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Environmental pressures from European consumption and production

A study in integrated environmental and economic analysis

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Context

This long-term project was begun by the European Topic Centre on Resource and Waste Management in 2005. An ETC/SCP Technical Report was published in February 2009 with the results of the first data collection, processing and analysis, with 1995 and 2000 data for the 'consumption perspective' analysis for 8 EU Member States and 1995–2005 for the production perspective analysis for the EU-25. The 2009 report can be found at http://scp.eionet.europa.eu/publications/working%20paper%20namea2009 online.

Updated input-output and environmental accounts data were made available by Eurostat during spring/summer 2009 and new material flow accounts data were provided during 2010 for some of the same and some additional EU Member States. This allowed the ETC/SCP to update graphs and analyses in the 2009 Technical Report, and produce some additional analyses.

Executive summary

Objectives and scope

It is increasingly recognised that the current consumption and production patterns of developed countries cannot be transferred to the rest of the world without overstretching global environmental services several times over. One part of the solution to the problem of limited resources and environmental services is to adjust patterns of consumption and production to reduce their demand on these resources. Identifying and encouraging such adjustments are the focus of the policy area of Sustainable Consumption and Production (SCP).

The European Commission's Communication of September 2011 on a Roadmap to a Resource Efficient Europe places the policy area of SCP as a key implementation area within the Flagship Initiative on Resource Efficiency.

To focus Resource Efficiency and SCP policy on areas where the greatest environmental gains are possible, policy makers need answers to some key questions:

- Which elements of European consumption and production patterns are the key causes of environmental pressures including resource use?
- Where can the greatest environmental gains be attained?

One tool which has the potential to provide some of the answers to these questions is the analysis of Environmentally-Extended Input-Output Tables (EE-IOTs) whose use and application are discussed in this report.

This technical report, prepared within the broad framework of EEA work on environmental accounts, presents and describes the tool of environmentally-extended input-output analysis and illustrates its potential uses. The analysis was conducted by the European Topic Centre on Sustainable Consumption and Production (ETC/SCP), using data collected by Eurostat and national statistical offices of selected countries. The report aims to:

- present the tool of environmentally extended input-output analysis of EE-IOT and assess its potential for answering key SCP policy questions;
- make use of the tool and the latest data available in Europe to identify the environmental 'hotspots' and leverage points in European consumption and production;
- identify weaknesses and potential for improvement in the current application of the tool.

A tool for SCP

Environmentally Extended Input Output Analysis (EE-IOA), a method applied on Environmentally Extended Input Output Tables (EE-IOT), allows the environmental pressures of a whole economy to be viewed according to two complementary perspectives: a production perspective (i.e. which industries are directly causing environmental pressures), and a consumption perspective (i.e. which consumed products directly and indirectly cause environmental pressures).

The production perspective which is drawn directly from EE-IOTs, gives a basic picture of direct pressures arising from economic sectors and their economic output both for domestic consumption and export.

The information on direct emissions of greenhouse gases (GHGs) and air pollutants given in EE-IOTs should not be confused with national reported emissions under the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Long-Range Transboundary Air Pollution (CLRTAP). National air emission totals reported under these conventions can differ significantly from those provided by EE-IOTs due to differences in accounting principles and the scope of organisations covered. EE-IOTs use a residency principle for setting a boundary (i.e. includes emissions of all resident citizens and organisations even if they take place in other countries) while the boundary for national emissions inventories is geographic.

However, the inclusion of economic data in EE-IOTs allows the environmental intensity (environmental pressure per monetary unit of output) of economic sectors to be compared. It allows success in decoupling of pressures from economic growth to be assessed for countries and for individual sectors. Finally, trends in decoupling at national/regional level can be decomposed into various contributing factors.

The consumption perspective is derived from EE-IOTs using EE-IOA. While the production perspective looks at the question 'what pollutants are being emitted by which industries?', the consumption perspective considers 'what are the consumed products driving these emissions?'.

Environmental pressures are re-attributed to the production chains of final products according to the monetary flows between different industries and between industries and final consumption. The products that indirectly cause the majority of environmental pressures can be identified and environmental performance of different product groups compared. Finally, the global pressures attributable to national or EU consumption can be estimated. This is a key piece of analysis in today's global economy where a large proportion of pressures caused by our consumption are being released overseas.

The consumption perspective is of key interest in identifying the drivers of environmental pressures. It provides information critical to SCP policy design complementing the role provided by national emissions inventories.

Hotspots in European production patterns

Economic data and environmental accounts were used to assess the production perspective with data from 1995 to 2006. The source for the economic data was the EU KLEMS database. The environmental accounts used were the latest Air Emissions Accounts and Material Flow Accounts (MFA) from Eurostat gathered in 2008 and 2009, respectively. The MFA accounts were subsequently supplemented with national data on unused extraction of resources.

A number of key aggregated pressure categories were assessed: greenhouse gas emissions, acidifying emissions and emissions of tropospheric ozone precursors from the air emissions accounts and domestic extraction used (DEU), direct material input (DMI) and total material requirement (TMR) from the MFA accounts and supplementary data.

Four economic sectors dominate direct environmental pressures arising within European economies. Agriculture, the electricity industry, transport services and some basic manufacturing industries (refinery and chemical products, non-metallic mineral products, basic metals) together account for 75 % of GHG emissions, 88 % of acidifying emissions and 68 % of emissions of ground ozone precursors arising from European production. Material extraction is dominated by agriculture and forestry (25 %) and mining industries (75 %).

Of the four economic sectors contributing most to GHGs and air emissions, only manufacturing shows a comparably large contribution to the EU-25 economy as it does to environmental pressures. The electricity and agriculture sectors provide only 4 % of gross value added and 7 % of total employment of the EU-25 economy but together emit 47 % and 57 % of GHG emissions and acidifying emissions, respectively. In other words, these industries have high environmental pressure intensities. Service industries, with the exception of transport, meanwhile, show low eco-intensities.

The EU has seen success in decoupling air emissions from growth in production. Production-related emissions of acidifying gases and tropospheric ozone precursors decreased by 27 % and 14 %, respectively, between 1995 and 2006 despite an economic growth of 40 %. Production-related GHG emissions remained fairly stable from 1995–2006.

For all three types of environmental pressure, decoupling appears mostly to have been achieved through reduction in the environmental pressure intensity (pressure per euro of output) within individual economic sectors. Structural changes in the economy, i.e. a growth in the share of services and a shift in heavy industry abroad, appear to have been a comparatively insignificant factor behind decoupling.

Some economic sectors have been more successful than others in decoupling pressures from growth in output. Of the hotspot economic sectors, both manufacturing and agriculture achieved absolute decoupling in all three air emissions-based aggregated pressures. The transport services industry fared worst with GHG emissions increasing by 42 % between 1995 and 2006, only slightly slower than growth in output of that sector.

In February 2011 the European Council confirmed the EU climate objective of an 80–95 % reduction in GHG emissions compared to 1990 levels by 2050. Looking at past trends it seems unlikely that these ambitious reductions can be met solely through eco-efficiency improvements in key industries. Structural changes in the economy may also be necessary, i.e. a shift from high pressure intensity industries to low intensity industries and services.

However, such structural changes will only bring global environmental benefits if they reflect an equivalent change in the products being consumed by Europeans. Otherwise pressure-intensive industries producing goods for Europeans will simply have been shifted to other global regions potentially with negative net environmental effects if they are shifted to countries with less stringent environmental standards (so-called carbon leakage).

Hotspots in European consumption patterns

The consumption perspective concentrates on global environmental pressures caused by all the products consumed in a country. Products can be broadly distinguished between material goods and services. In the EU, 60–70 % of total household consumption is made up of services, with material goods accounting for the remaining 30–40 %. Capital formation is dominated by consumption of material goods (~ 80 %), while government consumption is more than 90 % services.

A consumption perspective includes imported goods for final consumption but excludes goods produced for the export market. It also excludes goods and semi-finished products which are imported and then re-exported. Pressures caused by consumption include both pressures released directly during the consumption of a final product (mainly fuel combustion in cars and houses) and indirect pressures accumulated during that product's global production and distribution. These indirect 'embodied' pressures comprise more than 3/4 of the total pressures activated by consumption.

The direct pressures are drawn from national emissions inventories. The indirect pressures are estimated using EE-IOA methods to reallocate pressures given in EE-IOTs from industries to production chains of final products. At the time of reporting, suitable economic input output tables and environmental accounts were available for 9 EU Member States representing just over half the population and 62 % of the gross domestic product (GDP) of the EU (Czech Republic, Denmark, Germany, France, Italy, Netherlands, Austria, Portugal and Sweden) for 2005. For 2000 and 1995 all but the Czech Republic had necessary economic input-output data available.

Note that the format and data included in EE-IOTs do not currently allow pressures caused by the end-of-life of products to be considered under the consumption perspective.

Four product groups were identified which together contribute 42 %, 52 %, 37 % and 57 % to GHG emissions, acidifying emissions, ground ozone precursors and material input, respectively, embodied in all consumed products in the 9 EU Member States. The four groups — construction works; food products; products of agriculture, forestry and fisheries; and electricity, gas and water services — together represent only 17 % of total consumption expenditure. In other words they are among the most environmental pressure-intensive finally consumed products.

A further seven product groups added a further 30–40 % of environmental pressures embodied in all consumed products:

- wholesale and retail services;
- motor vehicles and other transport equipment;
- hotel and restaurant services;
- transport and auxiliary transport services;
- coke and refined petroleum;
- health and social work;
- public administration, defence and social security services.

However, these are much less pressure-intensive than the first four representing a 42 % share in consumption expenditure.

In addition, private households contribute approximately 20 % of environmental pressures directly — mainly associated with the use of fuels for private cars and for heating of houses.

The direct household pressures and indirect pressures embodied in consumed products were assigned further to some broad functional areas of consumption. The allocation has been made according to a number of assumptions (1). Based on these assumptions, demand for the three functional consumption areas of food and lodging, housing and infrastructures, and mobility were found to cause around 60–70 % of environmental pressures activated by national consumption in the 9 countries. This echoes findings from other European studies including the European Commission-funded EIPRO study.

Each of these three demand areas on their own cause emissions of 1.9–2.5 tonnes of carbon dioxide (CO_2)-equivalents per capita. In each case this is equivalent to, or more than, the quantity which Europeans will need to budget for all their activities in the long term if we are to achieve an 80–95 % reduction in GHGs by 2050.

The household consumption (COICOP (2)) categories of food and beverages; housing, water electricity and gas; and transport dominate pressures caused by household expenditure, followed by furnishings and household equipment. Food and beverages, transport and, to a lesser extent, housing, water electricity and gas are also the household consumption categories which cause some of the greatest pressures per euro spent within the five environmental pressure categories considered in this study.

Analysis showed large differences in environmental pressure intensities of individual product groups. Emissions of GHGs per euro spent ranged by a factor of more than 20 between most services at one end of the scale, and electricity and agricultural products at the other. Material use intensity was even more variable ranging by a factor of more than 150.

Two main directions were thus identified for reducing environmental pressures caused by European consumption. Firstly, reducing the pressure-intensities of production chains for key product groups (i.e. technology improvements), and secondly, shifting consumption expenditure from pressure-intensive product groups to less-intensive groups — mostly represented by services (i.e. a behavioural change).

Decomposition analysis showed that to date most decoupling of environmental pressures from consumption growth has come from technological improvements. To meet the tough challenges ahead in reducing environmental pressures caused by European consumption and production, a combination of technological improvement and behavioural change is likely to be necessary.

These two factors, and the means by which governments can encourage them, are markedly different. Encouraging technological improvements can be achieved through better regulation, increasing the price of material and energy inputs, encouraging and investing in innovative technologies, etc.

Encouraging behavioural change will require an entirely different set of measures. These would include the use of economic instruments, information campaigns and other means to urge consumers to spend their money on less pressure-intensive products and product groups. While much further research is needed to better understand the interplay of various policy instruments, addressing consumption patterns is critical to achieving the systemic change envisaged in the resource efficiency and green economy initiatives.

Realising the full potential

The analysis of national EE-IOTs has proved to be a potentially powerful tool for SCP analysis. However, some weaknesses in the underlying data and the method using these tables on their own currently act as barriers to the method achieving its full potential. These include the following:

1. Outdated data — reporting obligations for symmetrical input-output data required for the consumption perspective is five-yearly with an additional three-year time lag. This limits the potential of the method in guiding timely policy.
2. Level of aggregation — EU national accounts split economies into 60–120 different economic sectors, compared to several hundred in the United States and Japan. This can limit the method's potential in identifying lever points.
3. Production processes in other countries — in building the consumption perspective from national single region EE-IOTs the assumption was made that industrial processes abroad

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(1) On, for example, the proportion of electricity used for different purposes in the home, and the proportion of hotel and restaurant services which can be allocated to food.

(2) Classification of individual consumption by purpose (COICOP) developed by the United Nations Statistics Division to classify and analyse individual consumption expenditures incurred by households.

have the same pressure intensities as in the home country. While a standard assumption in this type of analysis, it can lead to significant underestimates in environmental pressures embodied in imported goods.

4. Environmental scope — environmental accounts produced by countries and available from Eurostat are mostly limited to air pollutants, greenhouse gas emissions and material flow accounts.

European initiatives are currently underway to tackle some of these issues.

Reporting obligations to Eurostat (issue 1) are unlikely to be changed in the near future. However, in the shorter term, gaps and time lags can partially be filled through use of 'now-casting' methodologies.

The EEA and Eurostat are currently assessing methods for improving the estimates of pressures embodied in imports (issue 3). This could range from applying country-dependent adjustment factors to imports, to integrating with multiregional input-output tables such as the EXIOPOL model representing the global economy.

In May 2011 Eurostat made available a single region EE-IOT for the whole of the EU-27. The ETC/SCP is currently carrying out EE-IOA of this new data to provide estimates of environmental pressures caused by European consumption as a whole. Since all internal EU trade is included within the EE-IOT, errors caused by the 'like domestic assumption' will be less pronounced than for an individual EU country. The EEA will present the results of this work in a supplementary report.

Eurostat is aiming to extend the environmental scope of national accounting matrices including environmental accounts (NAMEA) tables with energy resources, and water (issue 4). The energy accounts are most advanced with energy data collection from Member States having being piloted at the end of 2011. The European Parliament has called for the inclusion of forestry and ecosystem accounts in the future.

1 Background and objectives

Despite the fact that a substantial part of the world's population still lives at subsistence levels of consumption, there are indications that human activities are already overstretching the globe's limited resources and environmental services (EEA, 2010a; WWF et al., 2010). According to the European Commission's Roadmap to a Resource Efficient Europe, 'sources of minerals, metals and energy as well as stocks of fish, timber, fertile soils, clean air, biomass, biodiversity are all under pressure, as is the stability of the climate system. If we carry on using resources at the current rate, by 2050, we will need on aggregate more than two planets to sustain us and the aspirations of many for a better quality of life will not be achieved' (EC, 2011a).

The Roadmap to a Resource Efficient Europe fleshes out the Flagship Initiative on a Resource Efficient Europe (EC, 2011b) launched as part of the Europe 2020 Strategy (EC, 2010). It lays out the Commission's vision for resource efficiency by 2050 and milestones on the way to achieving that vision. The broad vision for 2050 is of an EU economy that respects resource constraints and planetary boundaries. A central means for transforming the economy will lie in encouraging consumption and production patterns with reduced demand on resources and environmental services. As such the policy area of Sustainable Consumption and Production (SCP) (see Box 1.1) is seen as one of the central elements in the implementation of the Roadmap.

Changing consumption and production patterns will require the involvement of all actors within society: government and civil society, business and consumers (UK Sustainable Consumption Roundtable, 2006). Government has a particularly important role to play. It can create the framework within which the other actors operate through setting targets, regulating industry, requiring product information for consumers, running information campaigns, using economic instruments to influence producers and consumers, supporting voluntary measures, funding research into eco-innovation and a host of other measures. However, good governance requires effective use of public resources to give maximum benefit and avoiding wasting effort on actions with little potential environmental gain.

To aid effective policy and action the following questions need to be answered:

- Which elements of European consumption and production patterns are the key causes of environmental pressures including resource use?
- Where can the greatest environmental gains be attained?

One tool which has the potential to provide some of the answers to these questions is the analysis of Environmentally Extended Input Output Tables (EE-IOT) whose use and potential application are described in this report. This tool allows the environmental pressures of a whole economy to be viewed according to two complementary perspectives: a production perspective (i.e. which industries are directly causing environmental pressures), and a consumption perspective (i.e. which consumed products directly and indirectly cause environmental pressures).

This EEA report presents analysis conducted by the ETC/SCP using data collected by Eurostat and national statistical offices of selected countries. The report, prepared under the broad framework of EEA work on environmental accounts, aims to:

1. present the tool of environmentally extended input-output analysis of EE-IOTs and assess its potential for answering the key SCP policy questions;
2. make use of the tool and the latest data available in Europe to identify the environmental hotspots and leverage points in European consumption and production;
3. identify weaknesses and potential for improvement in the current application of the tool.

Following this introduction the report is divided into four main sections. The first section describes

Box 1.1 Sustainable Consumption and Production — an implementation strategy for sustainable development

Sustainable Consumption and Production (SCP) is a holistic perspective on how society and the economy can be better aligned with the goals of sustainability. It has been defined as:

> *a holistic approach to minimizing negative environmental impacts from the production-consumption systems in society. SCP aims to maximize the efficiency and effectiveness of products, services, and investments so that the needs of society are met without jeopardizing the ability of future generations to meet their needs* (Norwegian Ministry of Environment, Oslo Symposium, 1994).

SCP is a practical approach to achieving sustainable development which addresses economy, society and environment.

SCP aims to reduce emissions, increase efficiencies and prevent unnecessary wastage of resources within society through the stages of material extraction, investment, production, distribution, consumption to waste management. In addition to these environmental and economic goals, the social component is concerned with equity within and between generations, improved quality of life, consumer protection and corporate social responsibility (CSR). Some key principles and challenges include:

i) improving the quality of life of populations without increasing environmental degradation, and without compromising the resource needs of future generations;
ii) breaking (decoupling) the link between economic growth and environmental degradation, by:
  - reducing the material intensity and energy intensity of current economic activities and reducing the output of emissions and waste during extraction, production, consumption and disposal;
  - encouraging a shift of consumption patterns towards groups of goods and services with lower energy and material intensity without compromising quality of life;
iii) applying life-cycle thinking which considers the impacts from all life-cycle stages of production and consumption processes and guards against unforeseen shifting of impacts from one life-cycle stage to another, one geographical area to another or one environmental medium to another;
iv) guarding against the rebound effect, where technological efficiency gains are cancelled out by resulting increases in consumption.

Cross-cutting in character, SCP needs an active involvement of all stakeholders and a wide range of locally-adapted policy responses.

Source: UNEP and EEA, 2007.

environmental accounts and IOTs, and how these can be combined to gain information on some key environmental pressures associated with production and consumption.

The second section uses the methods described to examine environmental hotspots in European production, while the third uses the EE-IOA methods to identify the environmental hotspots in European consumption patterns.

The final section summarises the potential of the tool for answering SCP-relevant questions. It examines data issues which currently limit the realisation of the method's full potential and briefly describes ongoing initiatives aimed at solving some of these issues including work planned for implementation by the EEA's ETC/SCP during 2012 and beyond.

This report has been developed as an updated version of a 2009 ETC/SCP working paper (ETC/SCP, 2009) with the latest European data available at January 2011 (3), for both the production and the consumption perspective. For the consumption perspective, the 2009 report included data and analyses for 1995 and/or 2000 for 8 EU Member States (4). After

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(3) IOTs for EU-27 (as a block) were published by Eurostat in May 2011.
(4) This report covered Denmark, Germany, Spain, Italy, Hungary, the Netherlands, Sweden and the United Kingdom.

publication of the 2009 ETC/SCP working paper, Eurostat released data that allowed consumption-based analyses:

- on air emissions: for 9 countries in 2005, and for 8 countries in 2000 and 1995;
- on resource use: for 8 countries in 2005, and for only 6 countries in 2000 and 1995. These were supplemented by additional data (5) on resource use, resulting in the same coverage as for air emissions.

This new data allows for consumption-based trend analysis over a 10-year period for countries representing more than half the population and 62 % of the GDP of the EU-27 (6). Temporal analyses of the consumption perspective have not been carried out on such a scale before in Europe, and as such this report represents a significant step in analysing European consumption and production patterns and their environmental implications.

Eurostat has recently made available supply and use input-output tables for the EU-27 as a single region. These tables allow a consumption perspective to be obtained for the EU-27 as a whole. At the same time, Eurostat published a short analysis of air emissions under a consumption perspective for the EU-27 (Eurostat, 2011a). The EEA will publish a more in-depth analysis using the new data in 2013, including both air emissions and material flows as a follow up to this current report.

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(5) Source for the additional data was the EW-MFA data sets of Wuppertal Institute.

(6) Although only a minority of the EU Member States is covered by this report (Czech Republic, Denmark, Germany, France, Italy, the Netherlands, Austria, Portugal and Sweden, hereafter called EU-9), they represent 62 % of the GDP and 52 % of the population of the EU-27.

2 Environmentally-extended input-output analysis — a tool for SCP

2.1 Why is input-output analysis useful for SCP?

EE-IO analysis can give two different perspectives for viewing an economy — both important for SCP analysis

Answering the first policy question defined in Chapter 1 —which elements of European consumption and production patterns are the key causes of environmental pressures including resource use? — requires both an overview of which economic sectors are responsible for key environmental pressures, but also an understanding of the consumption patterns which drive production and its related environmental pressures. Such a dual approach — with two complementary perspectives — provides much of the information necessary to focus policy actions in areas where they are most necessary and can have the most effect.

These two perspectives can, in principle, be obtained through the analysis of specific tables, which combine national economic accounts — i.e. flows of money — with environmental accounts — i.e. environmental pressures such as material inputs, outputs of air emissions, or outputs of waste products. These integrated environmental and economic matrices are termed EE-IOTs (7) (see Box 2.1) (Moll et al., 2007a; de Haan and Keuning, 1996; Keuning & Steenge, 1999; Keuning & de Haan, 1998).

