0	823.8	722.3	591.9	430.7	537.5
Peas, green	417	165.0	162.8	164.6	165.2	151.9	148.0	157.1	160.9	162.9	162.8
Pepper (Piper spp.)	687	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peppermint	748	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Persimmons	587	2.23	2.68	2.89	2.87	2.85	2.75	2.86	3.03	2.73	2.74
Pigeon peas	197	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pineapples	574	0.16	0.16	0.16	0.16	0.16	0.16	0.20	0.25	0.25	0.25
Pistachios	223	9.2	8.8	9.1	9.3	8.4	8.7	8.4	8.7	8.5	8.5
Plantains	489	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plums and sloes	536	222.3	221.7	206.7	218.5	221.3	209.1	192.8	190.0	185.2	187.9
Popcorn	68	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Poppy seed	296	57.5	52.4	54.3	64.8	57.5	76.0	85.2	83.4	95.6	80.4
Potatoes	116	3265.6	3094.7	2683.4	2557.1	2485.0	2301.1	2273.0	2210.2	2115.4	2087.0
Pulses, nes	211	283.5	329.7	337.3	349.3	343.3	327.5	259.5	265.6	249.0	157.0
Pumpkins for Fodder	645	7611.9	7992.3	7936.9	7755.4	7771.7	7900.6	7962.1	8048.5	8050.5	7950.5
Pumpkins, squash and gourds	394	61.43	58.38	61.64	66.44	88.80	42.32	49.01	49.00	47.23	43.71
Pyrethrum,Dried	754	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quinces	523	3.62	3.58	3.57	3.81	3.76	3.89	4.16	4.17	4.25	4.60
Quinoa	92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ramie	788	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rapeseed	270	4139.9	4172.5	4246.6	4161.3	4557.2	4867.0	5400.3	6533.8	6128.6	6489.2
Raspberries	547	27.7	26.9	27.1	27.5	28.1	28.1	28.5	32.0	30.8	31.1
Rice, paddy	27	409.3	405.9	405.1	412.5	431.5	416.6	410.9	421.1	414.3	463.3
Roots and Tubers, nes	149	0.30	0.39	0.40	0.35	0.57	0.51	0.48	0.68	0.53	0.54
Rye	71	3746.1	3567.0	2910.9	2568.7	2761.8	2484.2	2343.1	2571.3	2751.9	2779.5
Rye grass for forage & silage	638	4891.0	4657.2	4757.3	5392.0	5189.7	5348.2	5391.1	5351.7	5374.6	5381.7
Safflower seed	280	0.6	0.3	0.5	0.4	0.6	0.3	0.3	0.1	0.2	0.1
Seed cotton	328	512.9	509.7	474.8	472.3	465.5	451.7	437.4	429.1	303.3	249.2
Sesame seed	289	0.14	0.10	0.30	0.27	0.30	0.25	0.27	0.30	0.26	0.26
Sisal	789	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Item	Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Sorghum	83	114.0	125.3	123.4	111.8	107.2	96.5	105.8	98.0	96.4	115.0
Sorghum for forage and silage	637	44.5	40.0	41.7	41.3	44.2	41.7	41.7	42.0	43.2	42.2
Sour cherries	530	76.9	82.4	69.6	68.7	69.7	65.3	61.6	62.9	62.8	63.9
Soybeans	236	501.6	452.8	354.2	422.9	386.7	419.3	487.5	344.5	235.6	303.6
Spices, nes	723	3.5	4.0	4.0	5.9	7.9	8.1	8.0	8.0	8.2	7.5
Spinach	373	30.7	30.2	30.2	31.5	32.0	32.4	31.6	31.6	31.2	30.3
Stone fruit, nes	541	8.0	8.0	8.2	7.4	8.6	8.7	9.1	10.1	9.8	9.8
Strawberries	544	125.3	124.7	95.4	100.6	107.5	114.2	114.9	110.1	111.8	110.7
String beans	423	38.9	39.5	37.9	39.5	37.7	37.9	37.1	39.7	40.5	41.9
Sugar beet	157	2490.5	2458.3	2459.2	2298.6	2229.7	2243.0	1873.7	1805.8	1531.2	1619.5
Sugar cane	156	1.12	1.02	0.93	1.15	1.15	0.66	0.34	0.07	0.07	0.07
Sugar crops, nes	161	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sunflower seed	267	3693.6	3484.7	3473.3	4245.8	3716.1	3600.2	3922.4	3278.3	3748.3	3887.3
Swedes for Fodder	649	23.90	24.90	26.60	30.10	35.10	44.80	64.00	65.00	65.00	65.00
Sweet potatoes	122	5.34	5.79	5.92	5.55	6.37	6.29	6.22	5.22	5.42	5.48
Tangerines, mandarins, clem.	495	159.8	164.5	167.2	164.4	164.6	167.1	169.2	171.4	168.1	173.9
Taro (cocoyam)	136	0.100	0.095	0.095	0.107	0.107	0.110	0.110	0.090	0.085	0.090
Tea	667	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tobacco, unmanufactured	826	191.2	203.4	192.1	189.0	196.9	183.1	125.8	125.1	117.5	120.1
Tomatoes	388	383.6	363.8	326.2	347.1	375.1	344.7	315.1	308.7	294.0	303.6
Triticale	97	1845.2	2065.5	2243.3	2299.1	2473.7	2593.5	2437.6	2516.2	2671.5	2874.8
Tung Nuts	275	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Turnips for Fodder	646	51.4	52.2	52.0	52.9	49.9	49.7	49.7	52.2	52.2	52.2
Vanilla	692	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vegetables fresh nes	463	447.6	449.0	435.6	421.9	416.6	411.3	403.0	400.5	348.7	357.5
Vegetables Roots Fodder	655	265.4	248.7	183.9	176.6	163.9	157.5	152.4	151.3	150.2	150.2
Vetches	205	183.6	175.2	188.9	185.5	162.5	163.5	68.0	56.7	42.5	63.9
Walnuts, with shell	222	77.8	67.3	64.9	72.0	68.8	68.7	73.7	89.7	90.6	86.7
Watermelons	567	132.9	107.3	110.2	114.5	106.8	99.5	94.7	84.3	83.7	89.0
Wheat	15	26560.8	26412.8	26888.5	24329.1	26597.9	26446.4	24924.7	24829.2	26491.1	25637.9
Yams	137	0.130	0.130	0.130	0.130	0.130	0.130	0.150	0.160	0.165	0.165
Yautia (cocoyam)	135	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

ANNEX 2 INDICATORS RESULTS FOR THE EUROPEAN UNION (EU-27)

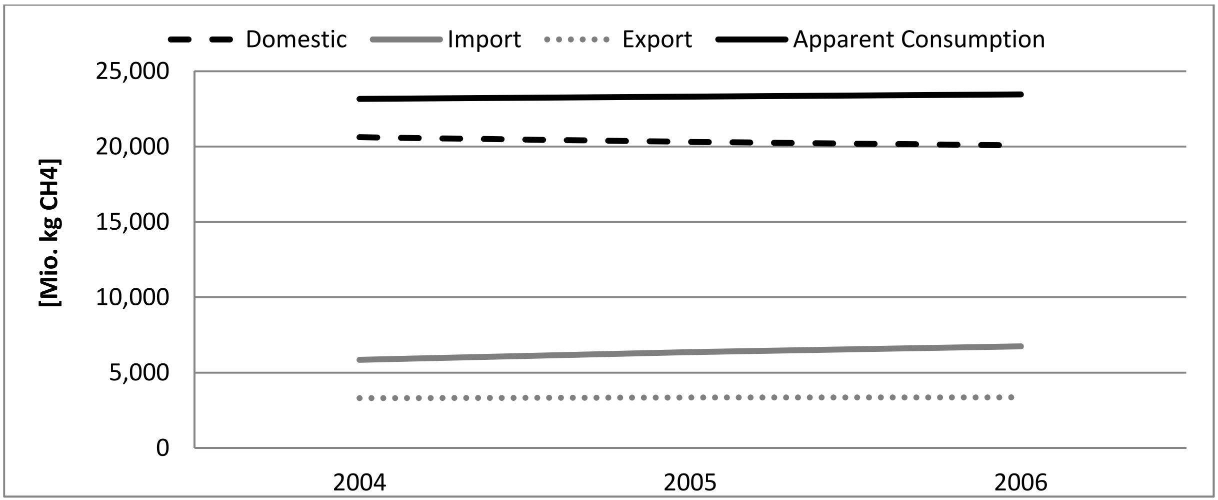

FIGURE 37 METHANE EMISSIONS (EU-27)

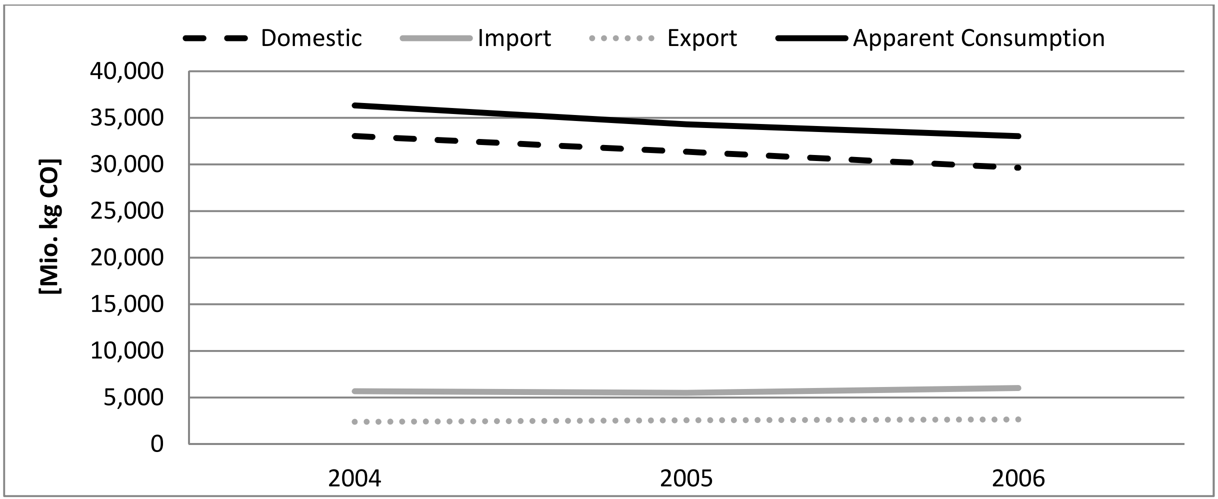

FIGURE 38 CARBON MONOXIDE EMISSIONS (EU-27)

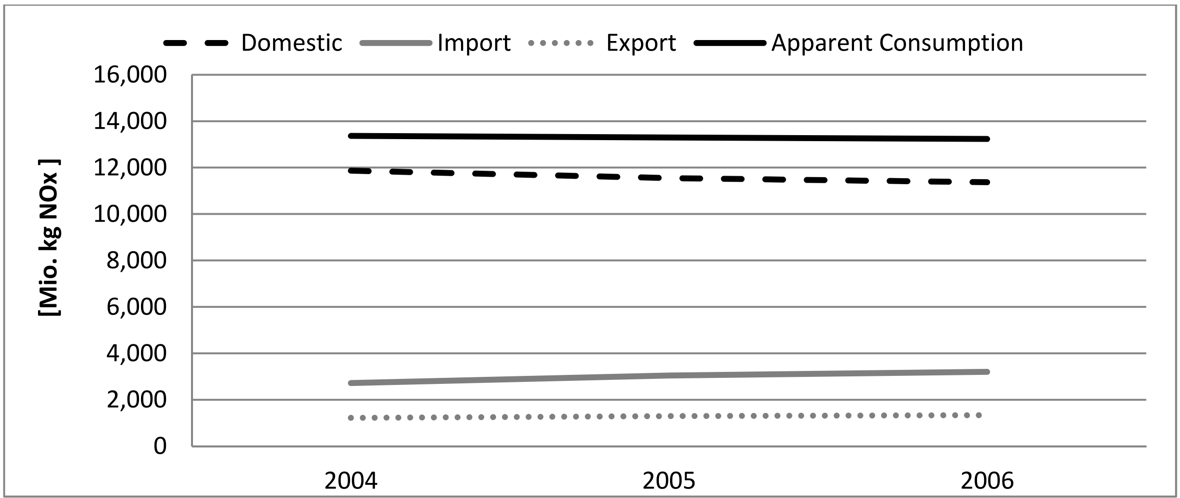

FIGURE 39 NITROGEN OXIDES EMISSIONS (EU-27)

TABLE 26 RESULTS FOR THE ECO-EFFICIENCY INDICATORS (EU-27)

Eco-efficiency indicator (midpoint)	Unit	2004	2005	2006
GDP/Climate change	EUR/kg CO_2 eq.	1.93	1.96	1.99
GDP/Ozone depletion	EUR/kg CFC11 eq.	107 072 770	54 498 998	106 645 725
GDP/Human toxicity, cancer effect	EUR/CTUh	2 885 460 098	2 702 118 397	2 837 677 795
GDP/Human toxicity, non-cancer effect	EUR/CTUh	-251 442 172	-251 594 910	-291 487 023
GDP/Particulate matter/Respiratory inorganics	EUR/kg PM2.5 eq.	2 963	3 037	3 120
GDP/Ionizing radiation, human health	EUR/kg U235 eq.	357	547	505
GDP/Ionizing radiation, ecosystems	EUR/CTUe	91 028 559	88 188 847	71 108 625
GDP/Photochemical ozone formation	EUR/kg C_2H_4 eq.	527	542	564
GDP/Acidification	EUR/mol H+	272	274	281
GDP/Eutrophication terrestrial	EUR/kg N eq.	92	94	98
GDP/Eutrophication freshwater	EUR/kg P eq.	765 458	744 071	754 236
GDP/Eutrophication marine	EUR/kg N eq.	1 784	1 827	1 896
GDP/Ecotoxicity freshwater	EUR/CTUe	2	2	3
GDP/Land use	EUR/(kg C deficit*year)	0.3881	0.5711	1.1247
GDP/Resource depletion minerals, fossil	EUR/Person Reserve	28 879	26 392	25 287

ANNEX 3 INDICATORS RESULTS FOR GERMANY (DE)

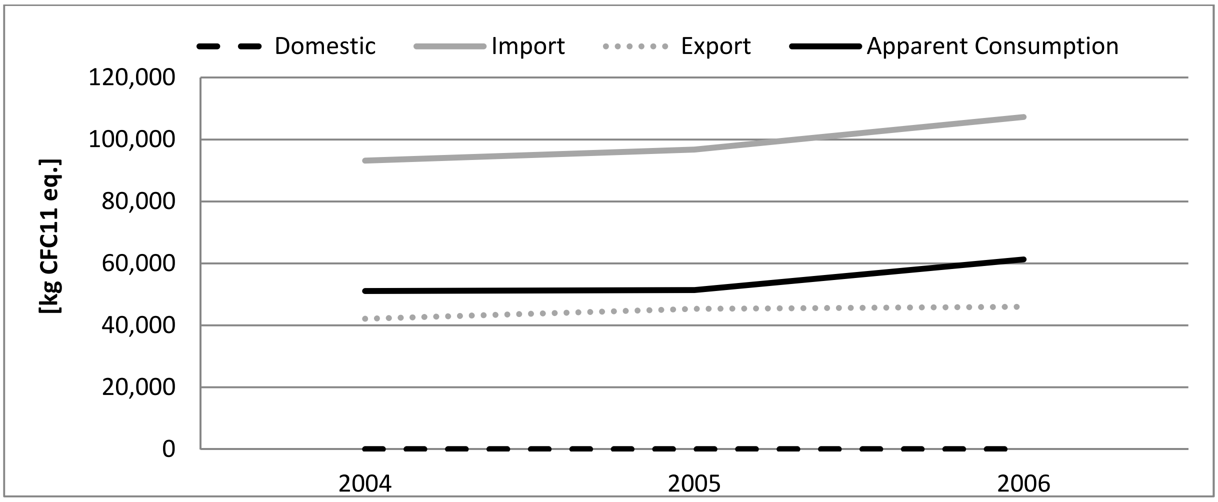

FIGURE 40 OZONE DEPLETION (DE)