The production perspective shows which parts of an economy are directly responsible for key pressures

In their basic format, the EE-IOTs provide the first perspective, i.e. a picture of which parts of the national economy key emissions, waste and resources are directly used or generated, and show how the total of a given environmental pressure is distributed across a country's economic activities. They also provide data on the economic output of each economic sector for domestic final consumption and export.

We term this perspective the production perspective (see Box 2.2 in Section 2.5). The tables containing the environmental information (environmental accounts) also include direct environmental pressures from household activities (8) and as such provide an overview of the total direct emissions attributable to a country (9).

The information on direct emissions of greenhouse gases and air pollutants given in EE-IOTs should not be confused with the 'territorial' perspective provided by national reported emissions under the United Nations Framework Convention on Climate Change (UNFCCC and the Convention on Long-range Transboundary Air Pollution (CLRTAP. National air emissions totals reported under these conventions can differ significantly from those provided by EE-IOTs due to differences in accounting principles and the scope of organisations covered. IOTs use a residency principle for setting a boundary (i.e. include emissions of all resident citizens and organisations even if they take place in other countries) while the boundary for national emissions inventories is geographic (see Section 2.5).

However, the tables can be used in a similar way to identify environmental hotspots of national production.

The integration of environmental and economic data gives the basis for some powerful analysis

The integration of compatible economic and environmental pressure data in EE-IOTs allows the environmental intensity (environmental

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(7) These matrices are also known under the name *national accounting matrices including environmental accounts* (NAMEA).

(8) This comprises not only the final consumption by households, but also by government, by non-profit organisations serving households (NPISH), by gross capital formation and by stock changes.

(9) In fact direct emissions attributable to national entities — i.e. people and businesses registered as resident.

pressure per monetary unit of output) of economic sectors to be compared. It also allows success in decoupling of pressures from economic growth to be assessed for countries and for individual sectors. Finally, decoupling trends for countries/regions can be decomposed into various contributing factors. Those factors which have contributed most to decoupling of pressures from economic growth can be identified.

The EE-IOT can be processed using some powerful econometric methods termed *environmentally extended input-output analysis* to provide a consumption perspective (Ten Raa, 2005; Miller & Blair, 1985; Moll & Acosta, 2006; Moll et al., 2007a). While the production perspective looks at the question 'what pollutants are being emitted by which industries?', the consumption perspective considers 'what are the consumed products driving these emissions?'.

The consumption perspective looks at all indirect pressures accumulated along production chains of products

Using the EE-IOA methods, environmental pressures directly emitted by an economic sector are re-allocated to the economic flows of intermediate goods and services it sells to other sectors and the final products sold to the end consumer (i.e. domestic final demand). The indirect pressures accumulated along the full production cycle of domestic finally consumed products can then be estimated (i.e. for food — all pressures released and resources used between 'farm and shelf').

Those product groups, which cause the majority of environmental pressures, can then be identified and the eco-intensity (environmental pressure per euro) of different product groups can be compared.

Box 2.1 Brief overview of environmentally-extended input-output tables

EE-IOTs integrate national environmental accounts with environmental data. At the national level they are termed NAMEA which refer to how these tables are composed by the two types of data:

The NAM part represents the monetary flows between economic activities or sectors within a country (i.e. between the food processing industry, transportation equipment industry, banking and insurance services, etc.) and between these and final consumers (10) (government, households and exports). They also include flows of imports for intermediate and final consumption and for re-export (11). The established statistical System of National Accounts (SNA) offers several accounting formats representing the monetary flows of a national economy (see Section 2.2). For the consumption perspective symmetric input-output tables (SIOTs) are needed. For the production perspective readily available gross output data by economic activity is sufficient.

The EA part of NAMEA represents environmental pressures, i.e. physical data on direct inputs and outputs to and from the environment, for each economic sector. The EA-part must follow the accounting principles and structures of the NAM part in order to allow integration into the NAMEA structure. Generally, primary data from environmental statistics do not fulfil this requirement and employ classifications and accounting rules that are not compatible with the SNA. Hence, primary environmental data, such as emission inventories or energy statistics, need to be adjusted to the classifications and accounting principles of national accounts before integrating them into a NAMEA table (see Section 2.3). This work step to generate environmental accounts from environmental statistics is complex. At the European level Eurostat supports the National Statistical Offices (NSOs) in this work.

Source: Eurostat, 2009a.

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(10) The correct term used in National Accounts is categories of final use.
(11) The correct term used in National Accounts is intermediate and final use.

The eco-intensity of a product group can also be monitored over time. In a further development of the consumption perspective, methods other than EE-IOA can then be used to allocate direct pressures from households to specific product groups.

The next two sections give some more detail on how NAMEA or EE-IOTs are constructed from national accounts and environmental information. Section 2.4 then provides an overview of the types of environmental accounts available in Europe, and Section 2.5 gives a brief overview of differences between national GHG emissions inventories for reporting under the UNFCCC, and total GHG emissions as identified in EE-IOTs.

Section 2.6 then describes how EE-IOTs and EE-IOAs are used to create the production perspective and the consumption perspective, while Section 2.7 describes how assumptions about environmental pressures embodied in imports can be improved to increase the accuracy of the consumption perspective.

Finally, Section 2.8 provides an overview of data used for this study.

2.2 A brief introduction to national accounts and environmentally-extended input-output tables

The System of National Accounts is a standardised system for representing key activities in a national economy

Economics is a long-standing scientific discipline with mature methods for measuring macro-economic phenomena such as consumption and production. Gross Domestic Product (GDP is the most prominent indicator to monitor macro-economic development. However, GDP is just one of many indicators derivable from a comprehensive data framework called *System of National Accounts* (SNA. Further prominent indicators derivable from the SNA include national income, gross value added of industry branches, trade balance and net savings.

The SNA is a standardised accounting system representing all economic activities in a given national economy. Its origin dates back to the 1920s, but it was first after World War II that a standardised system of national accounts was established internationally under the auspices of the United Nations (UN). The first version was published in 1953, followed by revisions in 1968, 1993 and 2008 (12), and it is under continuous development. The European System of Accounts (ESA) is the equivalent system used by members of the European Union (13). The current version is from 1995 but is under review to take account of the 2008 revision of the SNA. At the time of publication the draft revision was being discussed in the European Council.

Most environmental experts are not aware of economists' terminology. The objective of the following paragraphs is to provide a brief overview on how national economies and their interrelated components are systematically described within the SNA and ESA, respectively.

Industry represents the production of goods and services and households the largest final user of these goods and services

The most simplified presentation of a national economy is the 2-sector-model comprising industry and households (14). Industry represents the production of products (goods and services (15)), and households represents the largest final user of these products. The two components are mutually connected via transactions, i.e. physical flows and monetary flows. In Figure 2.1, physical flows are represented by continuous lines, while monetary flows by dotted lines. There is a physical flow of products from the production system to the private households. The reciprocal monetary flow is the purchase price that private households pay for these products. The physical flow from private households to the production system comprises the labour force that private households provide. The opposite monetary flow is the compensation of this labour through wages.

The SNA (and ESA) principally records only the bold arrows in Figure 2.1. These flows are represented in monetary values rather than tonnes of goods or numbers of employees and hours worked.

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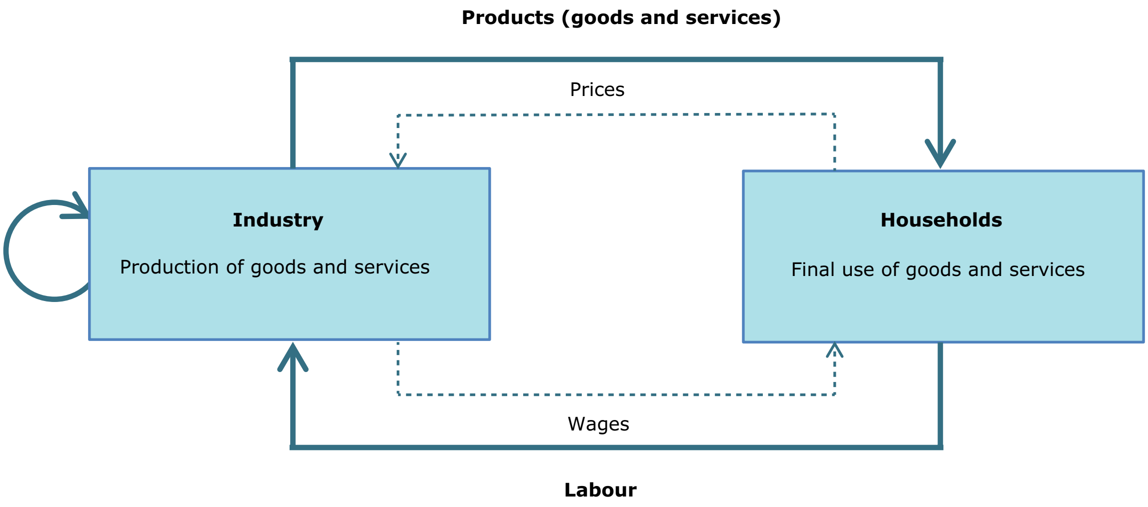
(12) See http://unstats.un.org/unsd/nationalaccount/sna2008.asp.

(13) See http://circa.europa.eu/irc/dsis/nfaccount/info/data/esa95/en/titelen.htm.

(14) This is a very simplistic image. It neglects further important sectors of the national economy such as government and financial corporations.

(15) 'Products' is the superior term comprising 'goods' and 'services'.

Figure 2.1 Simplified 2-sector-model of a national economy



An important insight, which can be derived from Figure 2.1, is that the production of goods and services and the final use of products are closely related. In a closed economy, they are actually two sides of the same coin ([16]).

The flows as shown in Figure 2.1 can also be presented as lists in a so-called T-account ([17]), where the left column represents the production of goods and services, and the right column shows the use of these products.

Table 2.1 shows the T-account for domestic production. The left column presents the inputs needed to generate the output from domestic production. Two generic inputs are required: intermediate inputs and factor inputs. Intermediate products are primarily physical products and services, which are used to generate other intermediate products and to generate products for final consumption. For instance, the steel industry requires iron ores and coal to produce steel and the domestic car manufacturing industry requires steel, tyres, glass, electricity, etc. to be able to assemble finished cars. These intermediate products come either from domestic producers or are imported.

Secondly, the industry needs so-called factor inputs such as machines and other capital inputs, and human labour. These are recorded under the item 'gross value added'. The costs of intermediate products, human labour, machines (at their acquisition price) and the costs of the other factor inputs give the total costs of production to the producing company.

The right column shows how this output from domestic production is used. A certain part of the output produced domestically comprises intermediate products for input to other domestic companies. The remainder of the output comprises finished products — termed 'final use'.

These final use products have a number of end destinations. The majority are used for consumption by households, non-profit organisations serving households ([18]) and government. A second part is used to build up the physical capital stock of machinery, buildings and infrastructures (termed 'gross capital formation'). A third part is exported, comprising both finished products and semi-finished products that are used as intermediate input in foreign industries. Stock changes represent a final but minor balancing item.

The two columns of the T-account presented in Table 2.1 should be exactly balanced, i.e. both columns should add up to the same total quantity at the bottom. Again, it shows two sides of the same coin: everything produced is also used, be it intermediate use or final use.

([16]) That is, in the global economy or other closed economies. In national economies many goods and services are provided to and from outside the system.

([17]) The term 'T-account' follows the table structure as indicated in Table 2.1 (grey areas form a T).

([18]) For simplicity, the final use category 'non-profit organisations serving households' (NPISH) will not be considered further in the following text.

Table 2.1 Simple T-account for domestic production

	Inputs (costs)			Outputs (turnover)
+	Intermediate products supplied for domestic production	=	+	Intermediate products used for domestic production
+	Imported intermediate products		+	Final use (of mainly finished products and services) from domestic production
+	Gross value added:			• final consumption expenditure
	• compensation of employees	=		• gross capital formation
	• profits			• stock changes
	• indirect taxes less subsidies			• exports
	• depreciation			
=	Input for domestic production	=	=	Output from domestic production

If the right column of the T-account in Table 2.1 is rotated by 90° counter-clockwise to overlap with the left hand column, we obtain the basic shape of an IOT as shown in Figure 2.2 (quadrants I, II, and III). Now, the intermediate use parts of both sides of the initial T-account are overlapping (quadrant I). In general, IOTs disaggregate the production into several distinct economic activities (i.e. industries and services). Each economic activity is represented by both a column and row. The columns show the inputs required by each activity for their production, while the rows represent the outputs of that activity (19), comprising both intermediate products for use by other branches (left hand side) and products for final consumption by households and government, for gross capital formation, for export as well as the stock changes (right hand side).

In this way, Quadrant I in Figure 2.2 shows the monetary flows of intermediate products exchanged between different economic activities, e.g. use of electricity by the food processing industry, or use of outputs of the rubber industry in the car manufacturing industry. Quadrant II shows the end destination (households, government, export) of final products from each economic activity. Quadrant III shows the inputs to each economic activity other than the domestically produced intermediate goods. Monetary values of imports for final use (quadrant IV) are added in underneath the final use matrix (20). These comprise products imported directly for final use.

The Eurostat monetary IOTs for domestic production disaggregate the production currently into 60 distinct economic activities (NACE rev. 1.1; 2-digits), whose production is grouped in 60 product groups. The imports for intermediate and final use are displayed as a row vector.

In order to extend an IOT with 'environmental pressures' and thus create the EE-IOT, environmental accounts (quadrants V and VI in green) are added underneath the economic matrices.

Environmental pressure data split by industry are added to the economic IOT to give the EE-IOT

They represent environmental inputs to, and outputs from, the economic branches (quadrant V) and environmental pressures resulting directly from final use (e.g. consumption activities of households — quadrant VI).

The environmental extensions may include several environmental pressures. The environmental accounts most commonly included in EE-IOTs are

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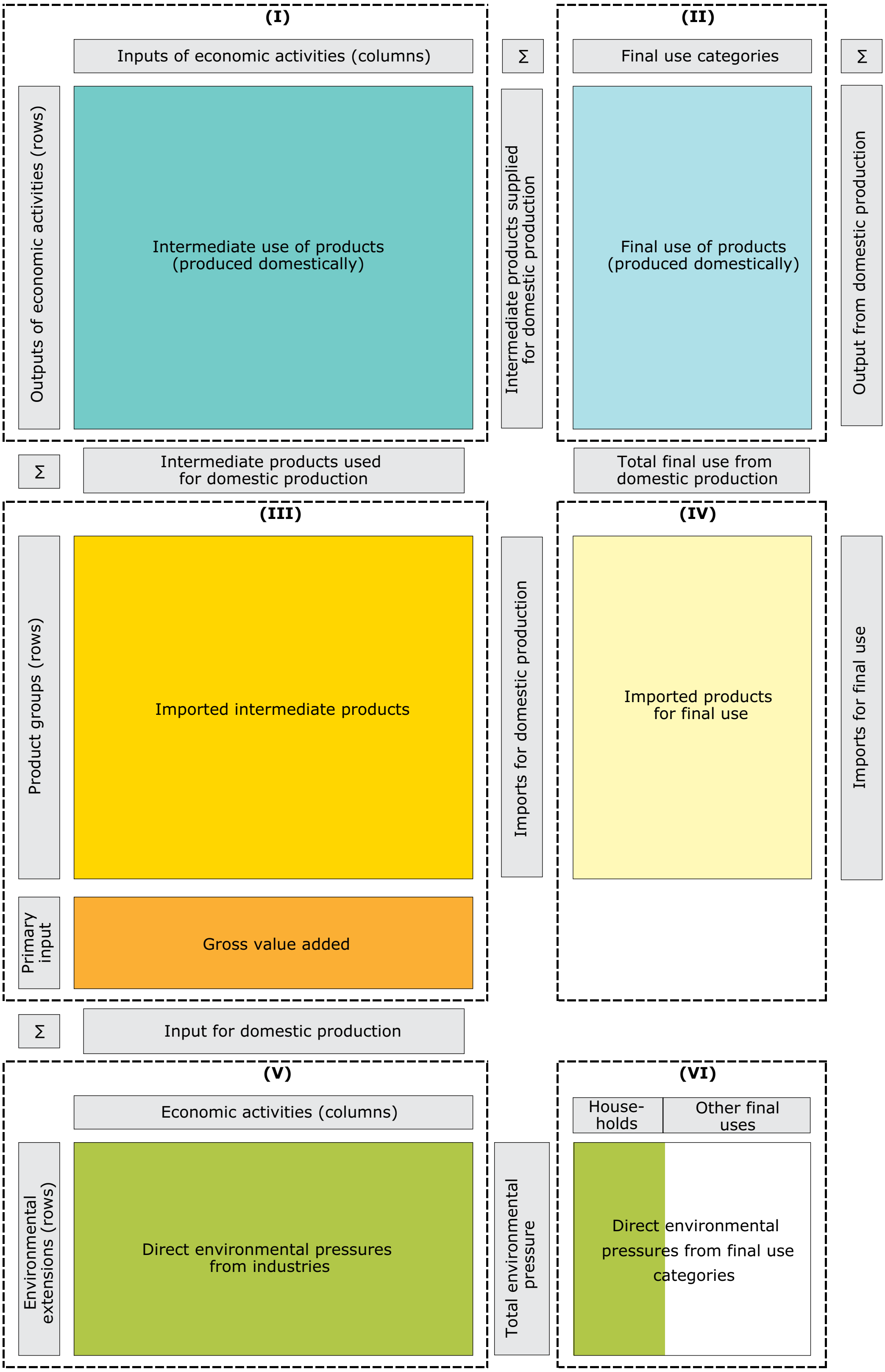
(19) In practice, countries use a number of different variations for defining rows and columns which are similar but not exactly the same, i.e. industry by industry, product by product as well as the standard used here which is product by industry. This is described in more detail in Appendix A.

(20) As such, the IOT shown in the EE-IOT in Figure 2.2 is of Type 0. The various possibilities for representing IOTs are described in Section A.1.2 of Appendix A.

Figure 2.2 Schematic of an environmentally-extended input-output table



key air pollutants, GHGs, material inputs and some toxic waste materials. This is described in more detail in Section 2.4 below.

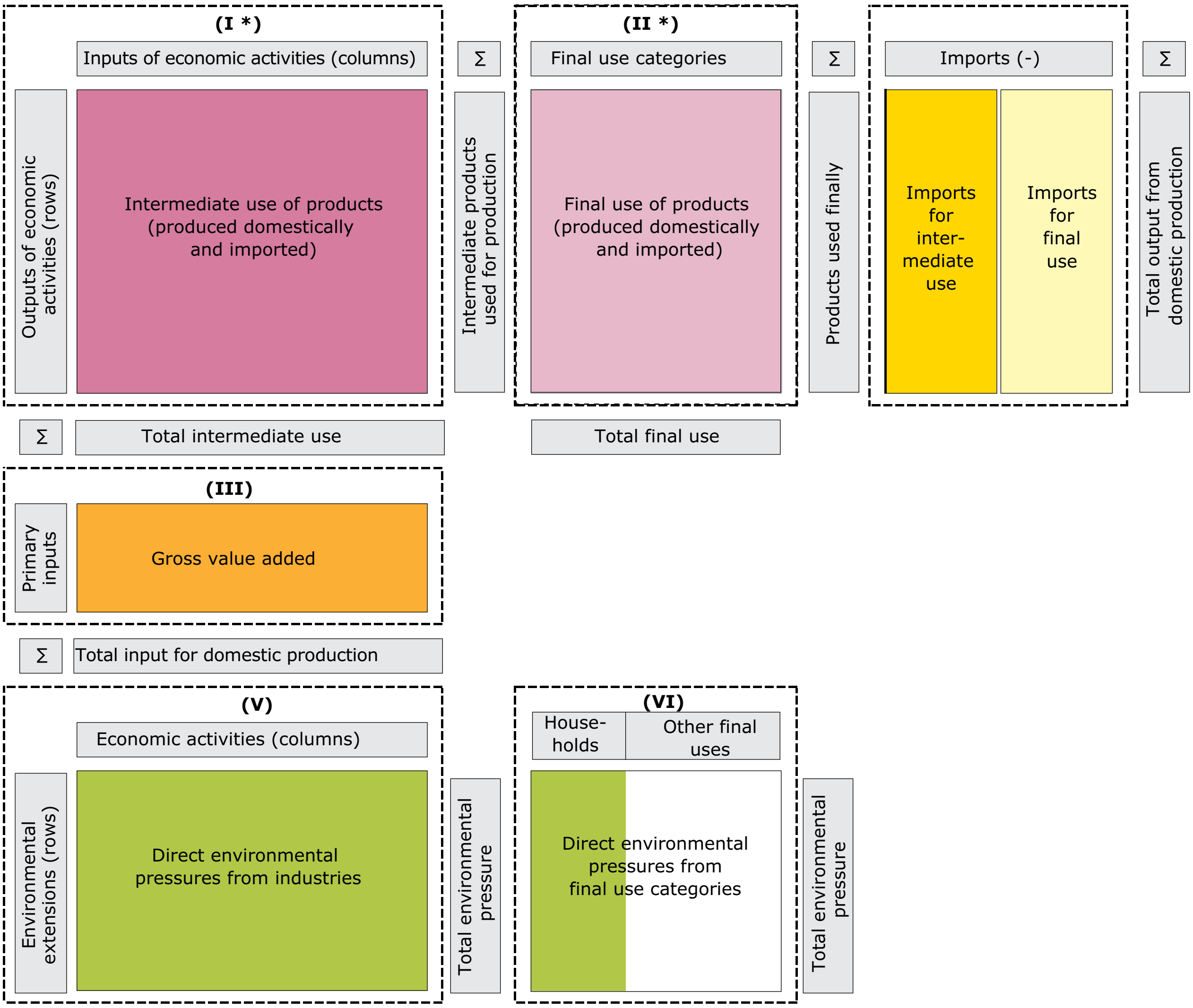
National Input-Output tables that are extended by these environmental accounts are also known under the term *National Accounting Matrix including Environmental Accounts* (NAMEA (see Box 2.1)).