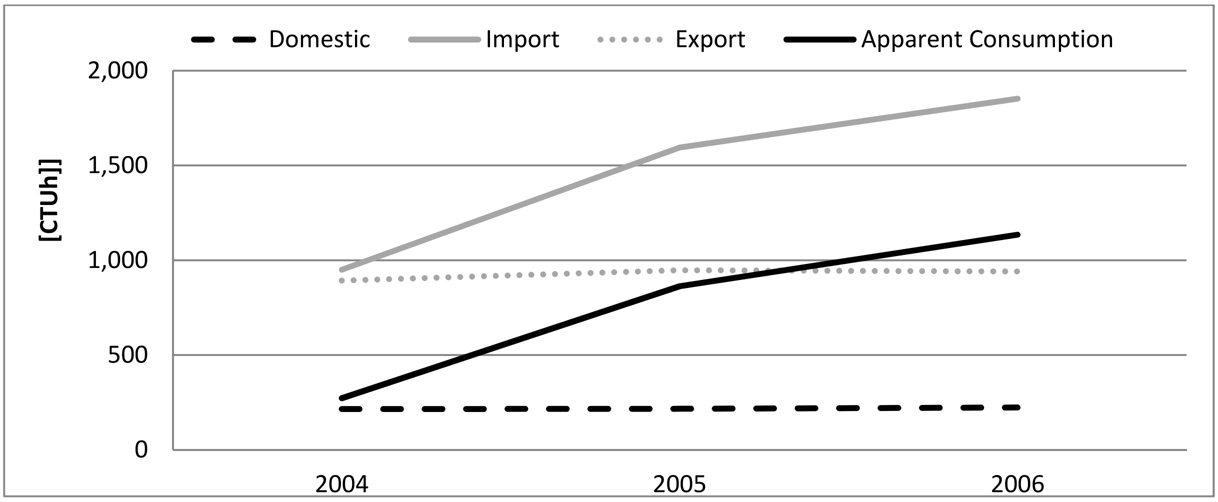

FIGURE 41 HUMAN TOXICITY (CANCER EFFECTS) (DE)

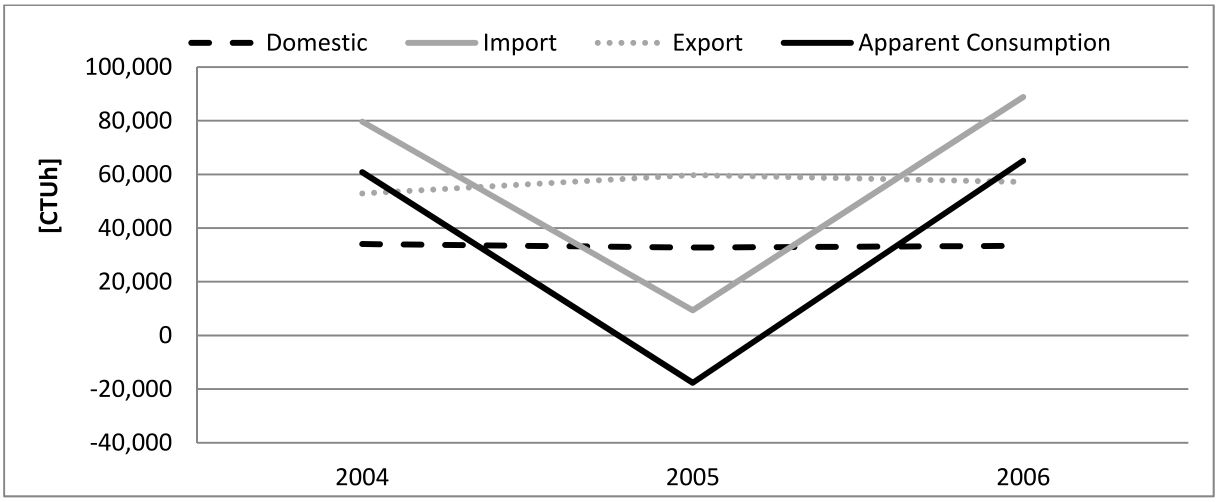

FIGURE 42 HUMAN TOXICITY (NON-CANCER EFFECTS) (DE)

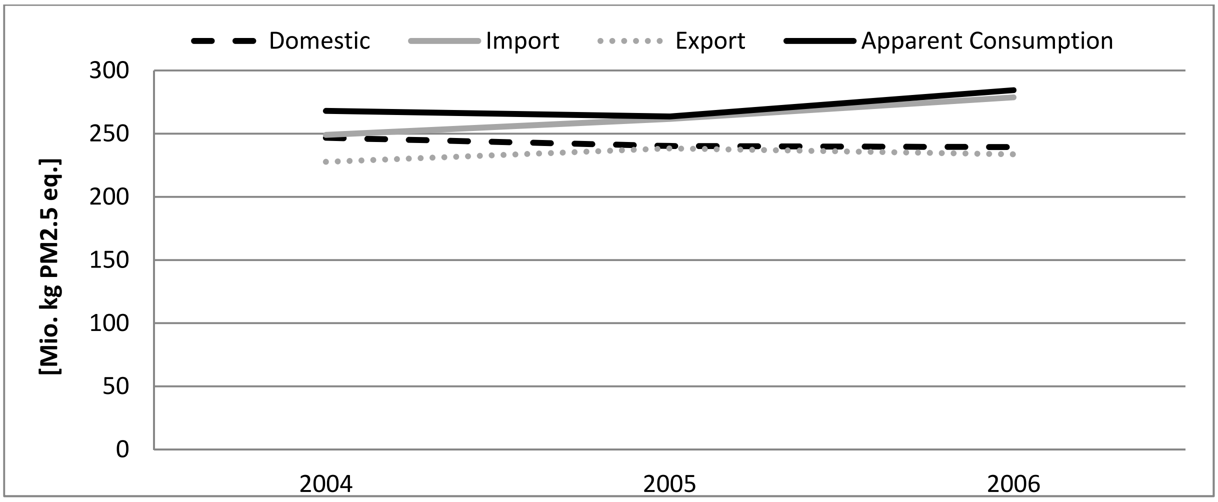

FIGURE 43 PARTICULATE MATTER/RESPIRATORY INORGANICS (DE)

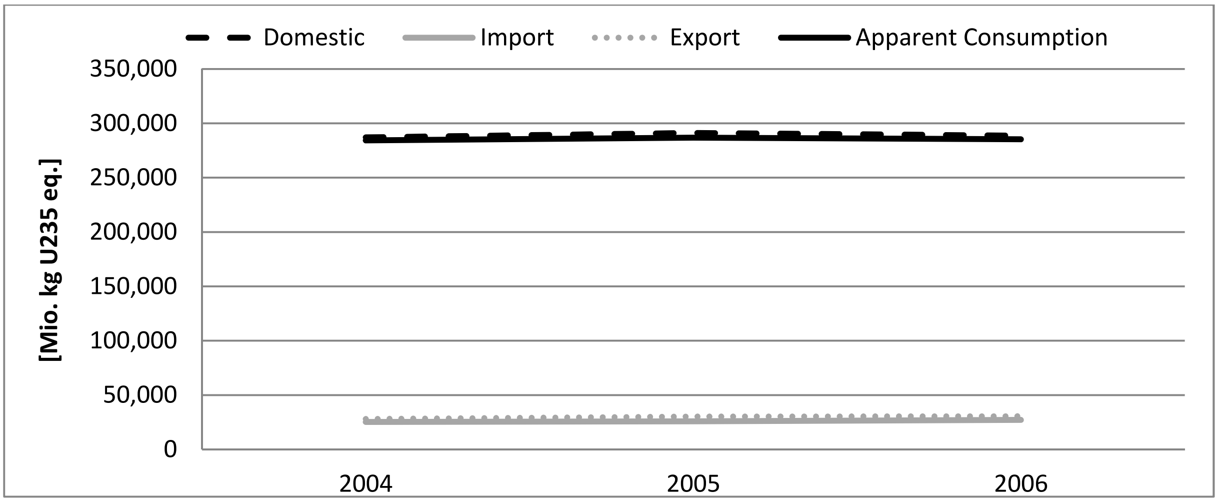

FIGURE 44 IONIZING RADIATION (HUMAN HEALTH) (DE)

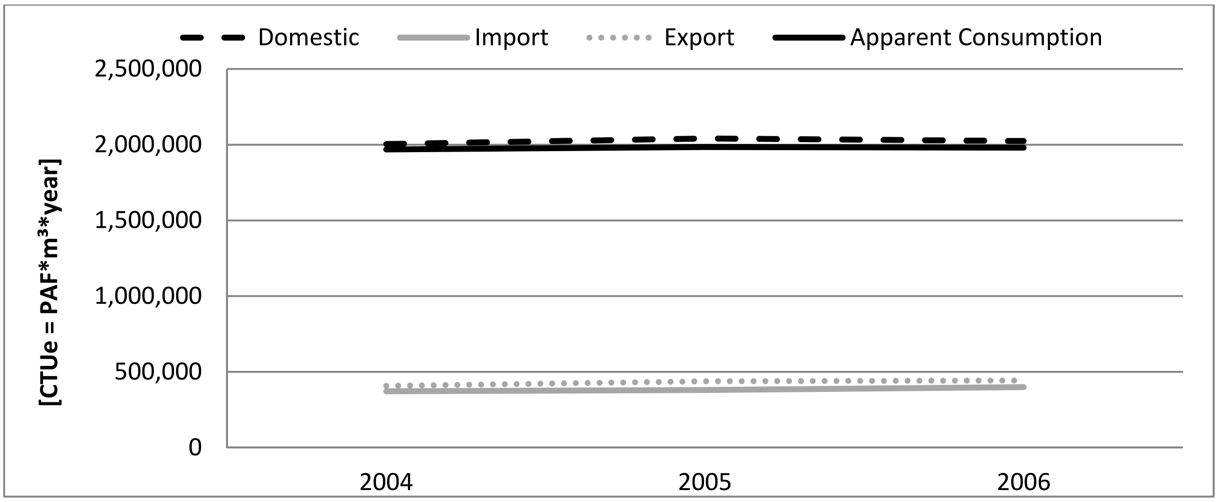

FIGURE 45 IONIZING RADIATION (ECOSYSTEMS) (DE)

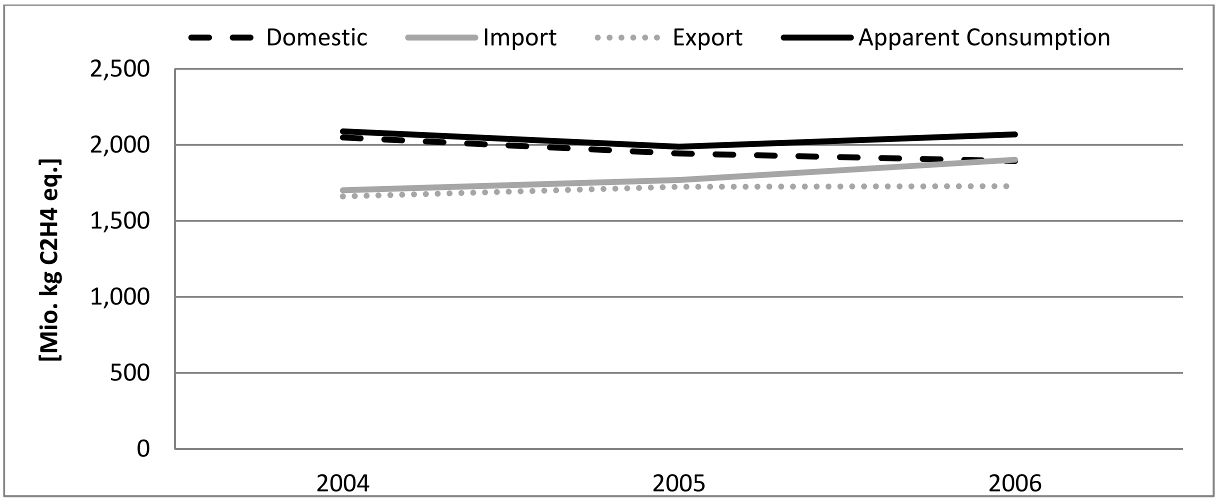

FIGURE 46 PHOTOCHEMICAL OZONE FORMATION (DE)

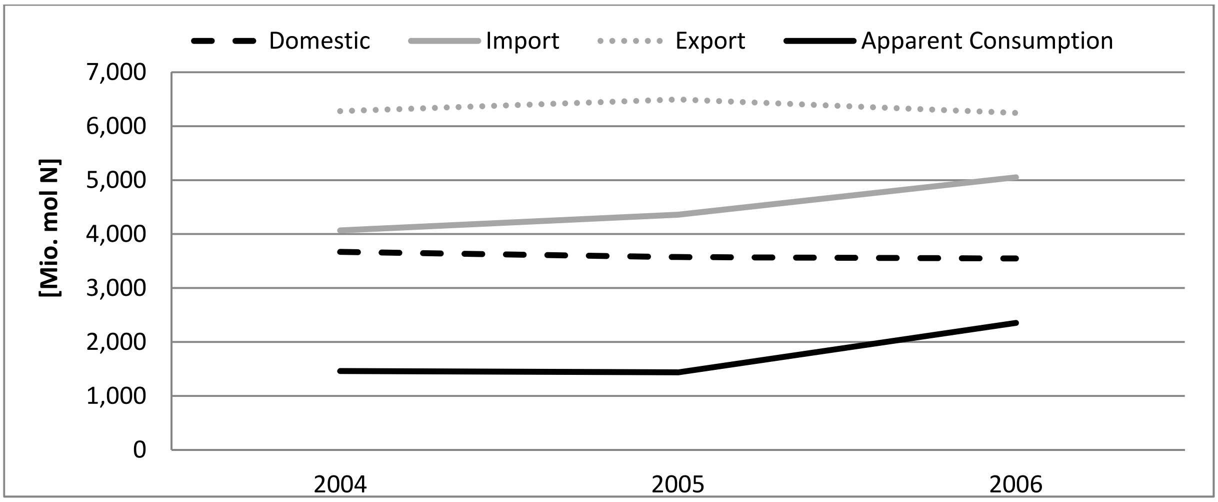

FIGURE 47 ACIDIFICATION (DE)

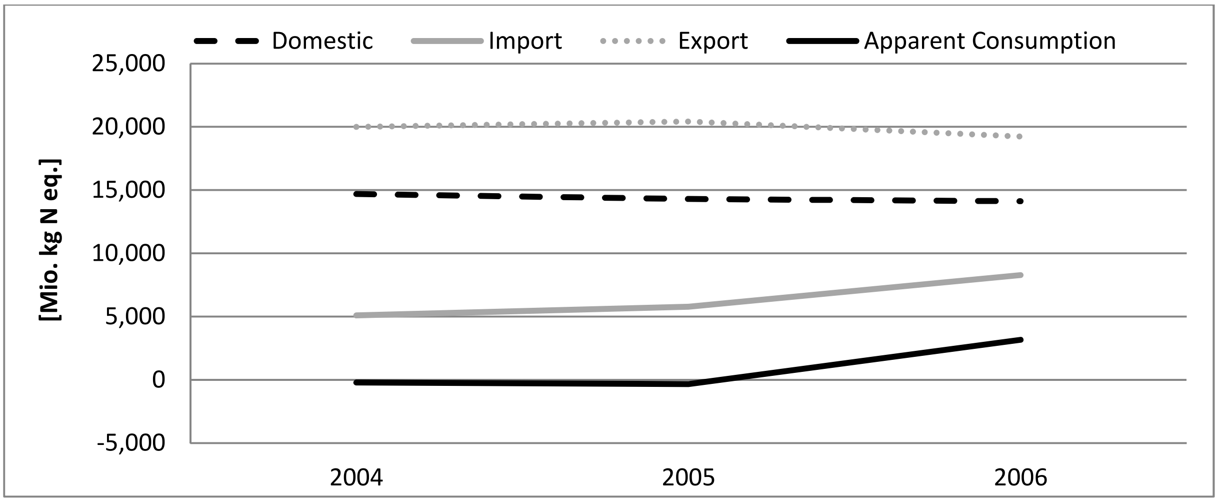

FIGURE 48 EUTROPHICATION TERRESTRIAL (DE)

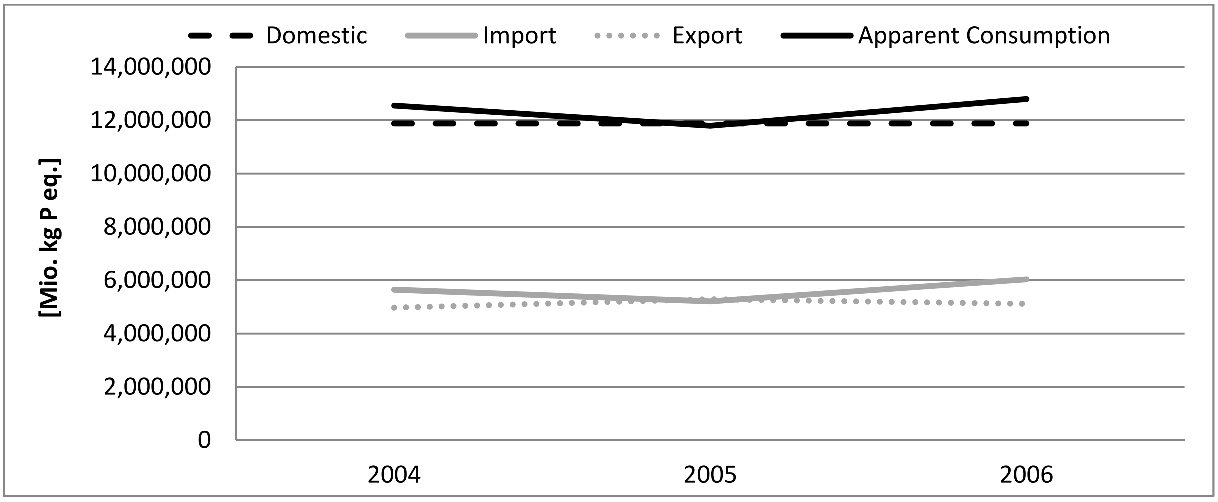

FIGURE 49 EUTROPHICATION FRESHWATER (DE)