To produce EE-IOTs that can be more readily manipulated to produce a consumption perspective of environmental pressures (see Section 2.6) it is useful to collapse quadrants I and III into a single matrix and do the same for quadrants II and IV. This is done through a rather technical iterative process described in Appendix A. The resulting so-called EE-IOT of total domestic use is shown in Figure 2.3 ([21]).

Quadrant I* now includes all intermediate products, both domestically produced and imported, required by each economic sector to produce its outputs. Similarly, quadrant II* includes all finally used products — both those finally produced domestically and imported final products for direct final use. As before, final use includes domestic consumption by households and government and gross capital formation which together are called domestic final use, and exports.

By integrating the imports with domestically produced products, global production driven by

Figure 2.3 Schematic of an EE-IOT of total domestic use



([21]) The IOT given in Figure 2.3 represents a Type II IOT. This is described in more detail in Section A.1.2 of Appendix A. The full EE-IOT shown in Figure 2.3 is identical to that in Figure A.6 in Appendix A.

total domestic consumption can be estimated. Further manipulations of these tables can then give quantitative estimates of the environmental pressures released globally to satisfy domestic demand for goods and services. This is described further in Section 2.6.

2.3 From environmental statistics to environmental accounts

The EEA, based on previous works by the Organisation for Economic Co-operation and Development (OECD) and others, has established the DPSIR assessment framework as a working principle for their provision of environmental information (22). Therein, the following three types of environmental data can be distinguished:

- environmental pressure indicators or data;
- indicators or data on the state of the environment;
- environmental impact data or indicators.

Of these types, only environmental pressure data can be linked directly to economic consumption and production activities. Typically, environmental pressures are immediate material and energy flows between the economic and the environmental sphere resulting from human activities. They comprise the input of materials (metal ores, non-metallic minerals, fossil energy materials/carriers, biomass, water, etc.), land use and energy; and the output of waste, and of emissions to air, soil and water. Those environmental pressures, unlike the state of the environment, or environmental impacts can be assigned to economic activities in EE-IOTs.

Statistics on environmental pressures are recorded by national statistical offices in various data formats. As shown by the scheme in Figure 2.2, those environmental pressure statistics need to be adjusted to accounting principles and structures of the System of National Accounts. Such adjusted environmental pressure statistics are termed environmental accounts (23).

Section 2.4 gives an overview of environmental accounts which are currently available and those which may be available in the future. The data presented in this report comprises environmental pressure variables in two areas, for which specific statistics exist and which can be readily (though not easily) adjusted to give environmental accounts:

- greenhouse gas emissions and other air pollutants as recorded in emission inventories;
- material inputs as recorded in economy-wide material flow accounts.

Methodological guidelines for emission inventories for GHGs and air pollutants have been established under the umbrella of two international conventions. With the CLRTAP, standards were developed to represent national data on emissions of a number of important air pollutants. The UNFCCC triggered the establishment of harmonised GHG inventories. The EEA is the responsible body collecting these inventory data from national authorities and compiling aggregated EU inventories every year (e.g. EEA, 2010b; EEA, 2011). The classification systems of both conventions have been harmonised to the Common Reporting Format (CRF). The CRF is not fully compatible with classifications used in national accounts. However, with the help of a transformation key the data can be transformed to a compatible format to give air emission accounts compatible with NAMEA tables (Eurostat, 2009b). Eurostat compiles air emission accounts under its work programme on environmental accounts.

Material inputs are recorded in economy-wide material flow accounts (24) (EW-MFAs) for which Eurostat has established compilation standards (Eurostat, 2001; Eurostat, 2009b). The classification of material inputs is multi-dimensional. There are some conceptual difficulties in linking all categories of material input flows to consumption and production activities as represented in national accounts. However, the category of DEU — i.e. the extraction of material resources for further use within national boundaries — can be linked without restrictions to the economic classifications used in national accounts.

There are some important rules to consider when transforming environmental statistics to environmental accounts. The general principle is to assign a given environmental pressure as precisely

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(22) The DPSIR is a conceptual framework, implemented by the EEA, addressing Driving forces, Pressures, States, Impacts and Responses. For more information, see EEA Environmental Terminology and Discovery Service (ETDS), http://glossary.eea.europa.eu/terminology/terminology/concept_html?term=dpsir.

(23) The term Environmental Accounts is used here to denote that environmental variables are organised in a SNA-compatible data format.

(24) Some prominent environmental pressure indicators can be derived from EW-MFAs, such as DMI, Domestic Material Consumption (DMC) or TMR.

Environmental data are converted into a format compatible with national economic accounts using complex transformation keys

as possible to a particular industry. In the European System of Accounts, industries (economic units) are defined and classified using the NACE classification (25). Basic environmental statistics, such as emission inventories, are partially classified according to technical characteristics rather than by industry and the transfer from those technically classified data towards an economic classification is not trivial.

2.4 Availability of environmental accounts

Environmental accounts are only available for a limited number of environmental themes. These can be grouped into physical environmental accounts describing environmental pressures as noted above, and monetary environmental accounts (i.e. monetary flows of environmental taxes, money spent on environmental protection). This study is restricted to the application of physical environmental accounts.

As described in the previous section, the physical environmental accounts provided by Eurostat are limited to the following thematic areas:

- air emission accounts (NAMEA Air);
- EW-MFAs.

These environmental accounts have been compiled in national statistical offices and transmitted to Eurostat on a regular basis via questionnaires under a so-called gentleman's agreement. However, the regularity and quality of reporting on environmental accounts of some countries is unreliable affecting coverage for studies such as this one. This situation shall be overcome by means of a new regulation by the European Commission (No. 691/2011) that makes the reporting by national statistics offices obligatory following the defined accounting rules (26).

Many important environmental pressures have so far not been developed on EU level — for example, emissions of toxic substances. According to the priorities set by the European Strategy for Environmental Accounting (ESEA), selected areas are currently being developed under national pilot studies in a few selected countries under the guidance of Eurostat.

The physical environmental accounts currently under development are:

- Energy Accounts (Energy-PIOT (27));
- Water Accounts;
- Waste Accounts.

The European Parliament, during their reading of the proposal for the now adopted Regulation on European environmental economic accounts also requested the future development of forest and ecosystem accounts (Eurostat, 2011b).

The methodological development of the Energy Accounts and Water Accounts began in 2010 and will continue beyond 2011. Only when the methods have become mature will their integration into regular reporting agreements (voluntary or mandatory) be considered.

A pilot data collection by national statistical institutes for Energy Accounts began towards the end of 2011. Water accounts are somewhat further behind (Eurostat, 2011b).

The development of the Waste Accounts is currently on hold due to the insufficient coverage of primary data (waste statistics as reported under the Waste Statistics Regulation).

2.5 Environmental accounts and national emissions inventories

The boundary for National Emissions Inventories is the territorial border.

For national EE-IOTs the scope is all nationally registered businesses — even those situated in other countries.

Although, as described in Section 2.3, the air emissions elements of environmental accounts in national EE-IOTs are derived from national air emissions inventories, there are some important differences between EE-IOTs and national emissions inventories both in their scope, and what the objectives are behind them.

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(25) The NACE classification is the Statistical classification of economic activities in the European Communities that provides the framework for presenting statistical data according to economic activity.

(26) Official Journal of the European Union, L192, volume 54: Regulation (EU) No 691/2011 of the European Parliament and of the Council of 6 July 2011 on European environmental economic accounts.

(27) PIOT = physical input-output table.

The main objectives of classical national air emission inventories are to:

- provide the main basis for assessing progress and compliance towards internationally and nationally agreed emission reduction targets (for example, under the Kyoto Protocol and the LRTAP Convention);
- disclose and analyse changes in trends of national and sectoral air emissions in line with international guidelines and formats;
- help direct mitigation efforts and evaluate effectiveness of international, national and sector-specific policies.

The main objectives of environmental accounts in NAMEA are to provide environmental information which is compatible with economic statistical data in order to:

- present environmental information alongside economic information for economic sectors in national statistics;
- carry out integrated analysis of economic and environmental accounts to give new insights into the environmental consequences of consumption and production;
- identify trade-offs between costs of prevention of environmental damages and macro-economic policy objectives.

National totals in air emissions reported by the two systems can differ due to differences in accounting principles and the scope covered, Differences in principles are a result of the different origin and objectives of the two systems. In particular, the residency principle of the NAMEA system can give significant differences in the emissions captured by the two systems (see Box 2.2).

Table 2.2 shows the main differences in the scope of environmental pressures included in national EE-IOTs and national air emissions inventories: in the case of GHG emissions.

It should be emphasised that the differences in total emissions are a result of the differing objectives and principles of the two systems and should not be perceived as inconsistencies. Similarly, the work here is intended to supplement insights that can be gained from emissions inventories and other environmental statistics and not to supplant them for reporting purposes.

Box 2.2 Direct emissions and residency principles

National air emissions inventories are based on a concept of direct emissions, i.e. including only those emissions which a state's government has direct influence over, regardless of who owns the emitting entity. It covers emissions occurring within a national boundary.

EE-IO accounting principles on the other hand follow national accounting systems which define an economic entity (i.e. businesses or consumers) and all its activities as being part of the national economy if it is resident or registered within the country. This is regardless of whether some of its operations actually take place in other countries

In short, the scope of national emissions inventories is restricted to the national geographic or territorial boundary, while the scope included in EE-IOTs are restricted to a national economic boundary.

In EE-IOTs, emissions from cargo lorries must be assigned to the resident country of the operating company, regardless of where these emissions occur geographically. Conversely, emissions by non-resident businesses within the national boundary (i.e. foreign lorries) are excluded. Similar rules are applied to direct environmental emissions of a country's resident population. These should be (but often aren't) included in a country's EE-IOT even if they take place while the person is abroad. Conversely, direct emissions by foreign tourists should not be (but often are) recorded in the country's EE-IOT.

Of key importance, EE-IOTs, at least partly, include emissions from international transport (i.e. air transport and shipping) and assign them to the country of registration of the transport operator. GHG emissions inventory totals do not include international transport emissions although they are included as memorandum items.

Table 2.2 Differences in scope of air emissions included in national EE-IOTs and in national emissions inventories

	GHG emission inventories	EE-IOT
Scope of national emissions reported	Direct emission within the geographical national territory and: • emissions from international bunkers allocated to country where fuel is sold; • emission/removals induced by land use change and forestry are accounted for; • all GHG emissions are included.	Emissions within the economic territory of the country covered, i.e: • emissions of entities registered in the country (e.g. ships, residents); • not all GHG emissions are currently included (e.g. CFCs and HCFCs are omitted).

2.6 Obtaining the consumption and production perspectives

In general, an economy is characterised by its production and consumption activities. In this sense, it can be analysed from two perspectives. We call these the industry or production perspective, and the product or consumption perspective.

The production perspective considers the direct environmental pressures arising nationally (as defined under the residential principle — see Box 2.2), from the activities of industries and services. In this perspective, it is the environmental performance of different industries and services that is in focus.

The consumption perspective covers the global environmental pressures, caused directly and indirectly along the production chains of all products consumed nationally (produced domestically and imported). It also includes the environmental pressures resulting from the use phase of the products, which are used or finally consumed by households (28). In this perspective, it is the total environmental pressures directly and indirectly caused by consumption of products (29) that are of interest. Note, however, that only the environmental pressures caused during the production of goods can be allocated to product groups using EE-IOA methods. Neither the direct emissions resulting from the consumption of products (i.e. emissions from the burning of fossil fuels in vehicles) nor the environmental pressures caused during waste management of end-of-life products can be allocated to product groups using EE-IOA. In this report the emissions caused during the consumption phase are allocated using other methods. The end-of-use phase has not been included at all.

While the application of the production perspective allows a comparison and analysis of environmental pressures caused by different industries, the consumption perspective allows the comparison of environmental pressures caused by the consumption of different product groups. See Box 2.3 for a comparison of the two perspectives.

The production perspective can be investigated directly using EE-IOTs in their basic form. EE-IOTs provide a picture of where exactly in the national economy resources are directly used and where air emissions and other wastes are directly generated. For this perspective, we need only the environmental accounts and gross output of each economic activity rather than the full scheme given in Figure 2.3. Total direct emissions and resource use attributable to a country can be obtained by summing contributions from each economic activity. It should be noted that EE-IOTs include direct pressures from households as well as from economic activities. However, the production perspective as used in this report refers only to the direct pressures from industries and services and excludes direct emissions from households.

Using the production perspective, the 'hot spots' in national production can be identified, i.e. which industries are contributing most to key national environmental pressures. The integration of economic and environmental data within the EE-IOT framework also offers the possibility of comparing the environmental pressure intensities (i.e. pressure per euro of output) of different industries and of following the environmental performance of a given industry over time. The pressure intensities of individual industries can be derived simply from EE-IOTs by dividing the total pressures they are responsible for by their economic output.

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(28) This includes all categories of domestic final use (excluding exports).

(29) The consumed products refer to groups of products and services according to statistical classifications (CPA).

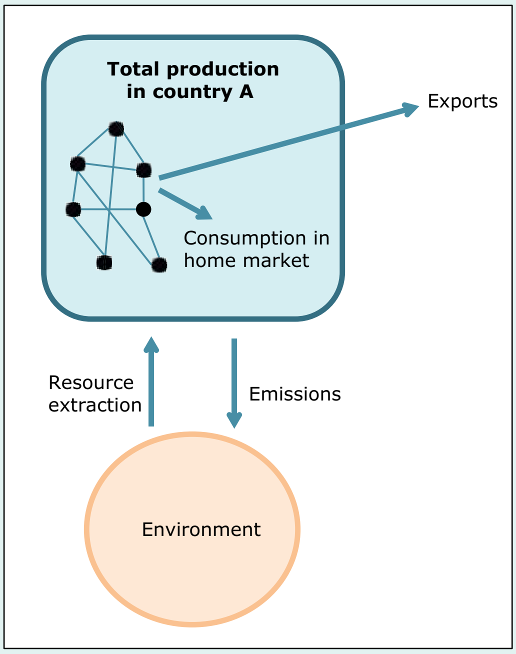
Allocating environmental pressures to products

Considerably more effort is required to shift to the consumption perspective which follows products consumed nationally (See Box 2.3). Complex analytical approaches developed by Leontief (1970) and others, termed EE-IOA, are applied to the data contained in the EE-IOT. These are described in detail in Section A.4 of Appendix A.

Through these approaches, direct environmental pressures attributable to a given industry or service are in a first step re-allocated to the flows of goods and services, which it sells to other economic

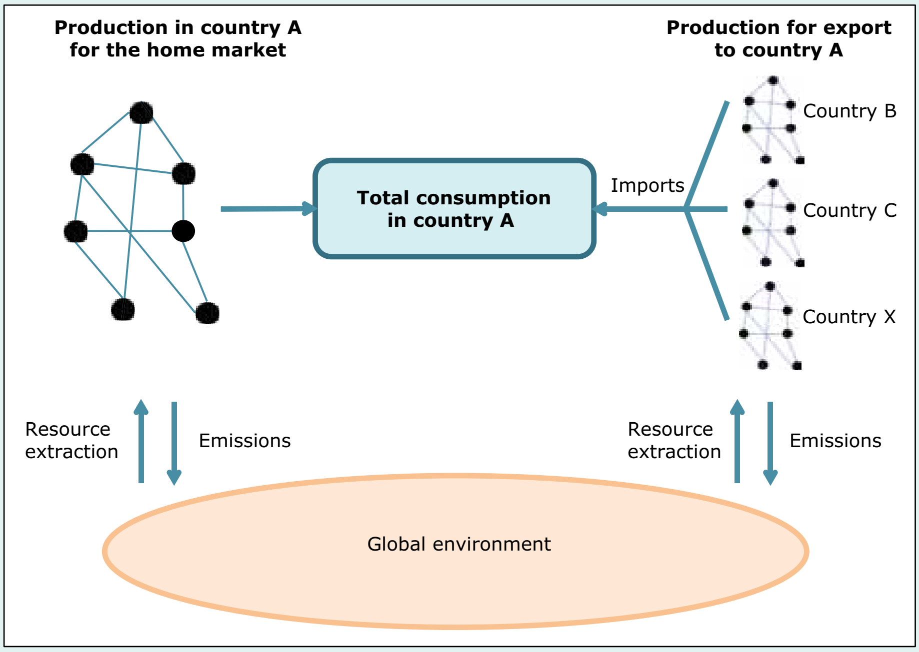
Box 2.3 The production and consumption perspectives

The **production perspective** focuses on direct pressures arising from nationally registered entities. For air emissions, for example, this would include all emissions to air from national production facilities, agriculture, transport services, etc. (identified as black dots in the figure).



The **consumption perspective**, meanwhile, includes all environmental pressures caused directly or indirectly by national consumption. This includes pressures from national production for the home market (i.e. excluding pressures caused by production for the export market) plus pressures occurring in other countries to produce all imported goods which are eventually consumed in that country. Finally, it includes direct pressures arising in private households, i.e. combustion of fuel for heating and private cars. This perspective can also be called a country's footprint.

Another way of looking at this perspective is that it includes all the pressures arising along the global production cycle of goods and services finally consumed within the home country.



activities or for final consumption. The pressures are allocated in accordance with the monetary value of these flows. For example, if the electricity industry in a country sells 30 % (by value) of its electricity to the vehicle manufacturing industry, 30 % to the food processing industry and 40 % to the households, then 30 % of the total direct air emissions are allocated to vehicles, 30 % to food products, and the remainder to electricity sold to households.

In a second step, the accumulated environmental pressures, which are associated with all intermediate inputs to each industry or service, are also re-allocated to the products it sells on to other sectors or for final consumption. For example, the electricity industry requires inputs like fossil fuels, machinery and equipment, which already have had environmental pressures allocated to them from the previous step. Allocation is again carried out according to monetary value of the outputs.

At the end of this iterative pressure 'accumulation' process, the pressures allocated to a finally consumed group of products are equivalent to the sum of all pressures accumulated along the full 'production chain' related to those products, In other words, the direct and indirect pressures embodied in these products.

The estimated environmental pressures embodied in the product group food and beverages, for example, includes all pressures emitted during the production of food from the farm through to the supermarket shelf, including pressures activated by the production of the required machines, the production and application of fertilisers in order to produce the agricultural inputs, the production and combustion of fuels in the used machineries, and the production of electricity consumed in food processing plants. To perform such calculations, one needs the full EE-IOT data as illustrated in Figure 2.3.

Dealing with imports

One difficult element in making these calculations in practice is how to deal with imports. National EE-IOTs only include information on direct environmental pressures caused by national economic activities. No information is included on what pressures are released by production facilities in trade partners. Moreover, the national EE-IOTs do not include information on where imports have come from: they have simply come from the 'rest of the world'.

> For now we can only roughly estimate pressures embodied in imported goods

Therefore, the method using national EE-IOTs as used by this report can only roughly estimate pressures embodied in imported goods. This is based on the assumption that industries abroad generate exactly the same waste emissions and use the same resources per unit output (30) as the same industries in the home country (what is actually being measured here are avoided national pressures). The 'like-domestic technology' assumption can underestimate, for example, GHGs embedded in imported goods on average by as much as 40 %, due to imports from Brazil, Russia, India and China (BRIC countries) and other transition countries with typically less eco-efficient industrial production processes and more impact-intensive energy mixes than EU Member States (e.g. Denmark — Rørmose and Hansen, 2009). A further assumption of the 'like-domestic technology' is that the flows of money between industries — i.e. the IOTs — are the same in the exporting country as they are in the importing country.

The EEA, via its ETC/SCP, is currently investigating methods for improving the estimates of the environmental pressures embodied in imports. A number of solutions have already been used and developed by other research teams (e.g. Minx et al., 2009; Rørmose and Hansen, 2009; Carlsson-Kanyama et al., 2007). Section 2.7 provides a brief overview of some of these. For all methods, the EE-IOTs developed under this project will need to be linked to additional data sources — for example, trade data.

An additional complication that would be caused by introducing differences in pressures embodied in imported goods and those embodied in the same types of goods produced domestically is that methods would also need to be developed for tracking the end destination of intermediate goods i.e. what proportion of imported intermediate goods end in domestically consumed goods and what proportion end in final goods for export.

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(30) Thus imports are assumed to be produced in the same way as in the home country with the same environmental pressure coefficients for each industry and environmental pressure combination. See Section A.2.3 in Appendix A.

Such methods are also needed even with the 'like-domestic production' assumption if one wishes to split the total environmental pressures caused by domestic final consumption into the share emitted at home and the share emitted in the rest of the world. That type of analysis has not been carried out for this report (31).

Differences in calculations for air emissions and material flows

Somewhat different approaches have been taken for allocating material extraction and inputs and air emissions to final products.

Depending on the issue in focus, two separate types of standard IO models can be set up. One which focuses on the domestic effects and one which focuses on the global effects caused by a specific type of final use demand (private consumption, government consumption, exports, etc.) or final use product group. The former includes the production chain within the country only. The latter includes in addition a model for the production chain abroad.

Model-wise, the first is constructed by estimating the Leontief inverse based on the matrix consisting of domestic intermediate consumption, while the second is constructed by estimating the Leontief inverse from the matrix sum of the domestic and imported intermediate consumption of products. The technical details are described in Section A.4.5 of Appendix A.

The choice of the model depends on the purpose. For the allocation of air emissions to final products, the second type was used because the intention was to assess the global emissions caused by domestic final use (private consumption, etc.) (global re-attribution model as described in Section A.4.5.1 in Appendix A).

For analysis of the material flows the first type was used. Not because the effects abroad were not relevant, but because IO modelling of total material requirement (TMR) based on the second type of model would imply certain double counting: TMR already includes some of the production chain effects in other countries, and if the IO model adds more indirect material use abroad the result would be an overestimate.