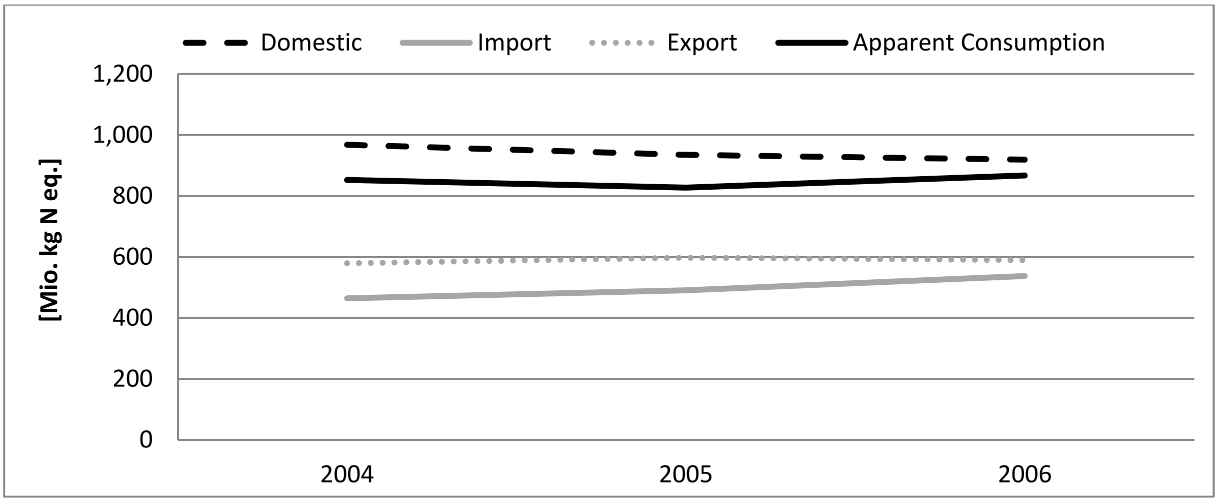

FIGURE 50 EUTROPHICATION MARINE (DE)

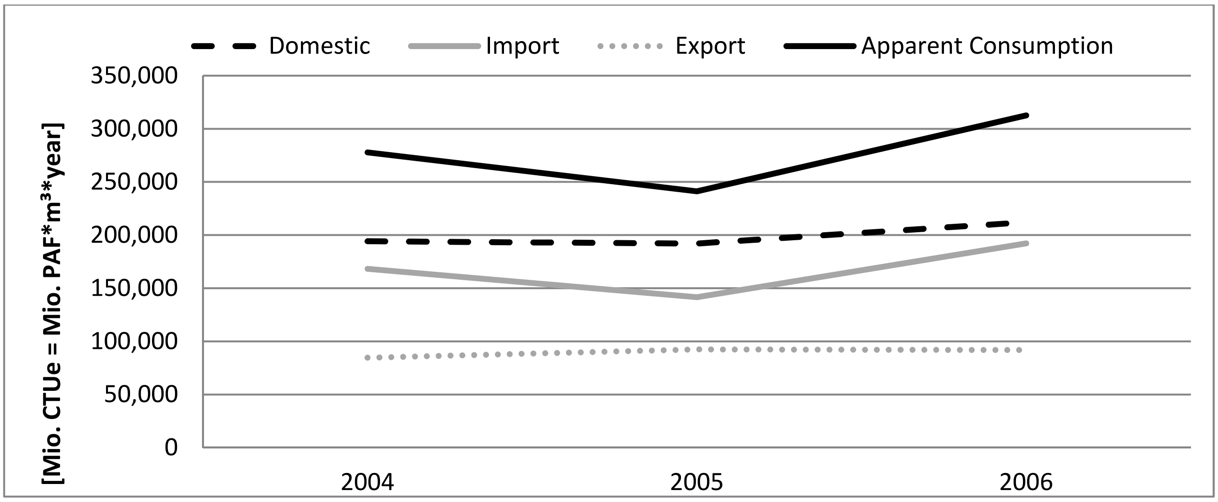

FIGURE 51 ECOTOXICITY FRESHWATER (DE)

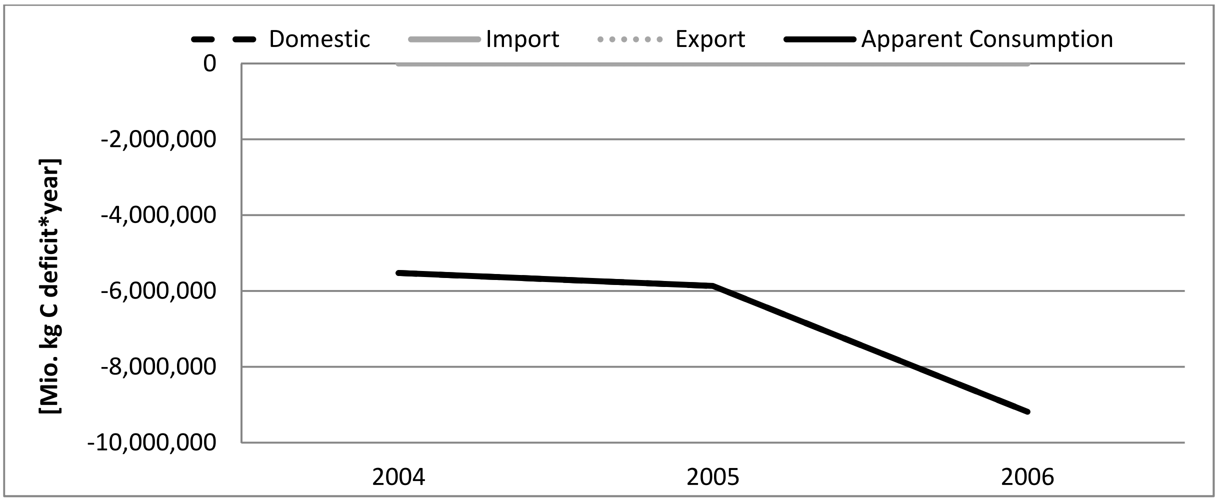

FIGURE 52 LAND USE (DE)

TABLE 27 RESULTS FOR THE ECO-EFFICIENCY INDICATORS (DE)

Eco-efficiency indicator (midpoint)	Unit	2004	2005	2006
GDP/Climate change	EUR/kg CO_2 eq.	2.24	2.44	2.29
GDP/Ozone depletion	EUR/kg CFC11 eq.	41 310 277	41 353 670	35 846 461
GDP/Human toxicity, cancer effect	EUR/CTUh	12 550 101 175	2 793 545 287	2 135 142 778
GDP/Human toxicity, non-cancer effect	EUR/CTUh	75 016 321	- 43 262 365	66 437 530
GDP/Particulate matter/Respiratory inorganics	EUR/kg PM2.5 eq.	7 868	8 060	7 719
GDP/Ionizing radiation, human health	EUR/kg U235 eq.	101	253	240
GDP/Ionizing radiation, ecosystems	EUR/CTUe	325 913 259	- 61 037 762	- 99 692 494
GDP/Photochemical ozone formation	EUR/kg C_2H_4 eq.	1 010	1 069	1 062
GDP/Acidification	EUR/mol H+	1 445	- 1 478	933
GDP/Eutrophication terrestrial	EUR/kg N eq.	- 9 712	- 6 135	693
GDP/Eutrophication freshwater	EUR/kg P eq.	3 137 201	- 25 548 332	2 388 419
GDP/Eutrophication marine	EUR/kg N eq.	4 079	4 322	4 133
GDP/Ecotoxicity freshwater	EUR/CTUe	11	15	10
GDP/Land use	EUR/(kg C deficit*year)	- 0.3816	- 0.3620	- 0.2390
GDP/Resource depletion minerals, fossil	EUR/Person Reserve	- 23 439	- 19 254	20 820

ANNEX 4 ESTIMATION OF EMISSIONS OF PESTICIDES TO AIR AND WATER

The procedure developed to estimate emissions of pesticides to air and water consists of five main steps that combine FAO data and modelling results from the PestLCI model as presented in the Figure 53. The following sections describe the five steps in more detail and give an outlook for possible future development.

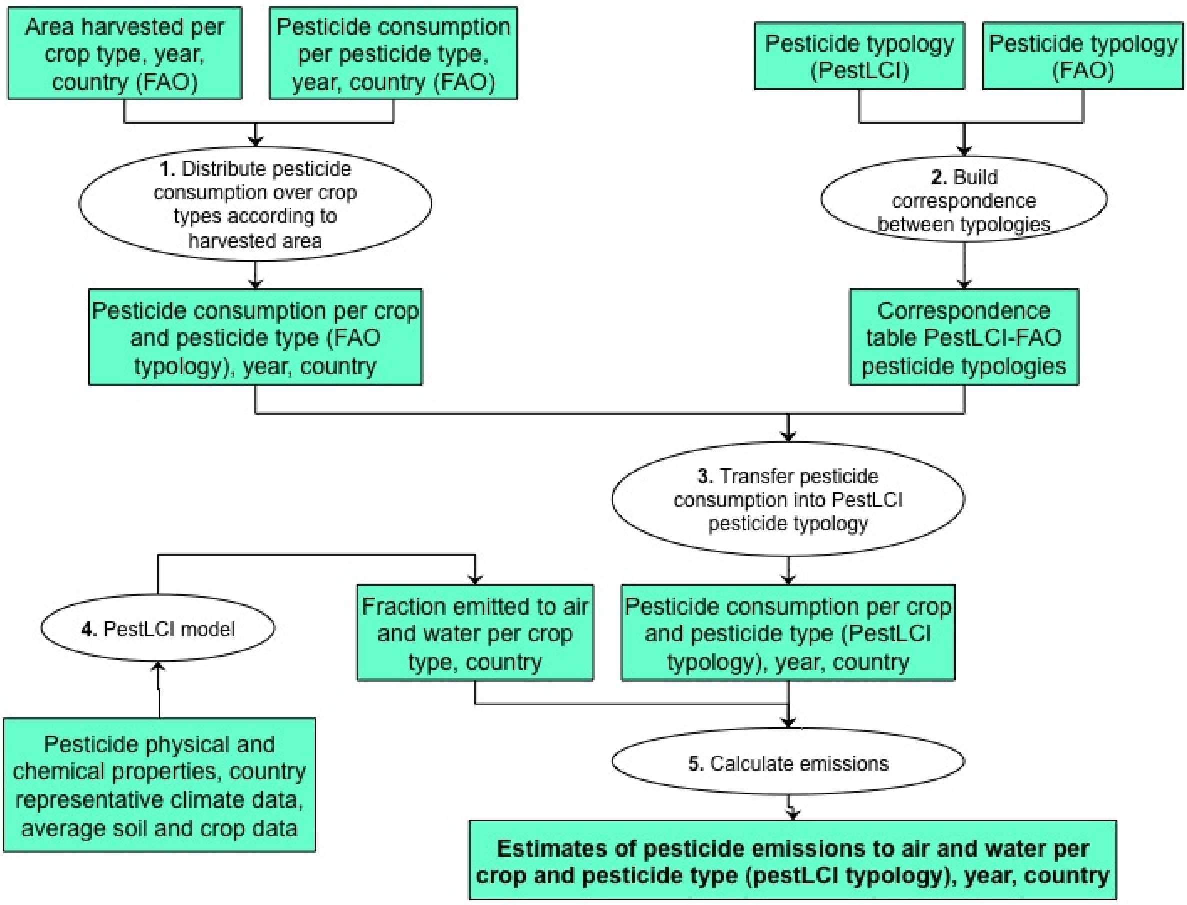

FIGURE 53 PESTLCI MODEL

STEP 1: PESTICIDE CONSUMPTION USING FAOSTAT PESTICIDE TYPOLOGY

Raw data are taken from the following FAOSTAT datasets:

- harvested area[45] (in ha) per crop type (cereals, citrus, fibre, fruit, oilcrops, pulses, roots & tubers, vegetables), country and year;
- pesticides consumption volumes[46] (in tonnes) per pesticide type (6 insecticides, 10 herbicides, 6 fungicides, 1 plant growth regulator), country and year.

Data pre-processing consists in:

[45] FAOSTAT-Agriculture > Production > Crops http://faostat.fao.org/site/567/default.aspx

[46] FAOSTAT-Agriculture > Resources > ResourceSTAT > Pesticides Consumption http://faostat.fao.org/site/424/default.aspx

- Aggregating pesticides consumption volumes in four geographical zones within the EU-27, as defined by FAOSTAT: Southern (CY+GR+IT+MT+PT+SI+ES), Northern (DK+EE+FI+IE+LV+LT+SE+UK), Eastern (BG+CZ+HU+PL+RO+SK), and Western (AT+FR+DE+NL+BE+LU) zones of the EU-27. Data for Germany are extracted separately.
- Aggregating harvested area in the same four geographical zones within the EU-27 and calculating the share of each crop type in total harvested area. The same is done separately for Germany.

Calculations consist in allocating pesticides consumption volumes to each triplet [crop type, country, year] assuming that pesticide consumption is directly proportional to harvested area. Total consumption volumes per year and country are also calculated.

STEP 2: CORRESPONDENCE BETWEEN FAOSTAT AND PESTLCI PESTICIDE TYPOLOGIES

FAOSTAT uses a semi-aggregated pesticide typology not directly suitable for compound-based fate and impact characterisation methods such as PestLCI and USEtox:

- FAO semi-aggregated pesticide typology: 6 insecticides, 10 herbicides, 6 fungicides, 1 plant growth regulator;
- PestLCI compound-based typology (including compounds to be added to PestLCI 2.0): 18 insecticides, 48 herbicides, 18 fungicides, 5 plant growth regulators.

The different steps are followed to establish a correspondence between these two typologies.. Using the *Compendium of pesticides common names* by Alan Wood[47], a list of common compound names is extracted for each of the FAO semi-aggregated categories. These names are then matched with the PestLCI typology so as to attribute the PestLCI compounds to the semi-aggregated categories used by the FAO. Some of the compounds in the PestLCI typology did not match any of the compounds extracted from the *Compendium of pesticides common names* and were therefore not further considered. In total 38 compounds from PestLCI could be attributed to semi-aggregated FAO pesticide categories. Six FAO categories could not be populated with corresponding compounds from PestLCI. The corresponding consumption volumes are not further considered for the emissions estimates. It is then assumed that the PestLCI compounds attributed to one FAO pesticide category contribute equally to the consumption volume reported for this category.

The result is a correspondence table displaying the contributions of PestLCI compounds to the FAO semi-aggregated pesticide categories.

STEP 3: PESTICIDE CONSUMPTION USING FAOSTAT PESTICIDE TYPOLOGY

The correspondence table (see previous section) is applied to the pesticides consumption data calculated in the first step.

The result consists of tables presenting consumption volumes of PestLCI compounds (in tonnes) for each crop type, country (or grouping thereof), and year. Total consumption volumes per year and country are also calculated.

[47] http://www.alanwood.net/pesticides/index.html

STEP 4: FRACTIONS EMITTED TO AIR AND WATER MODELLED WITH THE PESTLCI MODEL

The PestLCI 1.0 model (Birkved and Hauschild, 2006), originally developed to estimate field emissions of pesticides in agricultural LCAs, is used with a number of reasoned assumptions on macro-level averages for the key input parameters on climate, soil, crop, and compounds so as to approximate the fraction of pesticides used in agriculture and emitted to air and water. PestLCI 1.0 model was provided by the author (Morten Birkved). Some formulas had to be amended in order to be able to work with annual averages of climate data. The average plant interception parameter values were calculated for the different crop types covered in FAOSTAT data. The PestLCI 1.0 model was enriched with the input data and insights from Teunis Dijkman who develops PestLCI 2.0 which is to be released in 2011.

The model requires the following inputs:

- *Physical-chemical properties of the pesticides (for each compound):* we used the data already available within the model and added compounds that will be integrated into PestLCI 2.0 (personal communication, Dijkman, 2 June 2011). The missing chemical properties for these additional compounds were found in online pesticide databases.[48]
- *Pesticide application:* among the four possible characterisations for this parameter we assumed it to correspond to “Field crops/bare soil” for all non-fruit crops and “Tall crops” for citrus fruits and other fruits.
- *Crop parameters:* we built plant interception parameters corresponding to the crop types used in FAOSTAT, i.e. we calculated average parameters for cereals, citrus, fibre, fruit, oilcrops, pulses, roots & tubers, and vegetables (across all crops of each categories and all growth phases).
- *Soil data:* we used averaged soil data from the future PestLCI 2.0 (personal communication, Dijkman, 2 June 2011) rather than the data of the Danish soil sample provided in the model.
- *Meteorological data:* we used climate data from the future PestLCI 2.0 (personal communication, Dijkman, 2 June 2011) for the parameters Average temperature, Average precipitation, Number of days with precipitation > 1 mm, Average rainfall in one rainy day, and Solar irradiation. We recalculated the parameter Potential water balance because the provided data were not correct. Potential water balance is calculated as Average precipitation minus Potential Evapotranspiration (PET). To calculate the latter we used the Thornthwaite equation (1948):

$PET = 1.6(L/12)(N/30)(10T_a/I)^a$

where

PET is the estimated potential evapotranspiration (cm/month)