To be consistent with established MFA indicators, the first type of IO model was applied to both the DMI and TMR calculations in the project. The result is a re-allocation of DMI and TMR to final use products (domestic re-attribution model as described in Section A.4.5.2 in Appendix A. See also Section A.4.6 in Appendix A)). The model was not applied to domestic material consumption (DMC) data which is otherwise the MFA indicator most often associated with a consumption perspective. However, when the model is applied to DMI data, and limited to the domestic share of final consumption (so-called domestic final consumption in which exports are removed), the result is in fact the same as would have been obtained by applying the model to DMC data: in other words it provides a 'DMC equivalent'.

Adding direct pressures from final consumption

To represent the environmental pressures from the perspective of final consumption, only re-attributing the pressures associated with the production to the final consumption categories does not give a full picture. The pressures caused directly by households during the final consumption of goods (e.g. pollutants released while driving vehicles or burning gas or oil to heat houses) have to be added to these re-attributed production-based pressures.

Data on the direct pressures induced during domestic final consumption is, however, usually available from Eurostat or national emissions inventories for aggregated consumption categories only (e.g. transport, heating, etc.). In order to give a full picture of the extent to which given consumed products are responsible for the different direct pressures, this information has to be allocated to the related product groups. The allocation of these direct pressures requires in some cases additional estimation methods beyond those found in EE-IOA. The basic assumptions and the method applied for the current analysis are described in Section 4.5 of this report.

Since the final consumption of products by households does not *directly* lead to additional extraction of materials from the environment (i.e. in the context of the EW-MFA), the direct pressures caused by the consumption activities of households are only relevant for air emissions.

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(31) This is because a Type II IOT has been used for the calculations presented in Chapter 4 of this report combining imported intermediate goods with domestically produced intermediate goods in a single matrix. See Section A.2 in Appendix A for details.

2.7 Overview of methods for better accounting for imports

As described above, the standard approach to input-output model-based estimation of resource use and emissions embodied in imports to a specific country has been to assume that all related production in other countries takes place using the same technology as used in the importing country instead of the technology of the country which actually produces the imported products. The advantage of this approach is that it is rather simple and that it does not require too many data. This is also the approach applied for the analyses presented in this report.

The assumption of the same technology being used in all countries, however, is not correct, and in recent years a substantial effort has been made by many research teams to construct more realistic input-output models which specifically take into account different production technologies in different countries and regions of the world. These models are called multiregional input-output models (MRIO) models (see, for example, Wiedmann, 2009). It has especially been in relation to estimation of CO_2 emissions embodied in imports that these efforts have been done (see, for example, Andrew et al., 2009).

If comparable IOTs for all countries of the world and detailed data on imports and exports between all countries were available it would be possible to construct a MRIO model, which would take into account all possible links between sectors and countries and the specific production technologies in the countries where the production actually takes place. If data on resource use and emissions were also available for all countries, it would be possible to come up with correct estimates of the environmental pressures embodied in imports to a given country.

In practice, however, data for such a detailed worldwide MRIO is not available. It has therefore been necessary to build less detailed MRIO models based on some simplified assumptions.

The first type of simplification relates to the number of countries or regions in the model. MRIO models include country-specific IOTs and environmental pressure information only for the most dominant trade partners. The rest of the imports are then treated as coming from the rest of the world or from a few distinguished geographic regions. The latter may be, for instance, 'European OECD countries', 'other OECD countries', and 'non-OECD countries'. For the rest of the world, or each of the aggregate geographic regions, an overall IOT as well as more or less representative information on the environmental pressures are then added in order to complete the model. The starting point for MRIO models has in a number of cases been the OECD IO database or the so-called GTAP (Global Trade Analysis Project) database (32), which includes IO data for a large number of regions.

In all cases it is necessary to obtain information over source and type of imported goods. This information on imports is normally available from the foreign trade statistics of the country in focus. Ideally, the model should also take into account all other trade flows prompted worldwide by the initial import to the country. For instance, when Country A imports steel from Country B the latter needs to import iron ore from Country C. A model, which takes these additional bi-directional trade flows into account, is called a MRIO model.'

However, such a model is demanding to implement. Therefore a simplification related to those trade flows is often applied in practice. Instead of explicitly accounting for the trade flows based on observed statistical data, they are approximated by assuming that each country, except the country in focus, produces all of its import itself. Thus, in the example above it is assumed that Country A imports steel from Country B, but that Country B produces the iron ore itself instead of importing it from Country C. Such a model is often called a MRIO with uni-directional trade flows.

Between the simple standard approach as used in this report and the ideal comprehensive MRIO model with bi-directional trade flows, there exist a wide range of models with various levels of detail and assumptions with regard to production technology and trade flows.

The decision on whether to use uni-directional or bi-directional trade flows is a matter of data availability and human resources for implementing the model. In addition, there may be certain trade-offs to take into account. In order to explicitly include a high number of countries in the model, one may, for instance, often have to sacrifice a

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(32) See https://www.gtap.agecon.purdue.edu/.

detailed breakdown of sectors, which in the end may lead to poorer estimates.

At the EU level, the EXIOPOL (33) project, funded by the European Commission under the Sixth Framework Programme (FP6), has developed a detailed environmentally-extended IO database for EU-25 Member States for the year 2000, and potentially or further years if possible. Included in the database are also IO and environmental data for a number of non-EU countries, which have important trade relations with the EU. When using the model, information on environmental pressures in countries, which are not explicitly included in the database, will be added by extrapolation.

2.8 Data used in this report

Member States are obliged to deliver data required for NAMEAs to Eurostat…

For this report the EEA and the ETC have used the most up-to-date data available published by Eurostat by the beginning of 2011.

As described earlier, the production perspective can draw on economic and environmental accounts. As a result, data availability for the production perspective is comprehensive. Economic data (output) is provided for EU-25 on an annual basis (34). The consumption perspective requires the full EE-IOT given in Figure 2.3. Data availability for this perspective is correspondingly patchy.

…but only once every five years for the detailed data needed for the consumption perspective

Economic data are usually compiled and provided by national account units in national statistical institutions. Member States are obliged to provide Eurostat with economic data following the format provided by the ESA 95. Eurostat ensures that the collected data are harmonised as far as possible. Basic economic output data by industry, as required for the production perspective, is reported annually. SIOTs, as required for the consumption perspective, are reported by EU Member States every five years.

The environmental data sources are described in Section 2.4.

The most recent available data set used for analysing the production perspective in this report is based on the NAMEA Air survey conducted by Eurostat

Table 2.3 Calculation of aggregated pressures from 8 emissions to air

Theme	Substance	Weighting factors applied	Comments
Climate change (global warming)	CO_2	1	Aggregated GHG emissions, GHG, in CO_2-equivalents after 100 years
	N_2O	310	
	CH_4	21	
Acidification	SO_2	1.0	Aggregated acidification emissions in SO_2-equivalents (EEA, 2002, p. 83)
	NO_x	0.7	
	NH_3	1.9	
Ground-level (tropospheric) ozone formation	NO_x	1.22	Aggregated emissions of Tropospheric Ozone Forming precursors, in NMVOC-equivalents (EEA, 2002, p. 84)
	NMVOCs	1.0	
	CO	0.11	
	CH_4	0.014	

Note: Only the GHGs which are typically linked with national IOTs are included in this table. The three groups of fluorinated GHGs (the so-called 'F-Gases') are generally not included in national IOTs and therefore are omitted from GHG indicators emerging from EE-IOA. Weighting factors for GHGs are taken from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC, 2007). NMVOCS: non-methane volatile organic compounds.

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(33) See http://www.feem-project.net/exiopol/index.php.

(34) Economic parameters were taken from EU KLEMS (http://www.euklems.net/) that includes data for EU-25 for the period 1995–2006, but not for EU-27. Data on economic output by industries for EU-27 were not available in February 2011 when data were processed.

in 2008 (published 2009) and the EW-MFA survey conducted by Eurostat in 2009 and reported in 2010.

The NAMEA AIR data comprises a 1995–2006 time series of a number of important air emissions. Eight emissions are further aggregated to three important aggregated environmental pressures as given in Table 2.3 The aggregated pressures take account of the relative effect of the different emissions, i.e. 1 kg of laughing gas (N_2O) has 310 times the climate change effect of 1 kg of CO_2. The weighting factors applied are those used within the Kyoto Protocol. It should be noted that the NAMEA AIR database does not include emissions of CFCs and HCFCs and therefore does not provide a complete picture of anthropogenic GHGs.

The EW-MFA data, meanwhile, covers the EU-27 for the years 2000–2007. It includes DEU and imports in tonnes for six different material categories: biomass, metal ores, non-metallic minerals, fossil fuel materials and energy carriers, and waste for final treatment.

Data used for analyses by the production perspective

In Chapter 3 we look at aggregated production at the EU level. The chapter draws on a consistent economic-environmental data set from Eurostat. Suitable economic data (output) were not available for EU-27 at the time of data processing and therefore the data presented in Chapter 3 are for the EU-25 (see footnote 34). The industry breakdown is limited to 32 partially disaggregated economic branches. The datasets and coverage included in the analysis in Chapter 3 are given in Table 2.4.

The additional data input for the analysis of resource use are the EW-MFA and the ComExt database, which contains the official Foreign Trade Statistics on the intra-EU and extra-EU trading in goods of all EU Member States. The classification used was the 6-digit European Harmonized System (HS6).

The EW-MFA database at Eurostat provides 55 categories and aggregates thereof (Eurostat, 2009a). These are assigned to the extracting sectors (NACE code). The import data are listed in more than 7 000 categories. These categories were grouped by 59 product groups (CPA (35) code). This vector then was combined with the import table to form the starting point for the matrix manipulations.

The EW-MFA data set is for the EU-27. However, since suitable economic output data were only available for EU-25, the material flows for Bulgaria and Romania were subtracted from the totals for consistency.

A further material flow indicator was also developed for the analysis: the Total Material Requirement (TMR). This includes both direct and indirect material inputs into an economy: material used at home and in other countries for the production of domestically produced goods and imports, but also the unused extraction — i.e. mine tailings, etc.

To create the TMR data, the DEU data from Eurostat's material flow accounts were complemented by specific country data (36). Further, the unused domestic extraction (UDE) was derived from several country studies and own estimates (37). In addition to the unused extraction associated with raw materials (as presented by DEU), the UDE comprises:

- excavation (for construction);
- dredging;
- erosion (of arable land).

The direct material flows associated with imports were taken from Eurostat's external trade database ComExt (38). The corresponding indirect material flows associated with imports were estimated using coefficients from the Wuppertal Institute (WI)

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(35) CPA = European Statistical Classification of Products by Activity.

(36) Complementary data were added for DEU, 1995, of Germany and Sweden. Data for Germany were acquired from DESTATIS, data for Sweden were acquired from international data sources. While doing so, the accounting conventions form the 2009 Eurostat Compilation Guide for EW-MFA was applied (Eurostat, 2009).

(37) For the estimate of UDE, specific country data for all countries besides Portugal and Sweden were acquired from different sources. In addition, UDE related to DEU by materials was estimated based on a coefficient database developed by SERI and WI in the projects INDI-LINK and EXIOPOL, respectively. Excavation and dredging data were taken for as many countries as possible from original country data, and data gaps were filled by using coefficients; where necessary, given coefficients were adopted as coefficients of countries, for which no coefficients were available with data gaps, and coefficients from France and Denmark were used, respectively. Soil erosion from arable land was estimated based on land use data from FAOSTAT and erosion intensities from the WI database.

(38) Due to data gaps in the ComExt database, Czech data was acquired for 1995 from the Czech Statistical Office for the estimate of direct material flows related to direct imports. Further, some ComExt data required in part corrections/extensions using data from the Eurostat MFA data set; for the indirect material flows related to direct imports, disaggregated data had to be estimated based on the WI database, while aggregated data for the Czech Republic, Denmark, Germany, France, Italy and the Netherlands were used for comparison.

database that differentiates abiotic material, biotic material and soil erosion. The three categories form the total indirect material flows. More details of data sources for the various elements of the TMR are given in Section A.4.6.2 in Appendix A.

Data used for analyses by the consumption perspective

The consumption perspective requires symmetric input-output tables (SIOT) as data input for the modelling. EU Member States are obliged to provide Eurostat with the SIOT every five years, only, i.e. 2000, 2005, etc. The data has a typical reporting lag of two to three years. This report uses the SIOT for the years 1995, 2000 and 2005 (Table 2.5).

For the analyses of pressures, the environmental accounts used are air emission accounts and MFAs for individual countries.

The study aimed on a maximum of country-year-coverage with regard to the air emissions. The 2008 NAMEA Air survey was released in April 2009 following data quality checks by Eurostat. During 2009, nine countries were identified which had both environmental accounts at sufficient levels of disaggregation among industries and SIOT for 2005. These countries were: Czech Republic, Denmark, Germany, France, Italy, the Netherlands, Austria, Portugal and Sweden. Of these countries, all but the Czech Republic had corresponding data also available for 1995 and 2000, allowing analyses of air emissions by consumption perspective spanning a 10 year period.

This country-year-coverage was then checked to find the corresponding coverage for MFAs. Both EW-MFA and SIOT data are available for all nine countries for 2005, for eight countries (not the Czech Republic) for 2000 and for five countries (not the Czech Republic, Germany, the Netherlands or Sweden) for 1995.

Data collected and analysed by the consumption perspective is described in Table 2.5. The analysis using these data sets is presented in Chapter 4.

Table 2.4 Data input for analyses by production perspective

Economic data	
Data type	Gross output, breakdown by 32 economic sectors
Country coverage	EU-25 (aggregated)
Data source	EU KLEMS data set, Release November 2009
Time series	1995–2007
Environmental accounts — air emissions	
Environmental variables	Eight air emissions further aggregated to 3 pressures by 32 economic sectors: • emissions of GHGs (tonnes CO_2-equivalent); • acidifying emissions (kg SO_2-equivalent); • emissions of tropospheric ozone forming precursors (kg NMVOC-equivalent).
Country coverage	EU-25 (aggregated)
Time series	1995–2006
Data source	Eurostat Air Emissions Accounts by Activity (NAMEA air emissions) (*) 2009
Environmental accounts — material flows	
Environmental variables	EW-MFA, breakdown by 32 economic sectors covering: • DEU (tonnes); • imports (tonnes); • TMR (tonnes).
Country coverage	EU-25 (aggregated)
Time series	2000–2007
Data source	EW-MFA: DEU: Eurostat MFAs 2010, breakdown by Wuppertal Institute, Imports: ComExt database (**) UDE: data base of Wuppertal Institute including data from national statistics institutes Indirect (hidden) flows of imports: data base for coefficients (multipliers) of Wuppertal Institute

Note: * This can be downloaded from: http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/data/database (env_acc_ ainacehh).

** See http://epp.eurostat.ec.europa.eu/newxtweb/.

Table 2.5 Data inputs for analyses by consumption perspective

Economic data	
Data type	Symmetric IOTs (59 by 59 products/industries) comprising domestic production and imports
Country coverage	9 EU Member States — Czech Republic, Denmark, Germany, France, Italy, the Netherlands, Austria, Portugal and Sweden
Time series	1995, 2000 and 2005 (except Czech Republic — 2005 only)
Data source	Eurostat, ESA 95 IOTs
Environmental Accounts — air emissions	
Environmental variables	Eight air emissions further aggregated to 3 pressures by 59 economic sectors: • emissions of GHG (tonnes CO_2-equivalent) • acidifying emissions (kg SO_2-equivalent) • emissions of tropospheric ozone forming precursors (kg NMVOC-equivalent)
Country coverage	9 EU Member States — Czech Republic, Denmark, Germany, France, Italy, the Netherlands, Austria, Portugal and Sweden
Time series	1995, 2000 and 2005
Data source	Eurostat Air Emissions Accounts by Activity (NAMEA air emissions) (*) 2009
Environmental Accounts — material flows	
Environmental variables	EW-MFA, breakdown by 59 economic sectors covering: • DEU — biomass • DEU — minerals • DEU — fossil fuels • imports • Total Material Requirements — TMR
Country coverage	9 EU Member States — Czech Republic, Denmark, Germany, France, Italy, the Netherlands, Austria, Portugal and Sweden
Time series	1995 , 2000 and 2005
Data source	EW-MFA: DEU: Eurostat Material Flow Accounts 2010, breakdown by Wuppertal Institute, Imports: ComExt database (**) UDE: data base of Wuppertal Institute including data from national statistics institutes Indirect (hidden) flows of imports: data base for coefficients (multipliers) of Wuppertal Institute

Note: * This can be downloaded from: http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/data/database (env_acc_ ainacehh).

** See http://epp.eurostat.ec.europa.eu/newxtweb/.

3 Environmental hotspots in European production

3.1 Introduction to the production perspective

As described earlier we consider two perspectives for viewing the economic production and consumption system. The production perspective, which is the subject of this chapter, focuses on the creation and supply of goods and services. Findings under this perspective can contribute to identifying the production sectors on which implementation measures should focus within the coming Resource Efficiency Roadmap.

The perspective includes direct environmental pressures caused by the production of goods and services for consumption at home *and* abroad

The production perspective considers the direct environmental pressures arising from those entities registered in a given country providing goods and services for consumption at home and abroad. In national accounts production entities (i.e. business and government bodies) are grouped according to the type of good or service they provide. Here we will use the term economic sectors for those groupings. Together the groups represent total national production, including production for export.

It is important to note that national production is not equivalent to national consumption. Many goods and services produced domestically are not used on domestic markets but exported to foreign markets. Similarly, many products consumed domestically are imported from other countries. The export-share of domestically produced output can dominate, particularly in economies with high degrees of economic specialisation for global markets.

In today's global market total pressures caused by national production can differ markedly from pressures caused by national consumption

As a result, environmental pressures activated by national production can differ significantly from environmental pressures activated by national consumption (see, for example, Minx et al., 2009; Moll et al., 2007a; Gravgård et al., 2009; Davis & Caldeira, 2010; Helm and Phillips, 2007). Importantly, production-related pressures are mostly (but not always) released within the national environment, whereas consumption-activated pressures can be released anywhere in the world.

Looking at direct environmental pressures from a production perspective is nothing new. Most statistics on environmental pressures take the production perspective. For instance, emission inventories for GHGs and air pollutants record those emissions occurring on the national territory. They distinguish several sources which partly coincide with economic sectors as defined in economic statistics (i.e. national accounts). However, they also employ source categories which do not match with economic sectors as defined in national accounts.

Re-categorising environmental pressures so that they are compatible with national accounts, as occurs during the creation of EE-IOTs, allows integrated analyses of environmental and economic variables. As such it provides a useful tool for investigating the links between economic activity and environmental pressures. Such links are crucial to understanding how we can get closer to sustainable consumption and production.

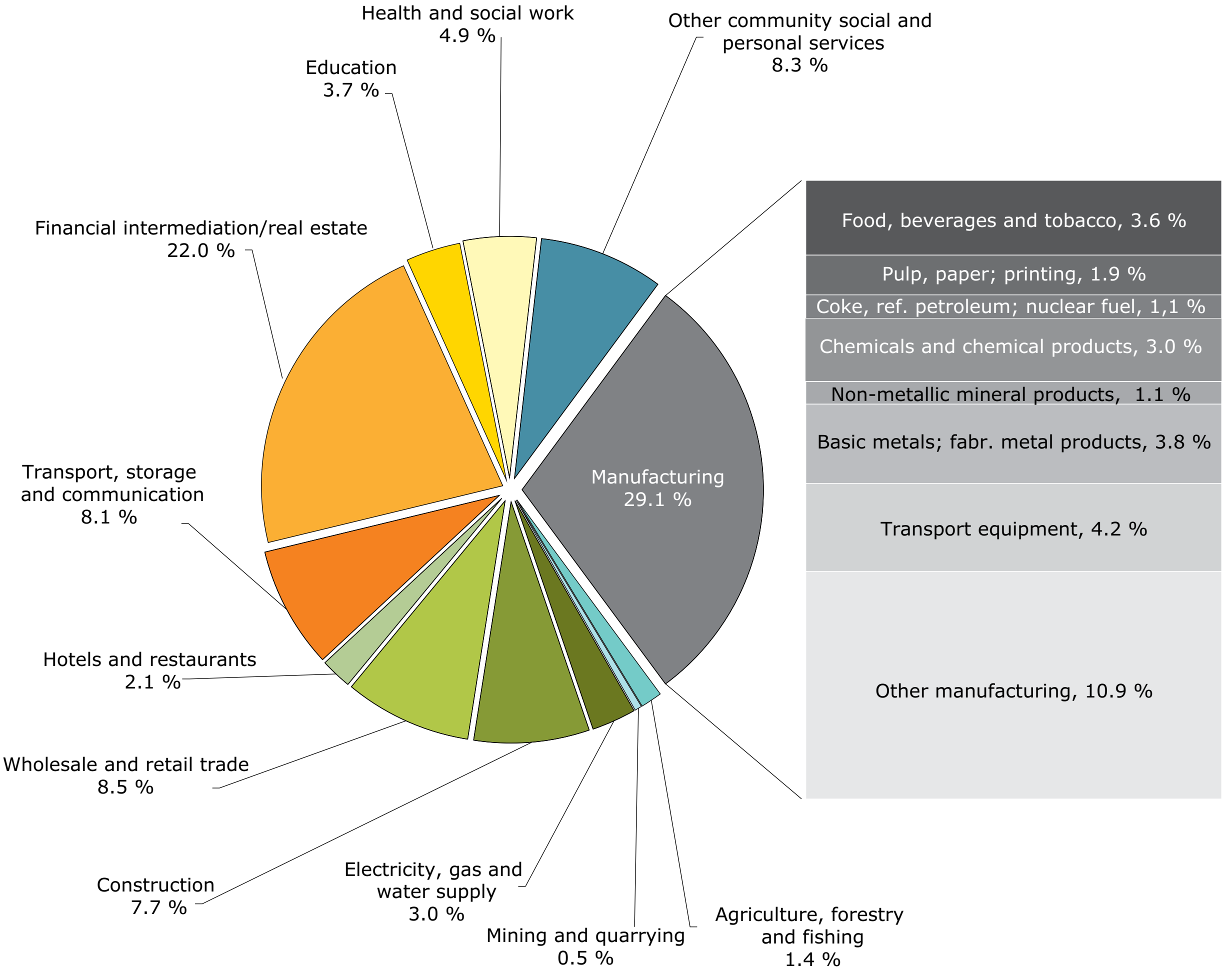
Economic and environmental data used for this analysis are given in Table 2.4 in Section 2.8. As described in the table, data has been used for the aggregated EU-25 economy, for the period 1995–2006.

3.2 Brief overview of European production patterns

European production output is dominated by services

Before considering pressures it is worth taking a brief overview of how European production is broken down. A good means to describe the structure of the EU production system is to look at the composition of total production output broken down by economic sectors (see Figure 3.1).

Figure 3.1 Gross output of the EU-25 by economic sector in %, 2006



Source: ETC/SCP based on Eurostat NAMEA data set.

In recent decades the tertiary service sector has grown at the expense of agriculture and industrial production in terms of share of economic output, i.e. agriculture and industrial sectors have grown but less rapidly than services. By 2006 (the latest year for which we have all environmental accounts), more than half (ca. 58 %) of the EU's total production output was generated by service industries. Market services (real estate, renting, retail and wholesale trade, hotels and restaurants, and transport services) accounted for ca. 42 %, and non-market services (public administration, education, and health and social work) for the remaining 17 %.

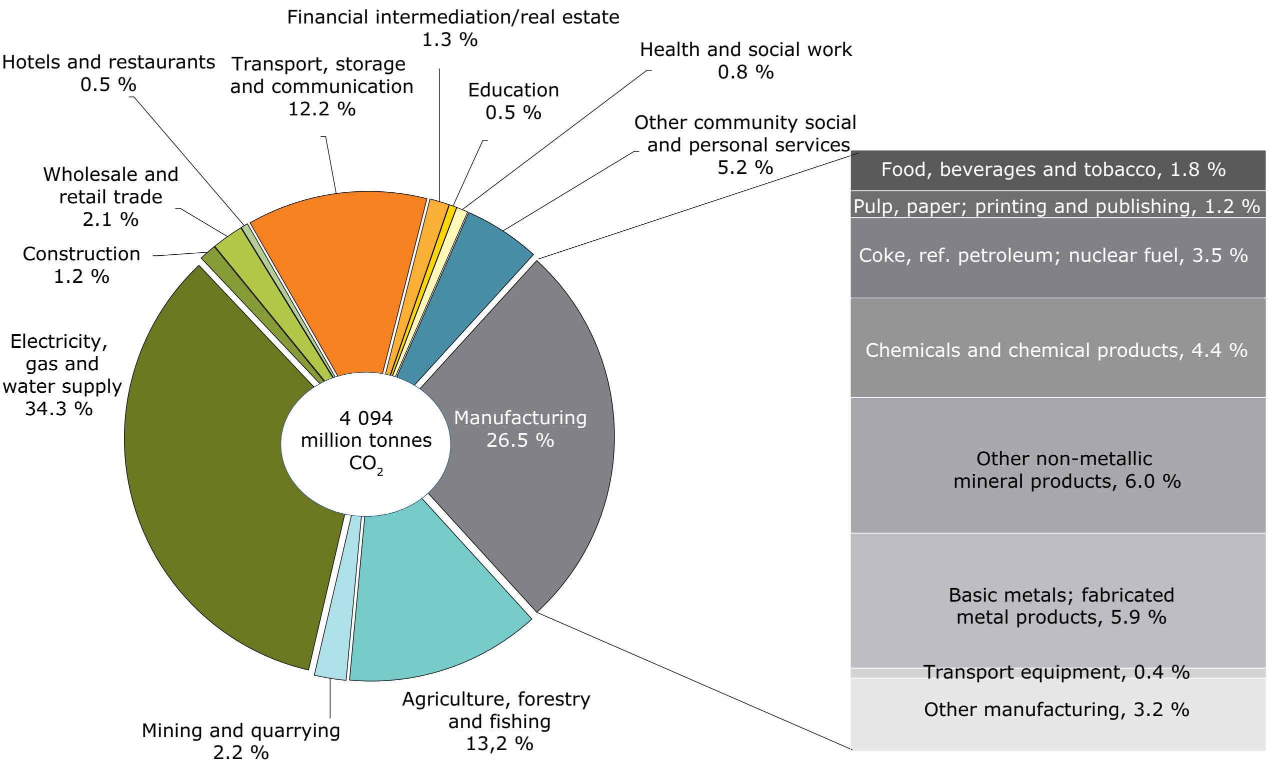
Manufacturing accounted for around 29 % of total production. Important manufacturing industries include manufacturers of refinery and chemical products, motor vehicles, food and drink, electrical and optical equipment, and machinery. Construction work contributed 7.7 % to EU output and supply of electricity, water and gas 3.0 %.

The primary sectors play only a minor role: agriculture, forestry and fishing with 1.4 % and the mining sector with 0.5 %.

3.3 Environmental pressures from European production

Analyses based on EE-IOTs are restricted to those environmental pressures which are provided by countries as environmental accounts (see Section 2.4). This study focuses on air emissions and resource use. Environmental accounts on air emissions have been assigned to three main categories: GHG emissions, acidification emissions

Figure 3.2 Direct emissions of greenhouse gases by economic sector in the EU-25, 2006



Note: The total GHGs given here differ from those reported under the UNFCCC for the EU-25 in 2006 at 4 865 million tonnes (excluding land use, land-use change and forestry (LULUCF)). The main contributor to this difference is that direct household emissions are not included in this figure. On the other hand, emissions from international shipping registered in the EU-25 are included, while they are not included in the UNFCCC reporting. Differences in accounting are described in Section 2.5.

Source: ETC/SCP based on Eurostat NAMEA data set.

and emissions of ground ozone precursors. Resource use comprises several EW-MFA indicators: DEU, DMI, TMR and imports.

A small group of economic sectors dominate the three air-emissions-based environmental pressures arising from EU production. Those sectors are:

- agriculture, hunting forestry and fisheries (agriculture);
- electricity, gas and water supply (electricity industry);
- manufacturing;
- transport, storage and communication (transport services) (39).

These four sectors together account for 86 % of total GHG emissions from all EU production (see Figure 3.2) with the electricity industry (34 %) and aggregated manufacturing industries (27 %) being particularly dominant. GHG emissions from the electricity industry, manufacturing and transport services chiefly comprise CO_2 emissions from the combustion of fossil fuels. GHGs from agriculture are dominated by CH_4 emissions from livestock and N_2O emissions from soils and manure management.

Within the broad manufacturing sector some important basic industries can be highlighted: manufacture of refinery products (3.5 % of total EU production-based GHGs), chemicals and chemical products (4.4 %), manufacture of non-metallic mineral products such as cement (6.0 %), and manufacture of basic metals including iron and steel production (5.9 %).

The same four key economic sectors account for some 94 % of total acidifying emissions from all

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(39) The production perspective applied in this chapter only takes into account transport business' emissions arising from road freight, public road transport, railways and air traffic, etc. GHG emissions directly arising from households' use of private cars are not considered here but discussed under the consumption perspective.

EU-25 production (see Figure 3.3). Agriculture's contribution is mainly due to ammonia emissions (NH_3). The electricity industry's contribution mainly comprises SO_x-emissions from fossil fuel combustion. Emissions of SO_x and NO_x from fossil fuel combustion in vehicle engines, particularly road freight transport, are the major source of acidifying emissions from transport services.

The broad manufacturing sector contributes some 15 %. Within this broader sector the same four manufacturing industries dominate the emissions of acidifying gases: manufacture of refinery products (3.6 %), chemicals and chemical products (2.0 %), manufacture of non-metallic mineral products (3.2 %), and manufacture of basic metals (2.6 %).

The four broad economic sectors also dominate emissions of ground ozone precursors, together accounting for 85 % of emissions from all EU production (see Figure 3.4). Manufacturing, agriculture and transport services contribute around a quarter each. For agriculture, ground ozone precursors are dominated by NMVOC and CH_4 emissions; for transport services it is NMVOC and NO_x emissions; and for manufacturing it is NMVOCs. The construction industry and wholesale and retail services are also fairly important contributors.

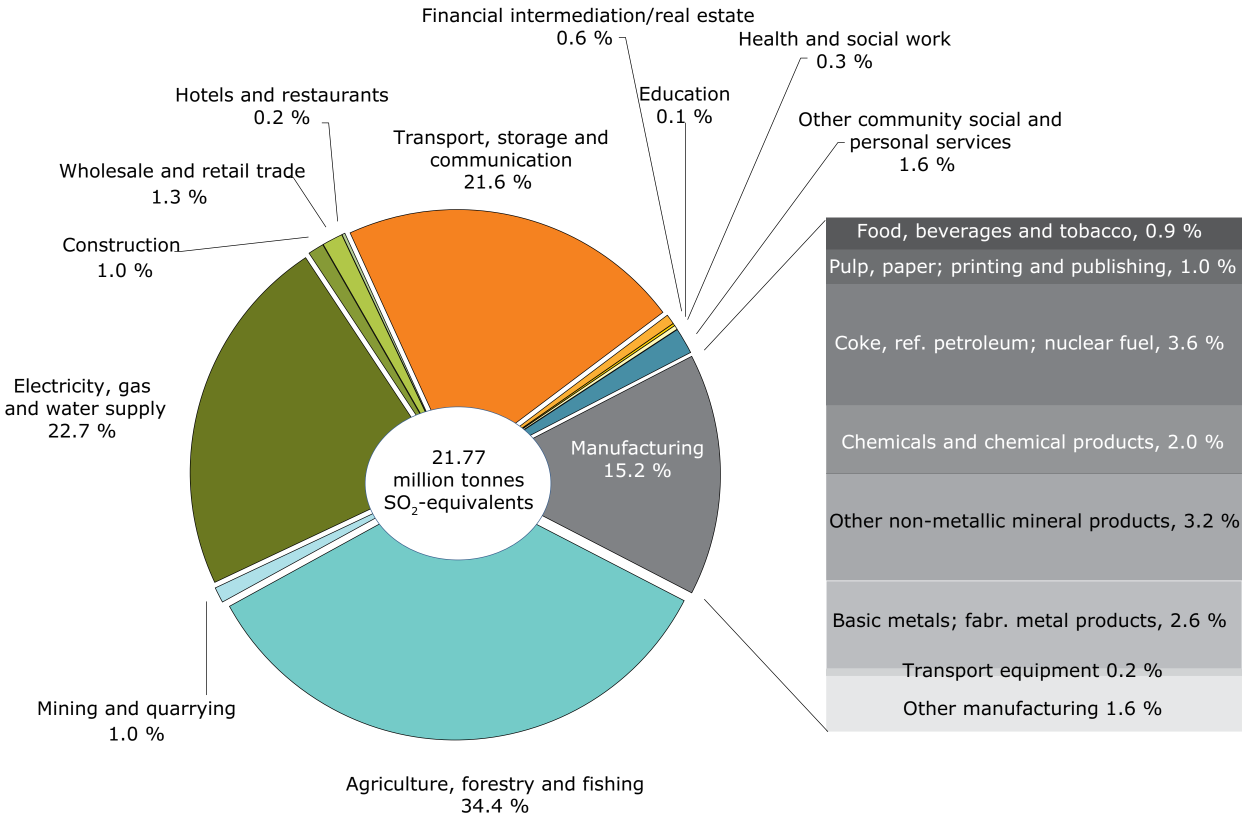
The same four basic manufacturing industries contribute significantly to emissions from the broad manufacturing sector but some other manufacturing industries are also important: the manufacture of motor vehicles, food products and paper products.

Finally, Figure 3.5 shows the domestic extraction of virgin materials by domestic economic sector in the EU-25 in 2007. Only the agriculture and the mining sectors extract material resources directly. Other sectors use material resources only indirectly, either through imports of raw materials or through intermediate deliveries from agriculture or mining.

A handful of industries dominate pressures from European production...

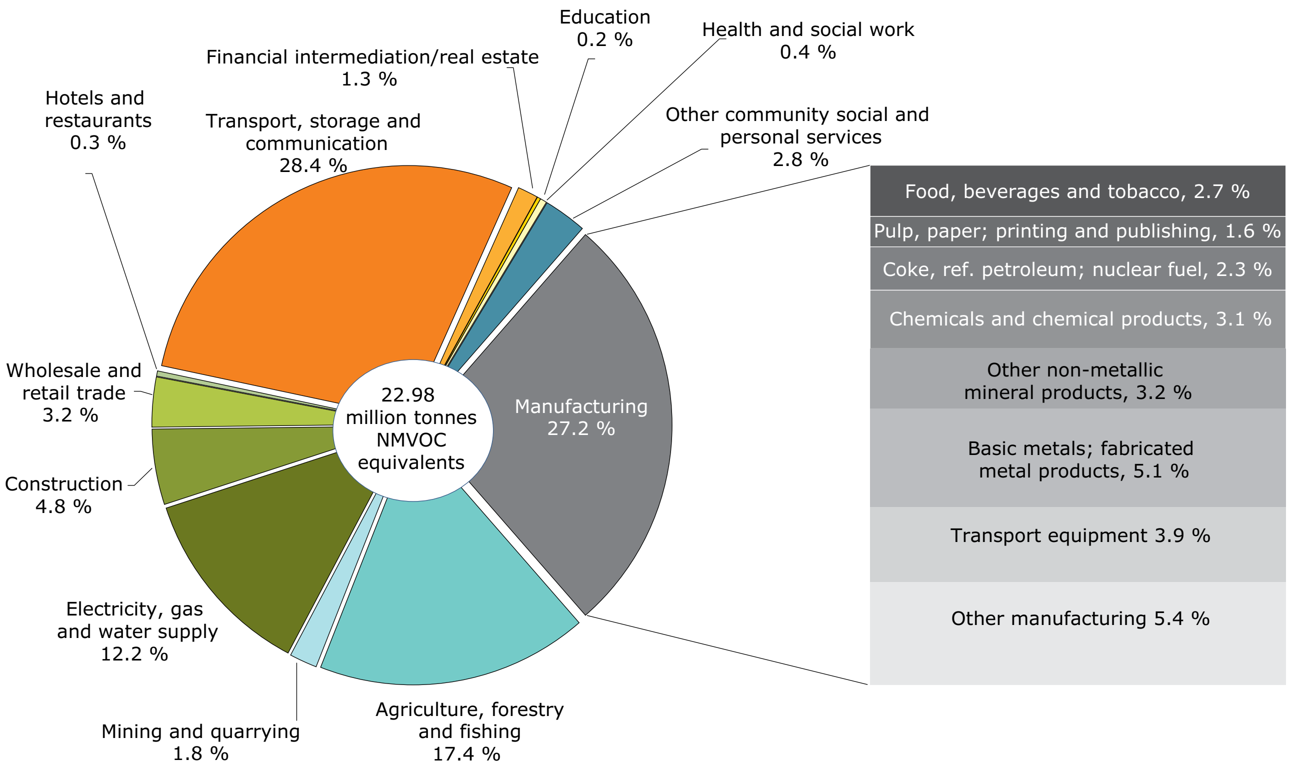
In conclusion, a limited number of economic sectors dominate environmental pressures within the categories

Figure 3.3 Direct emissions of acidifying gases by domestic economic sectors for the EU-25, 2006



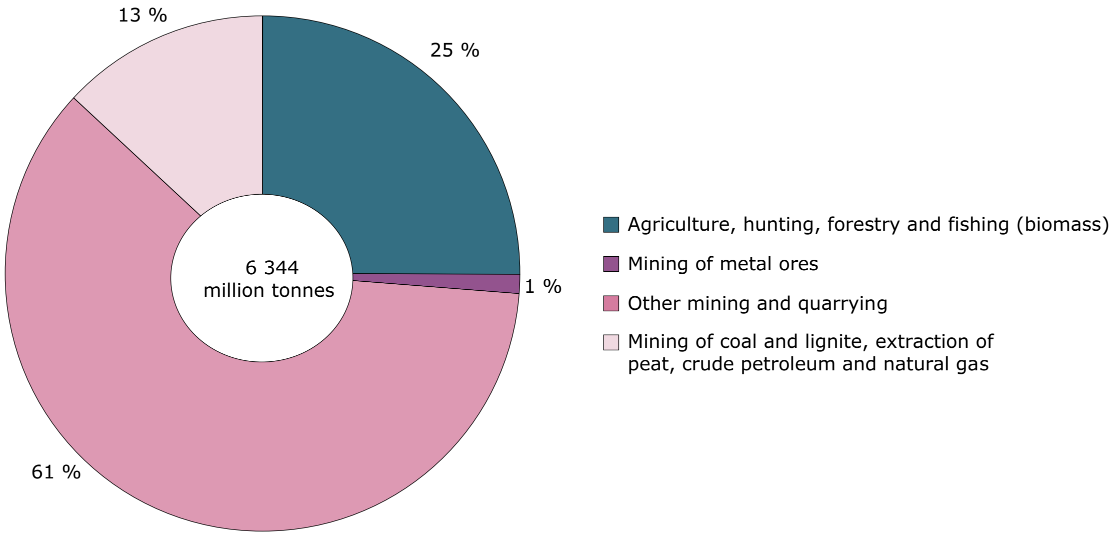
Source: ETC/SCP based on Eurostat NAMEA data set.

Figure 3.4 Direct emissions of ground-level ozone precursor gases by economic sector for the EU-25, 2006



Source: ETC/SCP based on Eurostat NAMEA data set.

Figure 3.5 Domestic extraction used in EU-25, 2007: direct use by economic sector



Source: ETC/SCP based on Eurostat MFA data set.

that are included in NAMEA accounts. Agriculture is a main contributor in all four categories of environmental pressures analysed in this report. The electricity industry and transport services and manufacturing are main contributors to the three air emissions-based categories. Within manufacturing, some basic industries dominate air emissions: the manufacture of refinery and chemical products, the manufacture of non-metallic mineral products such as cement, and the manufacture of basic metals including iron and steel. Finally, agriculture and the mining and extractive industries dominate direct raw resource use.

These environmental hotspots in EU production have been identified before through traditional sources of environmental information. As a consequence, those industries have been addressed by a number of policy measures often focused on 'end-of-pipe technologies' and the promotion of cleaner production (e.g. Integrated Pollution Prevention Control, IPPC). This has led to reductions in production-related environmental pressures and environmental pressure intensities, as shown in Section 3.5.

3.4 Do sectors which dominate environmental pressures also contribute most to economic output and employment?

…due in part to their high environmental intensities

Figure 3.6 shows the share of air emissions-based environmental pressures for each economic sector as earlier shown in Figures 3.2 to 3.4 alongside the contribution of that sector to total employment and economic output of the EU-25. The sectors are given in order of share in gross economic output.

As identified before, agriculture, the electricity industry and transport services clearly dominate environmental pressures. However, the same environmental hotspot economic sectors contribute relatively little to economic output and employment.

This is most visible with respect to agriculture and electricity which together contribute 48 %, 57 % and 30 % to GHGs, acidification emissions and tropospheric ozone forming emissions, respectively, but only 7 % to employment and 4 % to gross output.

Such comparisons effectively identify the pressure intensity (pressure per unit of economic output) of economic sectors. Agriculture, electricity and, to a slightly lesser extent, transport services have high pressure intensities.

At the other end of the scale are sectors such as public administration and services and the wholesale and retail trade which contribute significantly to employment and economic output but relatively little to air emissions-based environmental pressures, i.e. these sectors have low pressure intensities. In other words, as such services increase their share in the EU economy, environmental pressures will tend to decrease.

The aggregated manufacturing sectors meanwhile contribute similarly to environmental pressures (between 15 % and 27 % for the 3 categories) as they do to employment (17 %) and gross economic output (30 %).

However, within manufacturing the manufacture of non-metallic mineral products (cement, class, ceramics, etc.) and coke and refined petroleum products contribute significantly more to pressures than they do to employment or economic output.