T_a is the average daily temperature (degrees Celsius; if this is negative, use 0) of the month being calculated

N is the number of days in the month being calculated

L is the average day length (hours) of the month being calculated

$a = (6.75 \times 10^{-7})I^3 - (7.71 \times 10^{-5})I^2 + (1.792 \times 10^{-2})I + 0.49239$

[48] http://sitem.herts.ac.uk/aeru/footprint/en/index.htm

http://www.syrres.com/what-we-do/databaseforms.aspx?id=386

$I = \Sigma^{12}_{i=1} (T_{ai}/5)^{1.514}$ is a heat index which depends on the 12 monthly mean temperatures T_{ai}

Once the input parameters collected and stored in the correct place in the PestLCI model, the model is run for five climate zones, the 38 pesticides allocated in step 2, and the 8 (averaged) crop types. Each run returns three values: fraction emitted to surface water, to ground water (both are then aggregated into fraction emitted to water), and fraction emitted to air. “Representative” climate data were chosen as follows for the sake of simplification for Germany and the four geographical zones of EU-27:

- Germany: climate data from a meteorological station in Görlitz
- Southern EU-27: climate data from a meteorological station in Thessaloniki (GR)
- Northern EU-27: climate data from a meteorological station in Linköping (SE)
- Eastern EU-27: climate data from a meteorological station in Zhitomir (UA)
- Western EU-27: climate data from a meteorological station in Tours (FR)

The result consists of tables listing the emitted fractions to air and water of PestLCI compounds consumed for each crop type and country (or grouping thereof).

STEP 5: ESTIMATES OF PESTICIDE EMISSIONS TO AIR AND WATER

The emitted fractions to air and water (see previous section) are applied to the pesticides consumption volumes obtained in the third step to calculate the actual emissions resulting from this consumption.

The result consists of tables listing the emissions of pesticides (in tonnes) for each crop type, country (or grouping thereof), and year. Total emissions per year and country are also calculated.

OUTLOOK

A new—updated and improved—version of the PestLCI model is expected to be released in the second half of 2011. Therefore this new version should be used for future inventories. The underlying assumptions and parameter input data will, however, be largely similar to the present calculations since climate and soil data from the database of the yet unreleased version 2.0 have been used (personal communication, Dijkman, 2 June 2011). The overall methodology described in the previous sections should also be applicable when working with version 2.0.

PestLCI 2.0 will use a somewhat different approach to calculate the potential water balance: instead of potential evaporation, the actual evaporation will be calculated and used for each climate data set. This will probably deliver fewer negative values for the annual potential water balance which had led to some problems when running PestLCI 1.0. Because of these problems we chose to use climate data from meteorological stations, which helped us avoid a negative annual potential water balance. With PestLCI 2.0, this should no longer be an issue. The new version should further increase the possibilities to refine the geographical representativeness of the employed climate data.

ANNEX 5 ESTIMATION OF EMISSIONS OF OTHER HAZARDOUS SUBSTANCES TO WATER

The procedure developed to estimate emissions of hazardous substances to water consists of three main steps that combine Eurostat macro data and EEA's data on emissions to water from its Waterbase, as illustrated in the Figure 54. The following sections describe the three steps in more detail and give an outlook for possible future development.

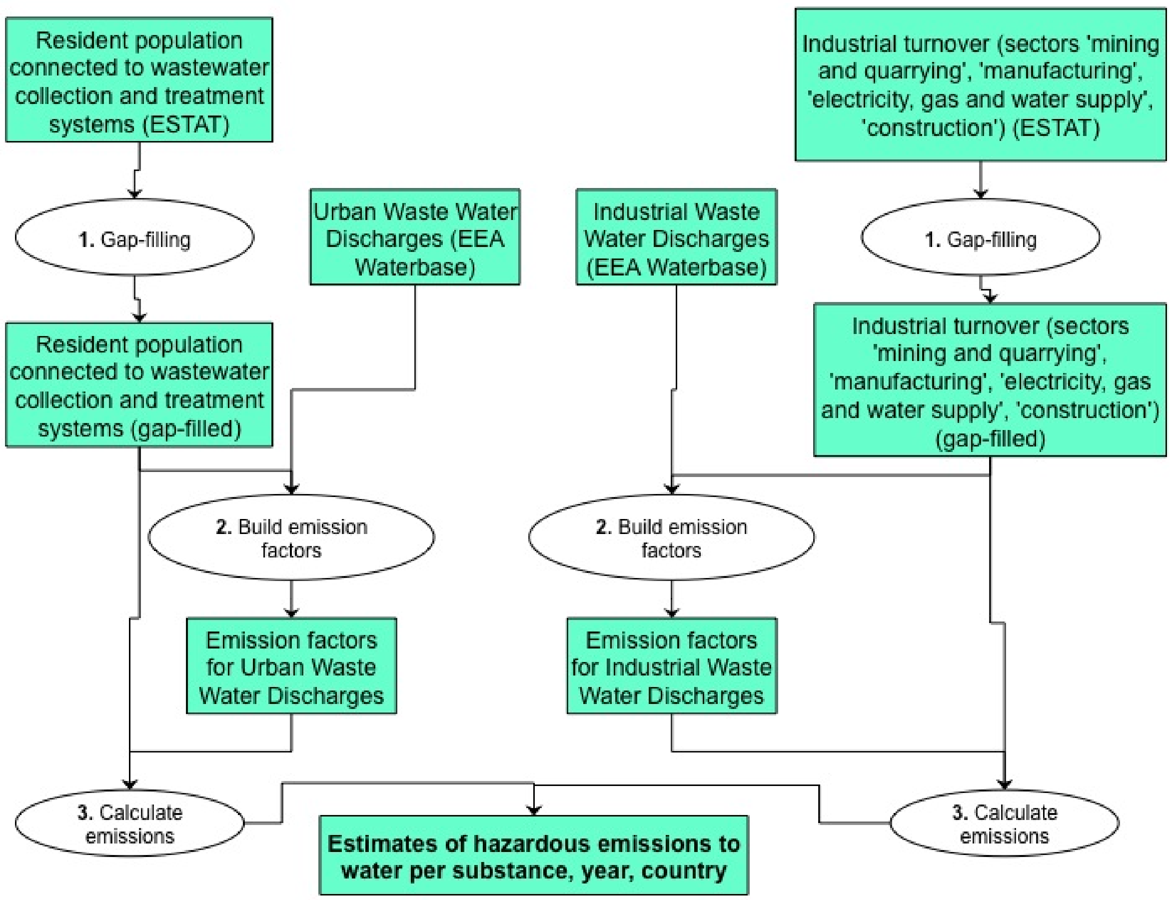

FIGURE 54 COMBINING EUROSTAT AND EEA'S DATA ON EMISSIONS OF HAZARDOUS SUBSTANCES TO WATER

STEP 1: GAP-FILLING AUXILIARY VARIABLES

Auxiliary raw data consist of the following Eurostat datasets:

- Resident population connected to wastewater collection and treatment systems: Urban wastewater collecting system, total
- European Business – selected indicators for all activities (NACE divisions): Turnover or gross premiums written

From the latter, the turnover of the industrial sector is calculated by aggregating the turnover of the following sectors: 'mining and quarrying', 'manufacturing', 'electricity, gas and water supply', and 'construction'.

A simple gap-filling method is applied so as to obtain complete datasets for all 27 EU Member Countries for the years 2004 to 2007. When gaps occur between two reported years, the gaps are filled using a linear interpolation. When gaps occur “left or right” of the last reported year, the closest known value is used to close the gap.

The result consists of two gap-filled tables of auxiliary data.

STEP 2: EMISSION FACTORS FOR POINT SOURCE EMISSIONS OF HAZARDOUS SUBSTANCES

Raw data consist of the following EEA Waterbase datasets:

- U: Urban Waste Water Discharges (point source emissions)
- I: Industrial Waste Water Discharges (point source emissions)

Both categories U and I consist of subcategories Different countries have reported different sets of subcategories (e.g. U1+U2), or only totals (e.g. U). For each country, the sum of the U or I subcategories that were reported is assumed to be complete, disregarding potential gaps (i.e. no gap-filling for these data).

The geographical coverage is as follows:

- eight EU-27 countries + Switzerland reported urban emissions to water
- nine EU-27 countries + Switzerland reported industrial emissions to water

The countries for which data are available did not, however, necessarily report for the same years or substances. Available data are therefore very much scattered across countries, years and substances.

List of the available raw data per country, substance and year is created. Emissions factors are calculated for each country, substance and year. The emission factors are calculated as follows:

- U: ratio [Urban Waste Water Discharges]/[Resident population connected to wastewater collection and treatment systems]
- I: ratio [Industrial Waste Water Discharges]/[Turnover of industrial sector]

An average emission factor is calculated for each country and reported substance (i.e. average across the reported years).