3.5 Decoupling pressures from growth in output

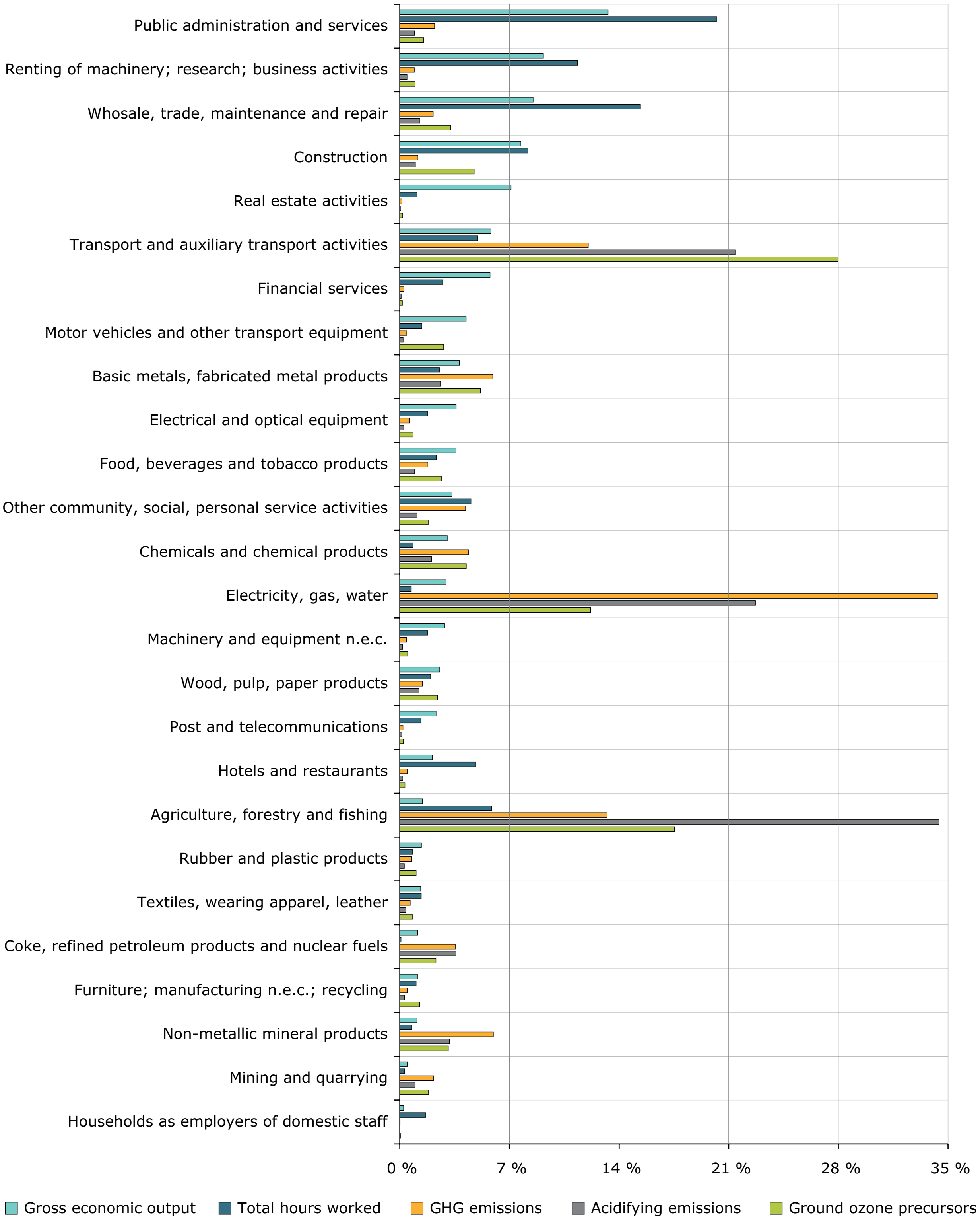
Decoupling refers to a break in the link between environmental pressures and economic growth

Decoupling of resource use and accompanying environmental pressures from economic growth is a central element of the European Commission's Flagship Initiative on a Resource Efficient Europe (EC, 2011b).

Decoupling can be relative or absolute. Absolute decoupling describes a situation where environmental pressures are stable or reducing, despite economic growth. Relative decoupling describes the case where environmental pressures are still growing but less rapidly than the economy (see Figure 3.7).

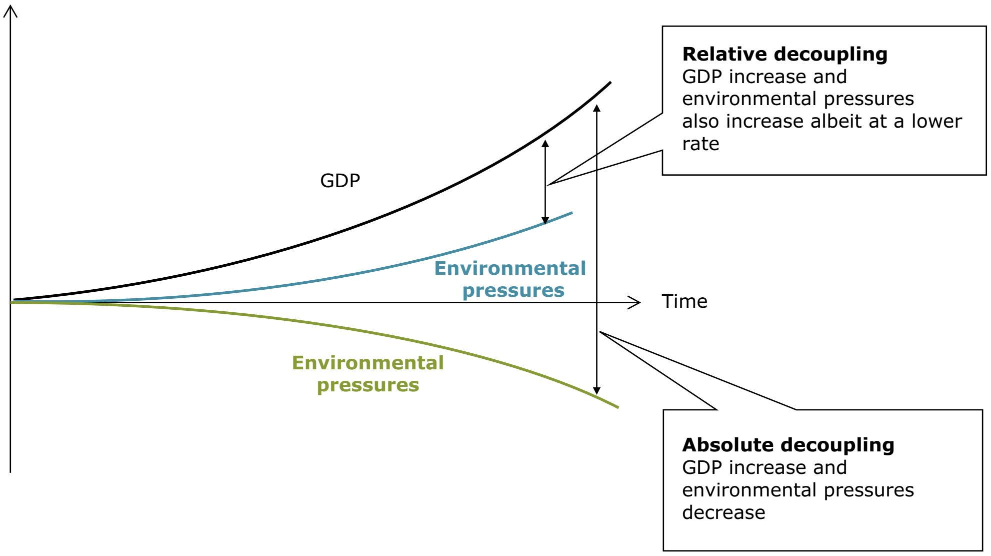
According to the ETC/SCP (2009), the rationale of SCP requires absolute rather than relative decoupling of key environmental pressures in the EU. With respect to GHGs, the European Union has the long-term objective of reducing EU GHG emissions by 80–95 % under 1990 levels by 2050 as the EU's contribution to keeping global temperature increases to under the 2 °C tipping point (EC, 2011c). The Commission's communication on resource efficiency also makes it clear that 'continuing our current patterns of resource use is not an option'

Figure 3.6 Contribution of economic sectors to total economic output, employment and environmental pressures, EU-25, 2006



Source: ETC/SCP based on several Eurostat data sets.

Figure 3.7 Relative and absolute decoupling



Source: EEA, 2012.

(EC, 2011b), implying the need for an overall reduction in resource demand.

Levels of decoupling can be analysed both for whole economies and individual economic sectors.

Decoupling in the whole economy

Between 1995 and 2006 the EU-25 realised a 40 % real growth in economic output. During this period, production-related emissions of acidifying gases and ground-level ozone precursors have decreased by 27 % and 14 %, respectively (see Figure 3.8), i.e. they have seen absolutely decoupling from economic output growth. Emissions of GHGs as recorded using the NAMEA categorisation system remained nearly constant over the same period growing by 1 %, 1995–2006.

> Using EE-IOA we can isolate two different causes of decoupling from economic growth — *eco-efficiency improvements* and *changes in the structure* of the economy

Direct resource use by the EU-25 economy has not seen strong decoupling from economic growth (Figure 3.9). DEU remained relatively stable, increasing by only 1 %, 2000-2007. However, the weight of imported resources grew as rapidly as the economy over the same period, both increasing by 20 %, 2000–2007. This rapid rise in imported resources led to an increase of 7 % in DMI, i.e. saw only relative decoupling from economic growth.

Specific IOA methods also allow decoupling trends to be broken down into various contributing factors. This method is called decomposition analysis (see de Haan, 2001; Dietzenbacher & Los, 1998; Jensen & Olsen, 2003). This can be a powerful tool in identifying the causes of decoupling, since some causes might have unwished for consequences. It can also give insights into which potential means for decoupling should be promoted in the future.

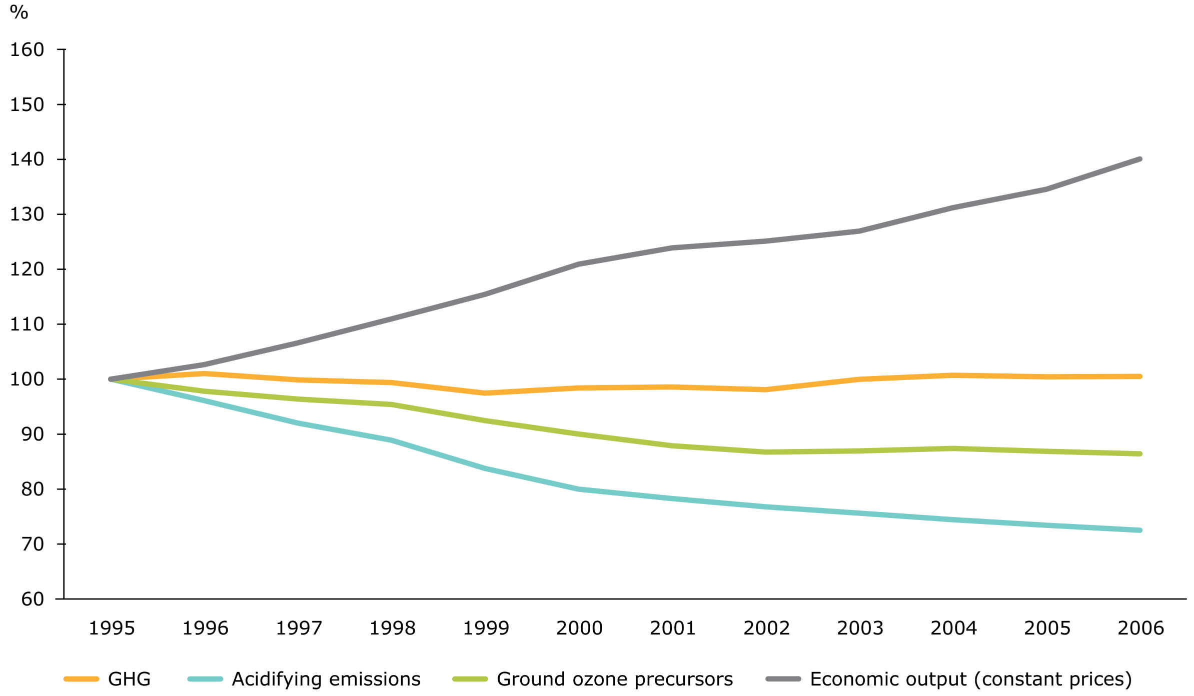
In general we can identify two broad factors behind decoupling of production-related pressures across the whole economy. These are:

- intensity effect — reductions in environmental pressure intensity within individual economic sectors;
- industry mix effect — changes in the national production mix.

The intensity effect is beneficial to decoupling when individual economic branches become less pressure intensive over time through, for example, improvements in production processes, energy savings, substitution of fuels and other inputs, and end-of-pipe technology to reduce the output of harmful substances.

The industry mix effect is related to the composition of the economy i.e. changes in the contribution of individual branches to the total economic output. If a branch with lower pressure intensity than average increases its share in the economy, this will have a positive decoupling effect. Conversely, if a pressure

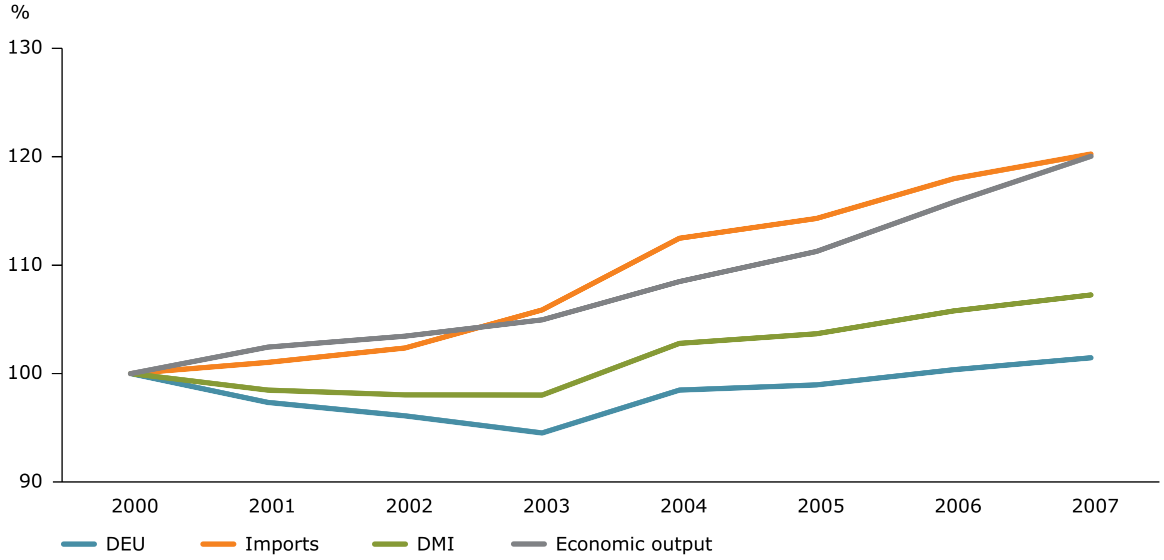
Figure 3.8 **Developments in economic output and direct air emissions, EU-25 — whole economy, 1995–2006**



Note: Economic output index measured on basis of 1995 fixed prices.

Source: ETC/SCP based on Eurostat NAMEA data set.

Figure 3.9 **Developments in economic output and resource use, EU-25 — whole economy, 2000–2007**



Note: Economic output index measured on the basis of 1995 fixed prices.

Source: ETC/SCP based on Eurostat MFA data set.

intensive branch expands its share in the economy, this will act against decoupling.

It is of key importance to note that if reductions in the share of heavy industries in the EU economy are a result of an 'outsourcing' of industrial production to countries outside the EU, rather than reflecting changes in consumption patterns, then the resulting decoupling effect is only regional. From a global viewpoint this development could even lead to increases in total (global) pressures. Eco-efficiency improvements within industries, on the other hand, will have a decoupling effect at all scales — national, regional and global.

At the time of going to print resource data allowing decomposition analyses of resource use at the EU level was not available. Therefore, decomposition analysis has only been carried out for emissions to air.

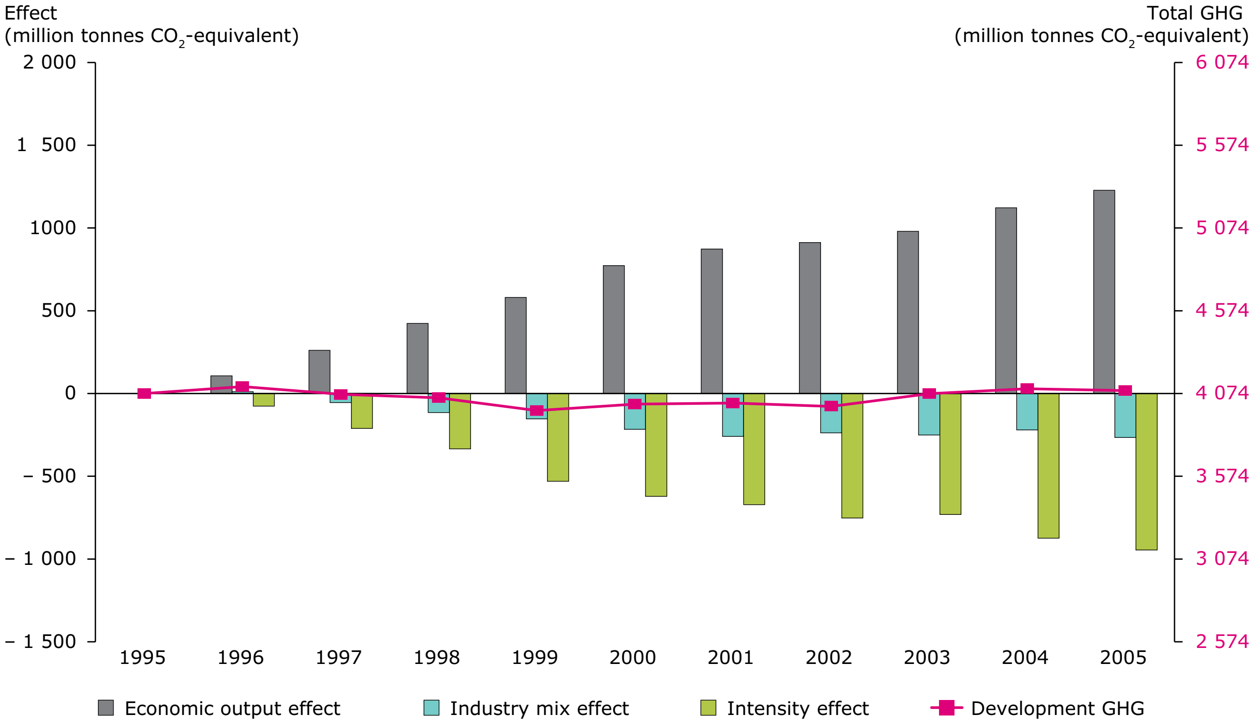
> Decoupling of air emissions from growth in the EU have been achieved mainly through improvements in eco-efficiency of production

Figures 3.10–3.12 show how the two factors have contributed to decoupling in GHG emissions, acidifying emissions and ground ozone precursors between 1995 and 2006. In each case the continuous blue line shows actual developments in emissions. The three sets of bars, meanwhile, show how economic growth, changes in emissions intensity of individual industries and changes in the mix of industries would individually have affected emissions trends. The blue curve is the sum of these effects.

Decoupling in all three cases appears mainly to have resulted from reductions in emissions intensities within individual branches. Changes in the structure of the economy have also had a reduction effect on emissions but this has been a comparatively small effect compared to the reduction in intensities.

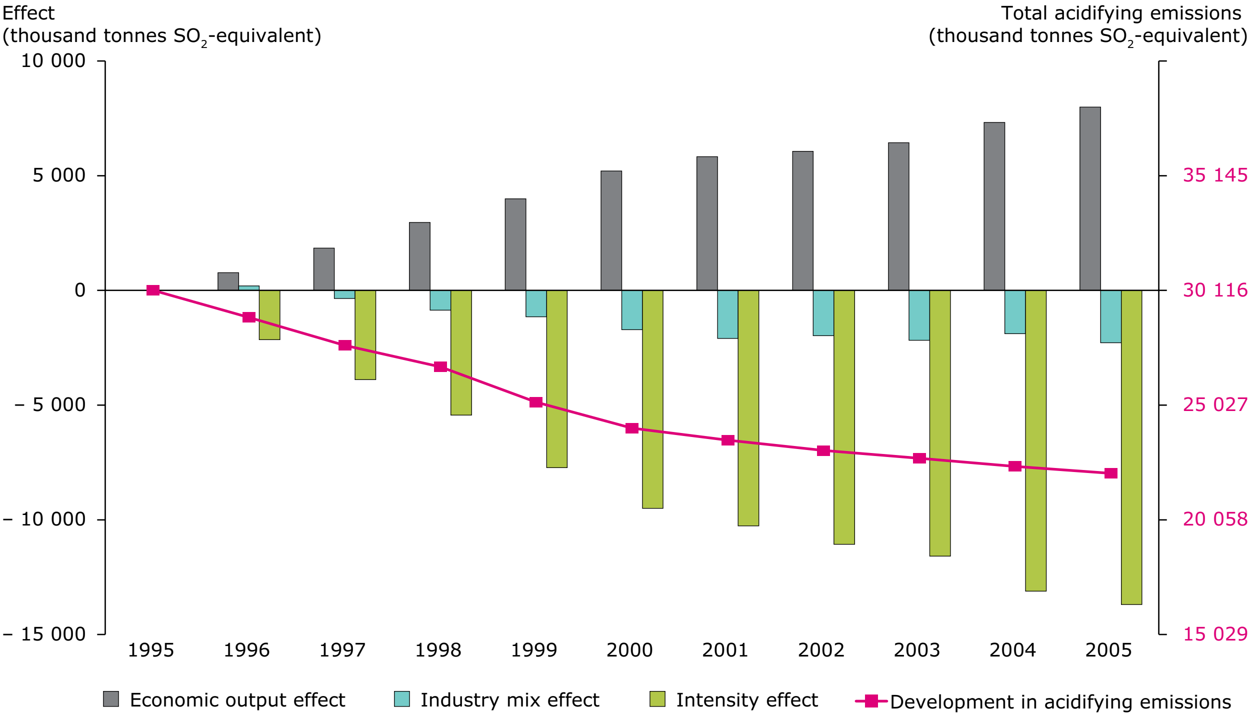
This result may be influenced somewhat by the level of aggregation of the economy (into 60 sectors) given in the NAMEA tables. Studies comparing the effects of aggregation levels on the results of such decomposition analyses show that increased levels of aggregation can overemphasise the importance of the eco-efficiency factor (Hass, 2008), though the effect is mostly observed at greater levels of aggregation than used in our analysis (60 sectors).

Figure 3.10 Contribution of eco-efficiency and structural changes in the economy to decoupling in GHG emissions from production, EU-25, 1995–2005



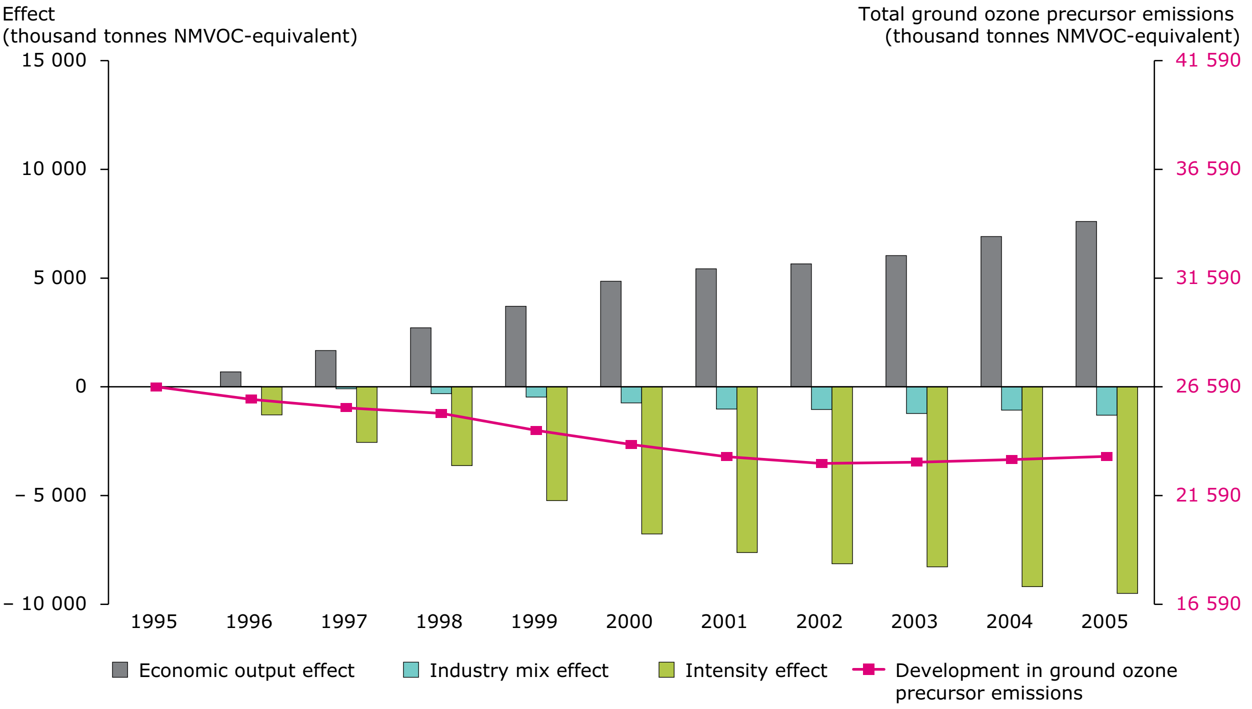
Source: ETC/SCP based on Eurostat NAMEA data set.

Figure 3.11 Contribution of eco-efficiency and structural changes in the economy to decoupling in acidifying emissions from production, EU-25, 1995–2005



Source: ETC/SCP based on Eurostat NAMEA data set.

Figure 3.12 Contribution of eco-efficiency and structural changes in the economy to decoupling in ground ozone emissions from production, EU-25, 1995–2005



Source: ETC/SCP based on Eurostat NAMEA data set.

Decoupling in individual sectors

As shown above, decoupling of environmental pressures for the EU-25 as a whole has resulted mostly from pressure intensity reductions in individual economic sectors. However, some sectors may have been more successful than others in reducing emissions intensities. Of particular interest are developments in the hotspot sectors identified earlier.

Agriculture

The economic output of agriculture, measured in constant Euros, grew by only 5 % between 1995 and 2006. The three emission-related environmental pressures arising directly have been decoupled absolutely from growth in the sector decreasing by between 7 % and 10 % over the same period (Figure 3.13). Decoupling in acidifying emissions and ground-level ozone precursors have not been as rapid as in the economy as a whole (see Figure 3.8), while decoupling in GHG emissions has been more rapid.

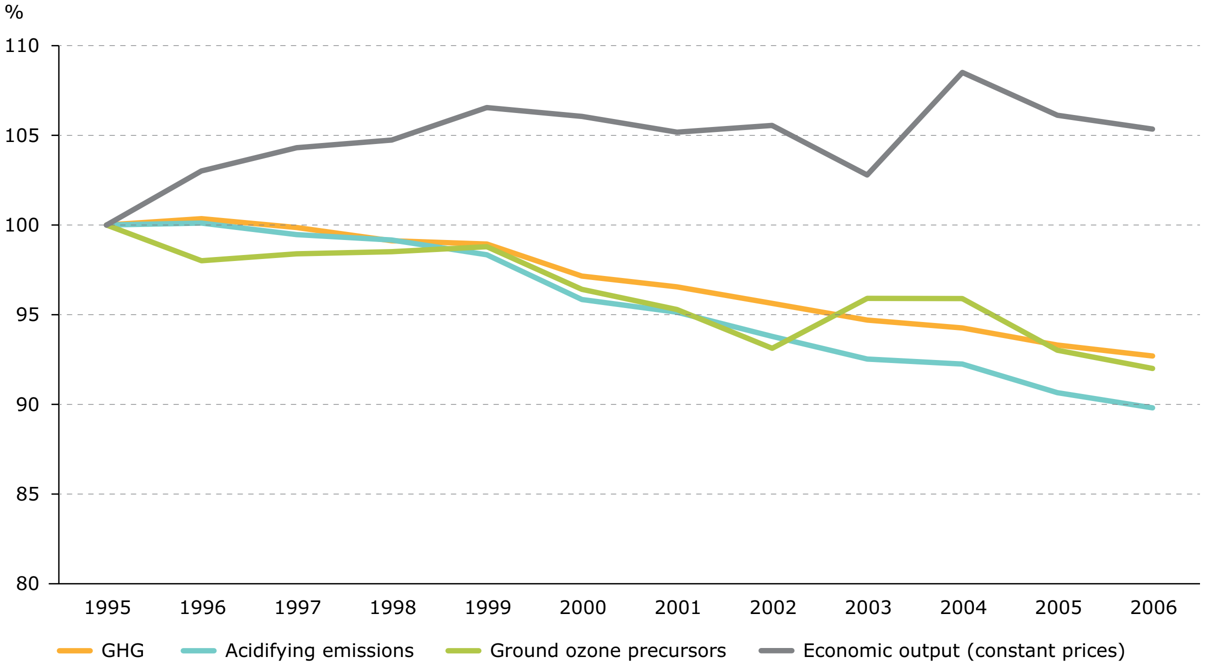
Unlike other sectors, the agricultural contribution to acidification is mainly through ammonia emissions rather than SO_x and NO_x emissions. In the EU, 94 % of ammonia emissions come from fertiliser use and animal husbandry in agriculture (EEA, 2010c). Ammonia emissions are linked to the size of animal livestock, and are diffuse and difficult to address. The same applies for methane emissions through which agriculture mainly contributes to ground-level ozone precursor generation and to GHG emissions. The Nitrates Directive (EC, 1991) encouraging changes in management practices has had a significant effect in reducing GHG emissions as has the milk quota system of the Common Agricultural Policy (CAP) by reducing animal numbers in the dairy sector (EEA, 2010d). The fall in livestock numbers has also led to reductions in ammonia emissions and therefore agriculture's contribution to acidification emissions as have improvements in the management of manure (EEA, 2010c).

Manufacturing

Manufacturing has been most successful in decoupling pressures from growth….

For the broad manufacturing sector (Figure 3.14) a stronger success story can be told in terms of absolute decoupling. The growth in output of almost 37 % between 1995 and 2006 —close to that for the whole economy — was accompanied by a decrease

Figure 3.13 Agriculture, hunting, forestry and fishing: decoupling of direct environmental pressures from growth in output, EU-25, 1995–2006



Note: Economic output index measured on the basis of 1995 fixed prices.

Source: ETC/SCP based on Eurostat NAMEA data set.

in GHG emissions of 8 %, a decrease in emissions of ground-level ozone precursors of 18 % and a decrease of acidifying emissions of 38 % (although emissions remained relatively stable after 2003). Those decoupling trends are more pronounced than for the economy as a whole. Since manufacturing represents 29 % of the EU economy, decoupling within this sector has contributed significantly to decoupling in the EU economy as a whole.

Within the broad manufacturing sector, there are a number of single industries of high environmental relevance. Figure 3.15 shows decoupling graphs for the four most important manufacturing industries.

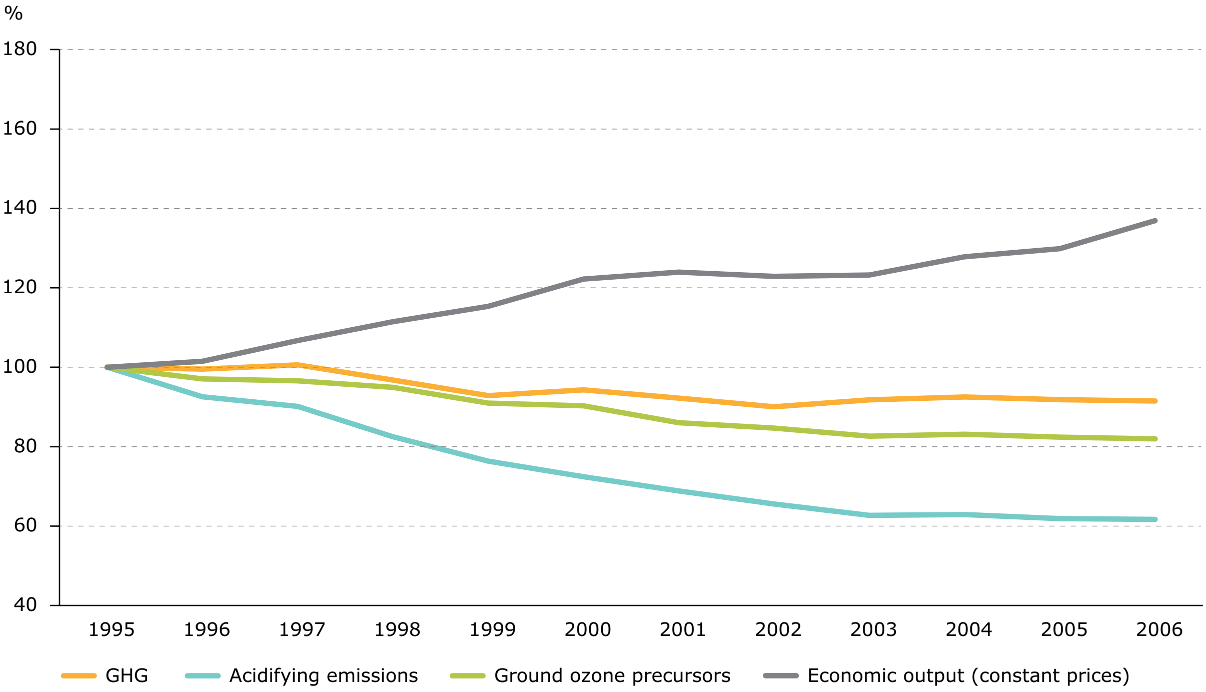
The manufacture of chemicals and chemical products has shown the strongest absolute decoupling in all three pressures. Comparatively little improvement in eco-efficiency was achieved in the manufacture of non-metallic mineral products, including cement, particularly for GHG emissions which rose by 10 %, 1995–2006. The manufacture of basic metals and fabricated metal products fared somewhat better.

The two previous sectors are typical providers of basic materials. Technological means to improve the material and energy efficiency in respective production processes are physically limited. Once a high standard of material and energy efficiency is reached, environmental pressures will be closely linked with production volume growth. In the case of basic metals it can already be seen that reductions in emissions slowed down considerably after 2003, when emissions even began to rise again. Cement production in Europe still has some potential for improvements in energy efficiency. Japan's cement kilns for example were 30 % more efficient than the average European kiln during the reporting period (Worrell et al., 2004). However, once this efficiency gap has been closed little potential is seen for additional efficiency improvements in the cement process. The only option for further reductions of GHGs from cement production will be from carbon capture and storage (CCS) (IEA, 2010).

Electricity, gas and water supply

The electricity sector's economic output grew 34 % over the period 1995–2006, somewhat slower than the growth in the whole economy (see Figure 3.16). Acidifying gases more than halved over this period mainly due to abatement solutions in power

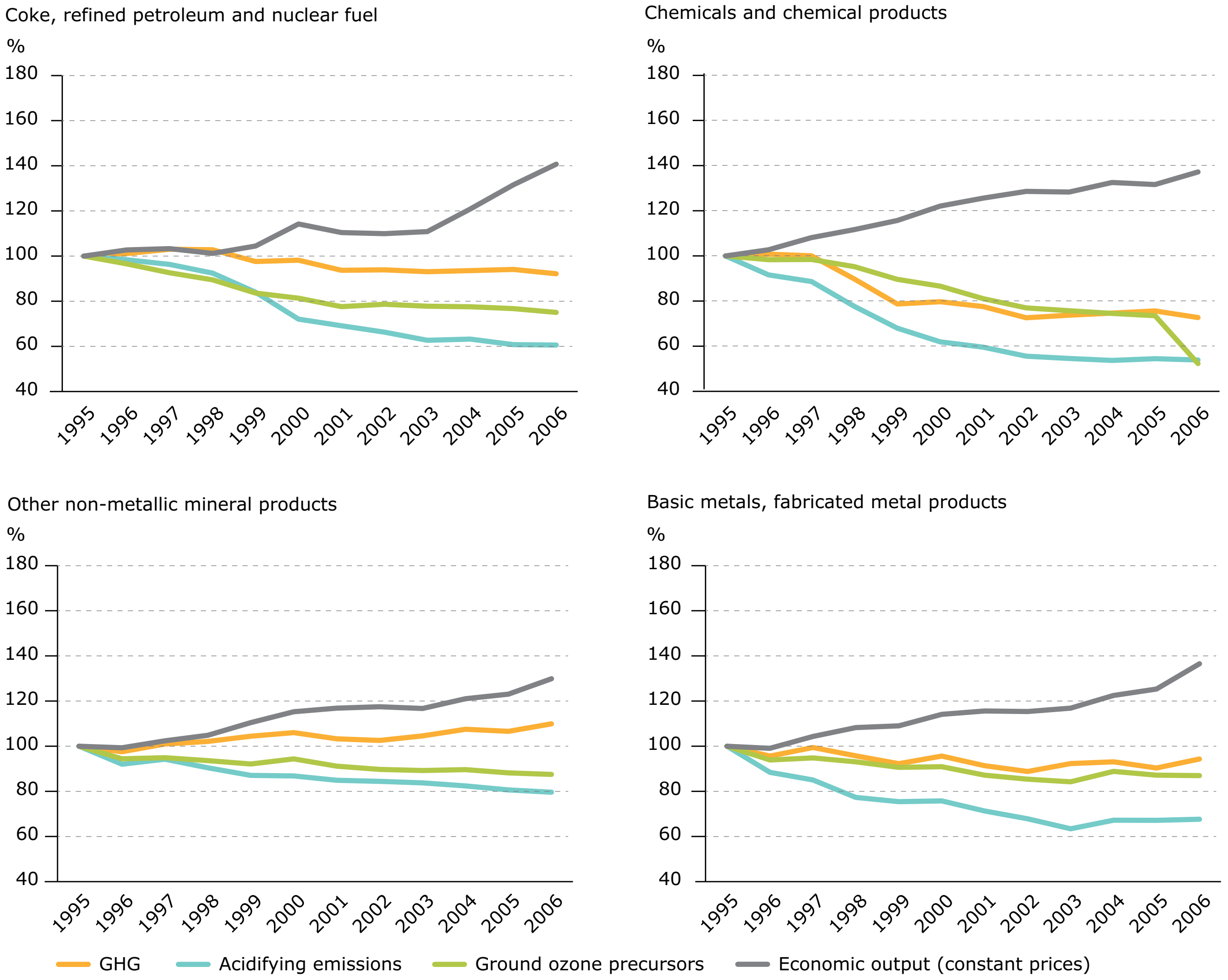
Figure 3.14 Manufacturing (broad): decoupling of direct environmental pressures from economic output growth, EU-25, 1995–2006



Note: Economic output index measured on the basis of 1995 fixed prices.

Source: ETC/SCP based on Eurostat NAMEA data set.

Figure 3.15 Selected manufacturing industries: decoupling of environmental pressures from economic output growth, EU-25, 1995–2006



Note: Economic output index measured on the basis of 1995 fixed prices.

Source: ETC/SCP based on Eurostat NAMEA data set.

stations and substitution of high sulphur with low sulphur fossil fuels (i.e. coal to gas) and to a lesser extent by efficiency improvements but very little from a switch to renewable energy sources (EEA, 2010c, pp. 26 ff.).

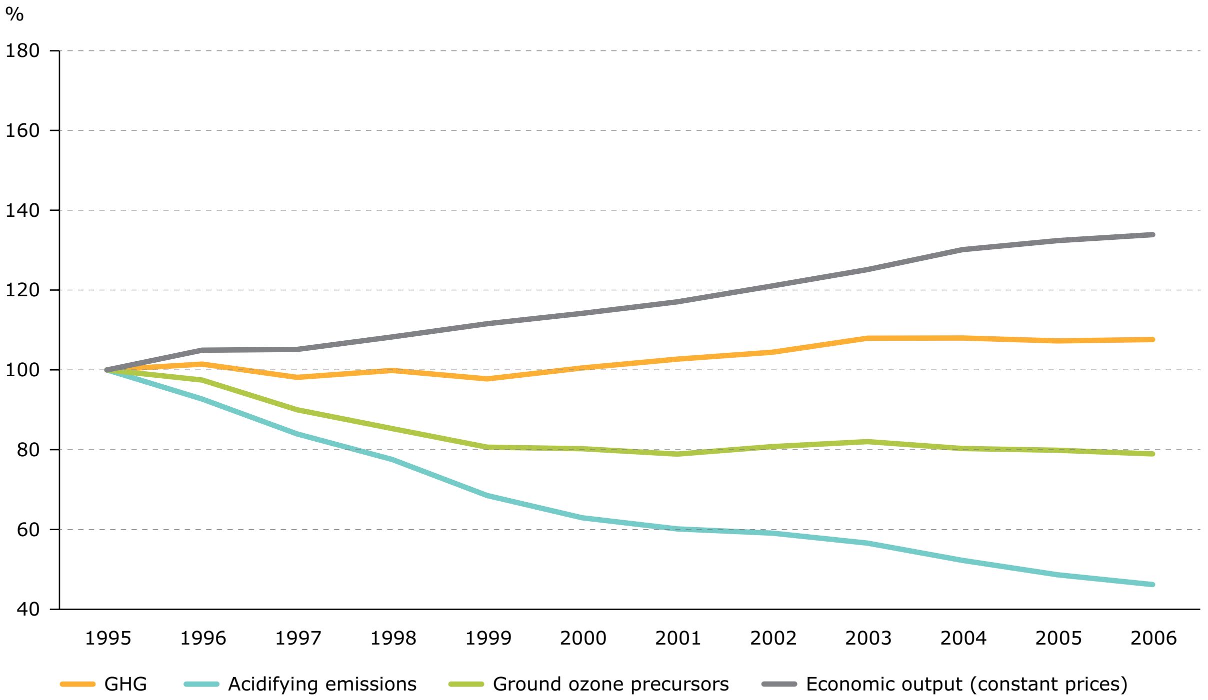
GHG emissions saw only relatively decoupling from growth in output having grown by 8 %, 1995–2006. Since the electricity sector contributes almost one third of total production-related GHG emissions, it will be critical to further improve the eco-efficiency of this branch. A switch to less carbon-intensive fuels and renewable energy carries will be key measures to reduce the GHG intensity of electricity production in the future.

Transport services

> ....transport services have been least successful in decoupling of pressures from growth

Transport services have shown the poorest performance of the priority economic sectors in terms of improvements in eco-efficiencies (Figure 3.17). The sector grew more rapidly than the economy as a whole at 47 %, 1995–2006. Emissions of GHGs have hardly seen any decoupling, increasing by 42 % over the same period. Only emissions of ground-level ozone precursors have shown any significant decoupling and even these are still growing (8 %, 1995–2006). The trends in GHGs are particularly worrying since the sector is expanding its share of the EU economy.

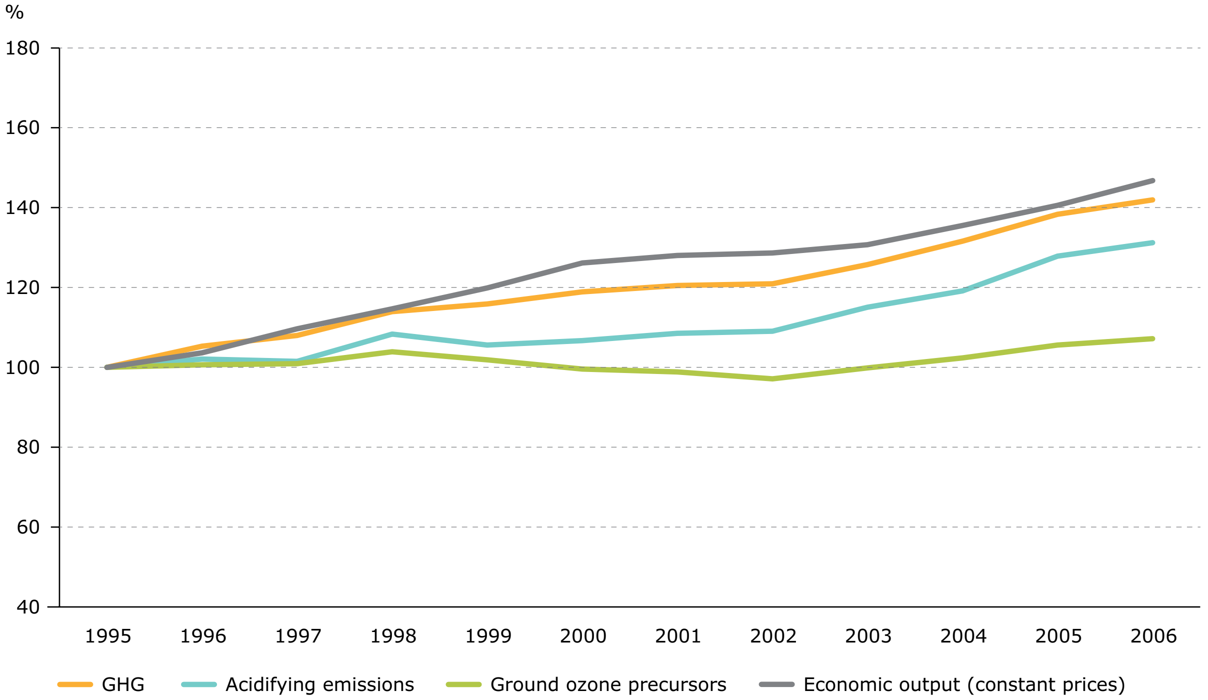
Figure 3.16 Electricity, gas and water supply: decoupling of environmental pressures from economic output growth, EU-25, 1995–2006



Note: Economic output index measured on the basis of 1995 fixed prices.

Source: ETC/SCP based on Eurostat NAMEA data set.

Figure 3.17 Transport services: decoupling of direct environmental pressures from economic output growth, EU-25, 1995–2006



Note: Economic output index measured on the basis of 1995 fixed prices.

Source: ETC/SCP based on Eurostat NAMEA data set.

3.6 Summary of environmental pressures from European production

A handful of hotspot economic sectors, or industries, dominate the environmental pressures arising directly from European production. Agriculture, the electricity industry, transport services and some basic manufacturing industries (refinery and chemical products, non-metallic mineral products, basic metals) account for ~ 70 % to 90 % of emission of GHGs, acidifying gases, and ground-level ozone precursors from all European production,

Of the four hotspot sectors, only manufacturing contributes to a similar degree to the EU-25 economy. The electricity and agriculture sectors provide only 4 % of gross value added and 7 % of overall employment in the EU-25 economy but together emit 48 % and 57 % of GHG emissions and acidifying emissions, respectively. Service industries, with the exception of transport, meanwhile, show low environmental intensities. Currently, 56 % of the EU's economic output is generated by service industries. A growing service sector will reduce the pressure intensity of the economy as a whole.