The result consists of the emission factors (averaged across years and countries) previously calculated presented separately for U and I point source emissions.

Note: The emission factors for diffuse emissions were not calculated because the coverage of these emission data is considered insufficient (data are available for only three countries, with large gaps).

STEP 3: ESTIMATES OF HAZARDOUS EMISSIONS TO WATER

The auxiliary data that were estimated in step 1 to fill identified data gaps are combined with the emission factors calculated in step 2 for the countries and year for which the amount of emissions of hazardous substances is to be assessed.

The results consist of the emission estimates (U, I, and total) for Germany and the EU-27, for a list of 48 hazardous substances, and for the year 2004 to 2007.

OUTLOOK

The data generated with the method described in the previous sections should be handled as low quality data, considering the poor coverage of the Waterbase datasets (in terms of years, substances and countries) that serve as a basis for estimating emission factors for hazardous substances. The auxiliary data are still incomplete due to substantial remaining gaps.

The method described above and applied here is, however, an attempt to combine existing established territorial data sources (from Eurostat and the EEA). The objective of this is to extend territorial inventories beyond established environmental reporting frameworks, such as UNFCCC for greenhouse gases.

Moreover, one can expect the coverage of the Waterbase data to improve in the future so that the quality of the estimates for point source emissions will also increase and estimates for diffuse emissions will become possible.

ANNEX 6 ESTIMATION OF EMISSIONS OF NITROGEN AND PHOSPHORUS TO WATER

The procedure developed to estimate emissions of nitrogen and phosphorus to water consists of four main steps that combine Eurostat macro data and EEA's data on emissions to water from its Waterbase, as illustrated in the Figure 55. The following sections describe the four steps in more detail and give an outlook for possible future development.

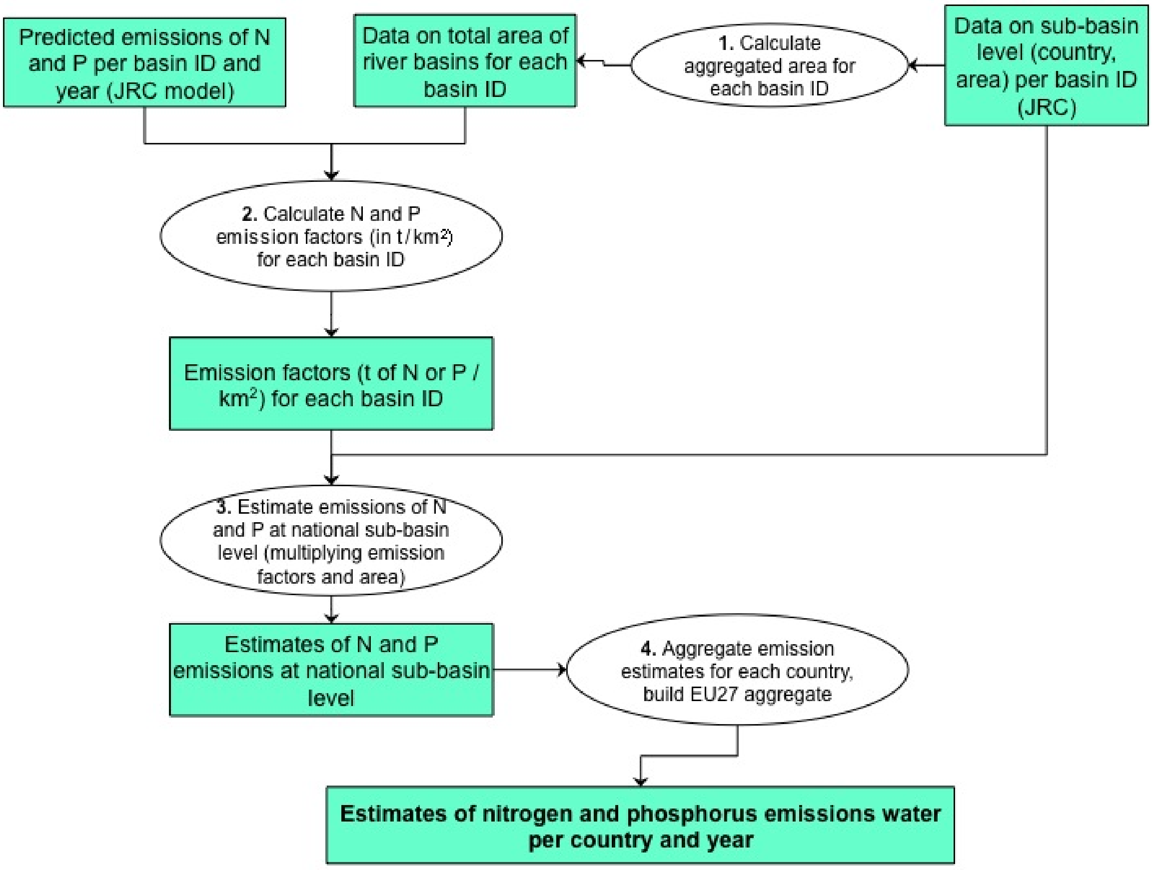

FIGURE 55 COMBINING EUROSTAT AND EEA'S DATA ON EMISSIONS OF NITROGEN AND PHOSPHORUS TO WATER

STEP 1: CALCULATING THE AREA OF RIVER BASINS

Raw data consist of documentation of the model Bouraoui et al. (2011). In this model, each river basin receives a unique ID (called basinID or HydroID*).* Each river basin consists of one or more *national* sub-basins, i.e. basins lying completely within a single country. Countries outside the EU + CH + NO are not listed. The areas in km^2 of the national sub-basins are). For each basinID, the areas of the corresponding sub-basins were aggregated.

The result consists of a two-column table giving for each basinID the corresponding covered area.

STEP 2: CALCULATING EMISSION FACTORS FOR EACH RIVER BASIN

Raw data consist of modelling results of the model Bouraoui et al. (2011). . For each basinID, the nitrogen and phosphorus emissions, predicted by the model (Bouraoui et al., 2011) are listed for the year 2005. The areas calculated in step 1 are then related to the modelled emissions values. The unique key used for matching both parameters is the basinID.

The result consists of emission factors (in tonnes/km^2) for each basinID, for the year 2005.

STEP 3: CALCULATING EMISSIONS AT NATIONAL SUB-RIVER BASIN LEVEL

Raw data consist of the same data as used in step 1: model of Bouraoui et al. (2011). For each sub-basin, nitrogen and phosphorus emissions are estimated by multiplying the area of the sub-basin and the emission factors (emissions per unit of area) calculated in step 2.

The result consists of nitrogen and phosphorus emissions (in tonnes) for each sub-basin, for the year 2005.

STEP 4: CALCULATING EMISSIONS AT COUNTRY AND EU-27 LEVEL

For each EU Member State, the emissions of the corresponding sub-basins calculated in step 3 were aggregated. Data for Malta are missing, but the impact on EU-27 aggregates is considered negligible.

The result consists of a table listing N and P emission estimates for each EU Member State (except for Malta).

OUTLOOK

The emission data generated with the method described above rely on the assumption that nitrogen and phosphorus are emitted homogeneously over the area of a river basin. This assumption allows to use the emission factors per unit or basin-area calculated in step 2 to estimate emissions at the sub-basin level. Since modelling results of Bouraoui et al. (2011) are not available at a more disaggregated level than river basin, this assumption is necessary and reasonable.

For this project, emission data available from the model of Bouraoui et al. (2011) were limited to the year 2005. If modelling results could be delivered in the future for earlier and later years, the same method as described above could be applied to estimate country-specific and EU-wide nitrogen and phosphorus emissions for further years.

European Commission
EUR 25517 – Joint Research Centre – Institute for Environment and Sustainability

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Abstract
Sustainable development is an underlying objective of the European Union treaties. An important part of sustainable development is its environmental aspect, as reflected in the Europe 2020 strategy and its Resource-efficient Europe flagship initiative.
For quantifying and monitoring our progress towards sustainability in terms of the environmental performance, indicators are needed. These indicators should provide an integrated view on the links between consumption, production, resource depletion, resource use, resource recycling, environmental impacts and waste generation. One of the approaches that facilitate such integrated view is life cycle thinking. This integrative approach underlies the development of life cycle indicators for quantifying and monitoring progress towards the sustainable development of the European Union.
This report outlines the development of the resource life cycle indicators. These indicators are intended to be used to assess the environmental impact of European resource consumption, efficiency of the use of natural resources, and decoupling of environmental impacts from economic growth.

LB-NA-25517-EN-N

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