The EU has seen success in decoupling air emissions from growth in production. Production-related emissions of acidifying gases and trospospheric ozone precursors decreased by 14 % and 27 %, respectively, between 1995 and 2006 despite an economic growth of 40 %. Production-related GHG emissions remained fairly stable during the same period.

For all three types of environmental pressure, decoupling appears mostly to have been achieved through reductions in pressure intensities within individual economic sectors. Structural changes in the economy, i.e. a growth in the share of services and a shift in heavy industry abroad, appear to have been a comparatively insignificant factor behind decoupling. However, this result may be influenced somewhat by the level of aggregation of the economy (into 60 sectors) given in the NAMEA tables. A greater level of disaggregation of the economy (into more sectors) might reveal an increased importance of structural changes in observed decoupling.

Of the hotspot economic sectors both the manufacturing sector and the agricultural sector managed to reach an absolute decoupling in all three pressure categories. However, the agricultural sector's achievement should be considered in the light of its moderate economic growth of only 5 %, 1995–2006. The transport services industry fared worst of all with GHG emissions increasing by 42 % between 1995 and 2006, only slightly slower than growth in output of that sector. This is particularly worrying since the sector is expanding its share of the EU economy.

> Achieving an 80–95 % reduction in GHGs in the EU will need both eco-efficiency improvements and changes in the structure of the economy……

The success in many sectors has been achieved through policy measures focusing on 'end-of-pipe technologies' and promoting cleaner production (e.g. Integrated Pollution Prevention Control, IPPC). In the case of local and regional environmental problems (i.e. acidification, ground-level ozone) this has lead to considerable reductions in production-related environmental pressures and improvements in the eco-efficiency performance.

The challenges for reductions in material resource use and GHGs in the future to meet SCP and climate change goals are considerable, for example an 80–95 % reduction in GHGs by 2050. Looking at past trends it seems unlikely that these challenges can be met solely through improvements in the eco-efficiency of key industries. Structural changes in the economy will also be necessary, i.e. a shift from a focus on high-pressure-intensive industries to low-pressure–intensive industries and services.

> ….but structural changes will only give global benefits where they reflect equivalent changes in consumption patterns

However, it is important to note that such structural changes will only bring global environmental benefits if they reflect equivalent changes in the products being consumed by Europeans. Otherwise pressure intensive industries producing goods for Europeans will simply have been shifted to other global regions with potentially negative net effects (e.g. carbon leakage).

The next chapter will look at the other side of the coin — European consumption — which remains the key driver of European production.

4 Environmental hotspots in European consumption

4.1 Introduction to the consumption perspective

National consumption comprises end products used by government, private households and investment goods

As described earlier we consider two perspectives for viewing the economic production and consumption system. The first focuses on the national economic sectors producing goods and services both for domestic consumption and export to other countries. This is the production perspective as presented in the previous chapter.

In this chapter we take a consumption perspective focusing on the production chains of all final products consumed nationally by the state and by households (including investments in machinery and infrastructure). This includes products produced in the home country for home consumption and products imported for consumption, but excludes production chains ending in goods for export. The perspective looks at the environmental pressures caused by consumption of goods. It allows the identification of the product types which cause the most environmental pressures and thereby opens the door to consumption-based actions to reduce environmental pressures from production. The Flagship Initiative on a Resource Efficient Europe recognises that changing of consumption patterns must be one of the central measures employed for reducing the European demand for resources (EC, 2011b).

Environmental pressures activated by consumption include both direct and indirect pressures. Firstly, we have the pressures that are emitted directly by consumption activities. These are dominated by air emissions from the combustion of petrol and diesel in private cars and the burning of coal, gas and oil in households for heating, cooking and hot water. Secondly, we have all the indirect pressures caused by consumption, which are emitted during the production of the goods and services we consume.

The second type of environmental pressures — the indirect pressures — are the most difficult to calculate because they take place at many different points within the global economy. When a consumer buys a new car a lot of environmental pressures have already taken place in the production phase, not only at the car manufacturing plant, but also at all the factories that supply the car factory with steel, aluminium, glass, energy, plastics, rubber, paints, carpets, etc. All the delivering firms also require inputs from other firms giving a long chain of deliveries that takes place through the global economy. The pressures arising along this chain of production make up the indirect pressures activated by the consumption of the final good — in other words the pressures embodied in that good.

The EE-IOA method offers the possibility for estimating total global pressures caused by national consumption

Using EE-IOA methods we can estimate the sum of all the indirect pressures embodied in all the products and services consumed by a nation. This is done by re-allocating direct environmental pressures released by industries, factories and other businesses to the final products to which they contribute as described in Chapter 2 (and in more detail in Section A.4 in Appendix A) . The pressures embodied in any final products which are sold abroad are removed from the equation, and estimates of pressures embodied in imported products are added in.

As noted in Section 2.6, the allocation methods used for air emissions and for material use are somewhat different and are described in detail in Sections A.4.5 and A.4.6 of Appendix A.

Economic and environmental data used for this analysis are given in Table 2.5 in Section 2.8. As described in Section 2.6, the consumption perspective requires complex national IOTs. Due to general limited availability of these tables the analysis is restricted to nine EU Member States for the year 2005 and for all but one of these countries for the years 1995 and 2000 for air emissions-based environmental pressures. For material flows, data availability is the same except for 1995 where only five countries have available data. The 9 countries available for 2005 analysis represent 52 % of the EU-27's population and more than 62 % of its GDP. Reference to this group of countries in graphs is indicated by the term 'EU9' ([40]).

4.2 Brief overview of European consumption

Before considering environmental pressures it is worth taking a brief overview of European consumption and how it is broken down by end consumer and type of product consumed.

Private household consumption represents about 55 % of total national consumption

Most final products end up in households. Within the EU, private household consumption represents ~ 55 % of domestic final use. Government consumption represents ~ 25 % and capital formation 20 %.

Services account for about 2/3 and material goods for some 1/3 of national consumption

Products can be broadly distinguished between material goods and services. In the EU, 60–70 % of total household consumption is made up of services while material goods account for the remaining 30–40 %. Capital formation is dominated by consumption of material goods (~ 80 %) in the form of machinery and buildings, while government consumption is dominated by services (more than 90 %).

We will now look at environmental pressures activated by consumption in the nine EU Member States studied. We look first at the indirect pressures embodied in the goods and services nationally consumed. The pressures directly emitted by households are then added in, and these and the indirect pressures are allocated to various broad function areas. We will see if any functional areas of consumption emerge which cause the greatest environmental pressures.

4.3 Indirect pressures embodied in consumed products

Figures 4.1 and 4.2 break down environmental pressures embodied in total products consumed in the nine EU Member States into 28 broad product groups. They show the share of each product group in consumption expenditure (domestic final use by private households, government and by gross fixed capital formation) and the product group's contribution to global environmental pressures caused by purchase of all goods and services. As an example it can be seen that real estate services represents just over 11 % of all consumption expenditure and contributes approximately 2–2.5 % to global environmental pressures caused by purchase of products in these 9 EU Member States.

The product groups are placed in order of expenditure with the product groups at the top having the largest share. Some product groups contribute much more to environmental pressures than they do to total expenditure: food and beverages; electricity, water and gas; products of agriculture: and coke and refined petroleum products. These products have high pressure intensities.

Conversely, products such as real estate services, education and financial services have low pressure intensities contributing much more to total expenditure than they do to environmental pressures. Shifting consumer spending from eco-intensive product groups to eco-efficient products can reduce environmental pressures related to consumption. This is considered in more detail later, in Sections 4.6 and 4.7.

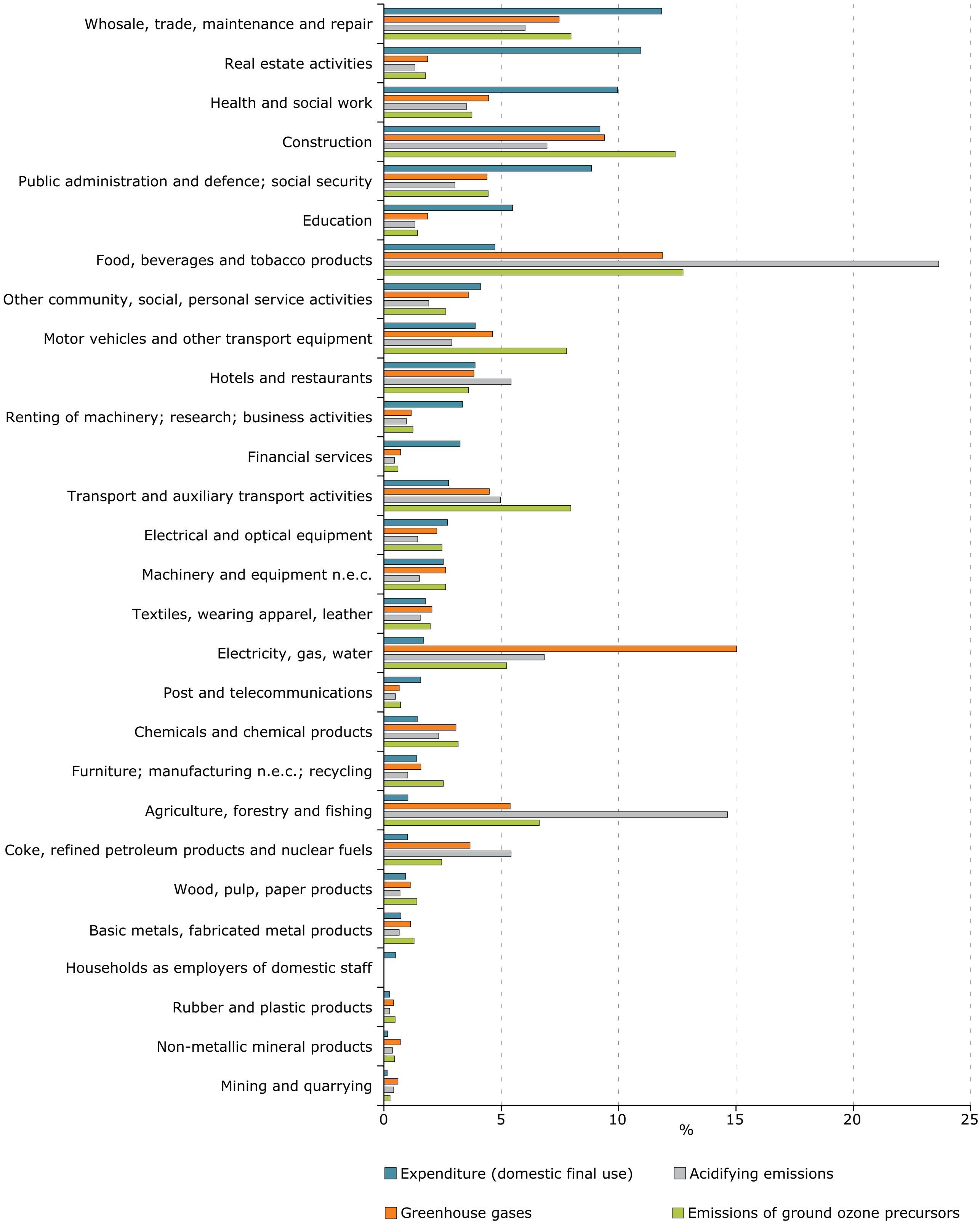
Figures 4.1 and 4.2 present the relative importance of each product group in terms of its share in total consumption expenditure and its share in key environmental pressures caused by national consumption as a whole, averaged across the nine EU Member States.

It is clear from Figures 4.1 and 4.2 that just a few product groups contribute significantly (30–50 %) to environmental pressures. These are:

- construction works, i.e. buildings and infrastructures;
- food products, beverages and alcohol;

([40]) In contrast to EU-27 or EU-25, we omit the hyphen here in order to stress that this is not an abbreviation used as common jargon regarding EU, but simply a group of countries defined by data availability within this study.

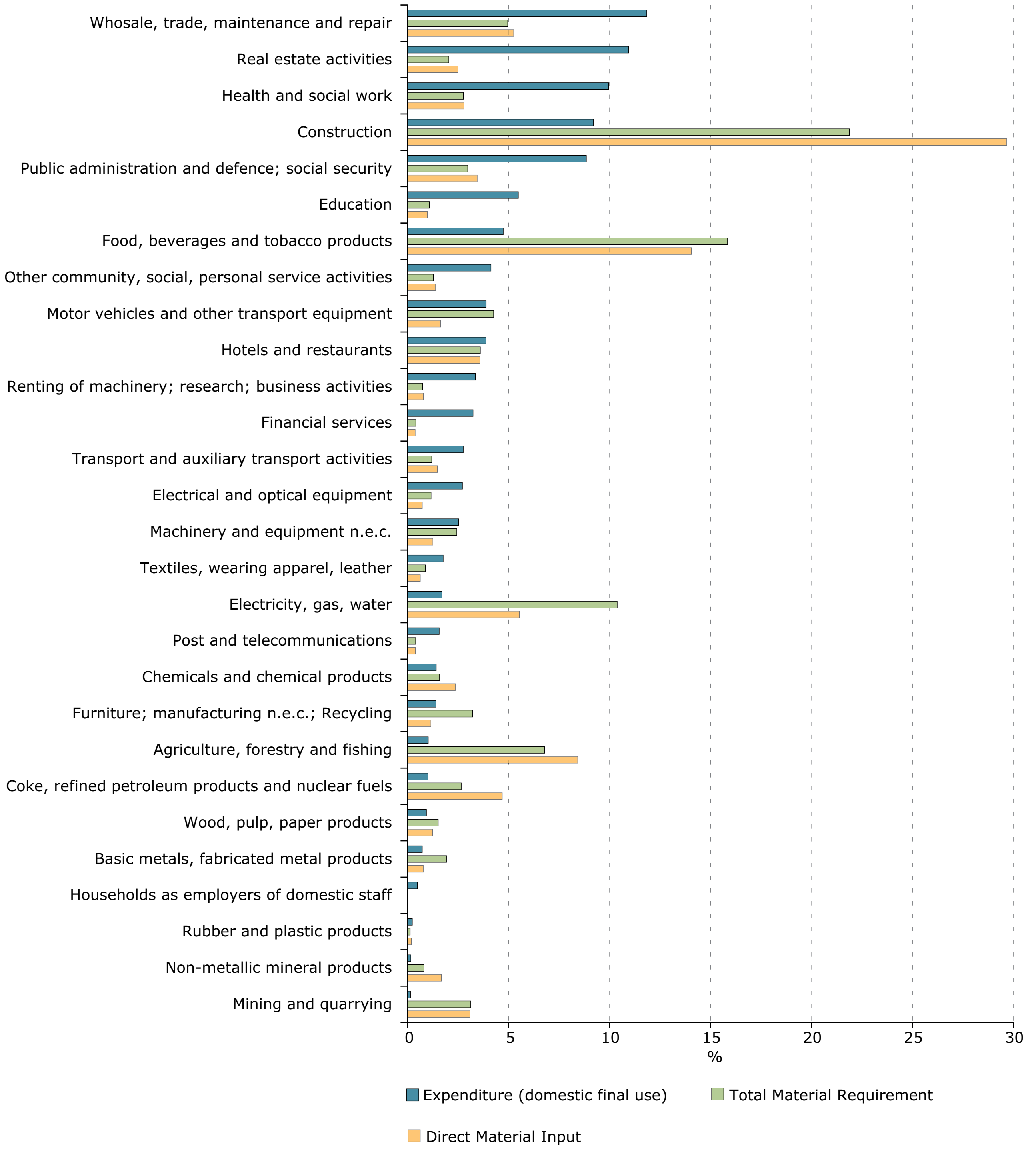
Figure 4.1 Share of product groups in consumption expenditure (domestic final use) and global air emissions caused by domestic final use (*), EU-9, 2005



Note: (*) The allocation of air emissions to final product groups given in this figure and all following figures follow a 'global re-attribution model' as described in Section A.4.5.1 of Appendix A.

Source ETC/SCP data set based on Eurostat NAMEA data set.

Figure 4.2 Share of product groups in consumption expenditure (domestic final use) and material use (TMR and DMI) caused by domestic final use (*), EU-9, 2005



Note: (*) The allocation of material flow indicators to final product groups given in this figure and all following figures follow a 'domestic re-attribution model' as described in Section A.4.5.2 and Section A.4.6 in Appendix A.

The size of the bars in Figures 4.1 and 4.2 represents the contribution of each product group to total pressures caused by all product groups as a percentage. The bars do not represent absolute levels of pressures caused by the product group. This explains why for some product groups the DMI bar is larger than the TMR bar. For example, the product group Construction (i.e. completed building projects) is responsible for just under 30 % of total DMI caused by all products as a whole, but only around 23 % of TMR caused by all product groups. In absolute terms (i.e. measured in tonnes), the TMR caused by a product group would always be higher than the DMI.

Source: ETC/SCP data set based on Eurostat NAMEA data set

- products of agriculture, forestry and fishing (also mostly food products but bought directly from farms rather than via food manufacturers);
- electricity, gas, steam and hot water the majority of which is electricity.

These four product groups together contribute 42 %, 52 %, 37 % and 55 % to GHG emissions, acidifying emissions, ground ozone precursors and TMR, respectively, embodied in all consumed products in 2005. They represent only 17 % of total consumption expenditure.

Production chains for a further seven products also accumulate quite significant environmental pressures, though less than the first four groups. These are:

- wholesale and retail services;
- motor vehicles and other transport equipment;
- hotel and restaurant services;
- transport, and auxiliary transport services;
- coke and refined petroleum;
- health and social work;
- public administration, defence and social security services.

The eleven key product groups together account for 75–85 % of the key environmental pressures caused by expenditure on goods and services.

However, the final seven product groups are generally much less pressure intensive than the first four and represent a 42 % share in consumption expenditure. This is more than they contribute as a group to global environmental pressures (30–40 %).

4.4 Pressures from total consumption

To get total pressures caused by consumption we need to add in the *direct* pressures from households

In the previous section we looked at the indirect environmental pressures from consumption, accumulated along production chains of products finally consumed by private households, government and by gross fixed capital formation. To gain a picture of the total environmental pressures activated by domestic consumption we need to add in the direct pressures released by households.

Total direct and indirect pressures arising from consumption are as follows:

Greenhouse gas emissions

The average per capita GHG emissions associated with consumption in the 9 EU Member States in 2005 were just under 12 tonnes CO_2-equivalents — 4 to 5 times the estimated global per capita average which would keep global temperature rise to within the critical 2 °C target set by the Copenhagen Accord.

Of this total, nearly 2.5 tonnes are emitted directly by private households through the combustion of fossil fuels for transport (around 43 %), and directly in the home for space heating and hot water and other purposes (around 57 %) ([41]). The remaining 9.4 tonnes are embodied in finally consumed products according to the proportions given in the second bar down in Figures 4.1 and 4.2. The most important product with respect to GHG emissions is electricity, followed by food and beverages and construction works.

Emissions of acidifying substances

National consumption in the 9 EU Member States caused global emissions of around 48 kg of SO_2-equivalents per capita in 2005. Private households directly emit ~ 10 % of the total acidifying substances through combustion of fuel in cars (~ 2/3) and fuel for heating and hot water in houses (~ 1/3), with the remaining 90 % arising indirectly from the consumption of products (see Figure 4.1). Food and beverages, and agricultural products (also food) dominate embodied acidifying emissions in products mostly due to ammonia emissions from fertilisers and livestock husbandry.

Emissions of ground ozone precursors

National consumption in the 9 countries causes on average around 58 kg NMVOC equiv. of ozone precursor substances per capita. Private households directly emit just over 40 % of the total, again through combustion of fuel in cars (~ 2/3) and fuel for heating and hot water in houses (~ 1/3). The remaining ~ 60 % of ozone precursors activated by consumption are indirectly caused by the consumption of final products as given in Figure 4.1. Food and beverages and construction works are

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([41]) Derived from the Eurostat NAMEA AIR data set.

the most important indirect contributors. Motor vehicles, transport services and the wholesale, maintenance and repair services are also important, due to the use of solvents in paints.

Material use

The average material use activated by consumption in the 9 EU Member States stood at 36 tonnes per capita of TMR (Total Material Requirement) and 11.4 tonnes of DMI (Direct Material Input) in 2005. Direct extraction of materials by households is negligible. We can, therefore, assume that all material use activated by consumption is indirect, taking place during the production of goods and services delivered to the consumer. Unsurprisingly perhaps, the consumption of construction works followed by food and beverages and electricity are the most important indirect drivers of material use. Agricultural products, wholesale, maintenance and repair services, hotels and restaurants, motor vehicles and refined petroleum products are also of importance (see Figure 4.2).

Allocating pressures to broad consumption areas

A useful perspective for analysing total pressures caused directly and indirectly by consumption is to allocate pressures to particular consumption activities or functions. For example, global pressures caused by purchase of food, beverages and tobacco, products of agriculture, forestry and fisheries, and hotels and restaurants can largely be allocated to the function of Food and lodging although this is a simplification since neither tobacco nor the majority of forestry products constitute food.

Other functional activities to which final products can be allocated include: Use of housing and infrastructures, to which most final electricity use can be allocated, along with most construction works and real estate services, and Mobility to which product groups such as motor vehicles, coke and refined petroleum products, transport and auxiliary services, etc. can be allocated. Note that although business and industry is a large user of electricity and transport services, for example, they are not final users. Only governments and households (and gross capital formation) represent final domestic consumption. This makes the allocation of use of transport services to Mobility more obvious since most transport services sold directly to households are for the movement of people by bus, train and taxi, rather than the movement of goods.

> The consumption areas *Food and lodging, Use of housing and infrastructure and Mobility* account for ~ 2/3 of key environmental pressures

Similarly, direct pressures from households (cf. Section 2.6) can also be allocated by functional activity. A relatively complex approach has been used for the allocation of the air emissions of households (due to heating, transport and other activities) to the 59 CPA product groups for each country. The method was developed as part of the EXIOPOL project commissioned by the European Commission (⁴²).

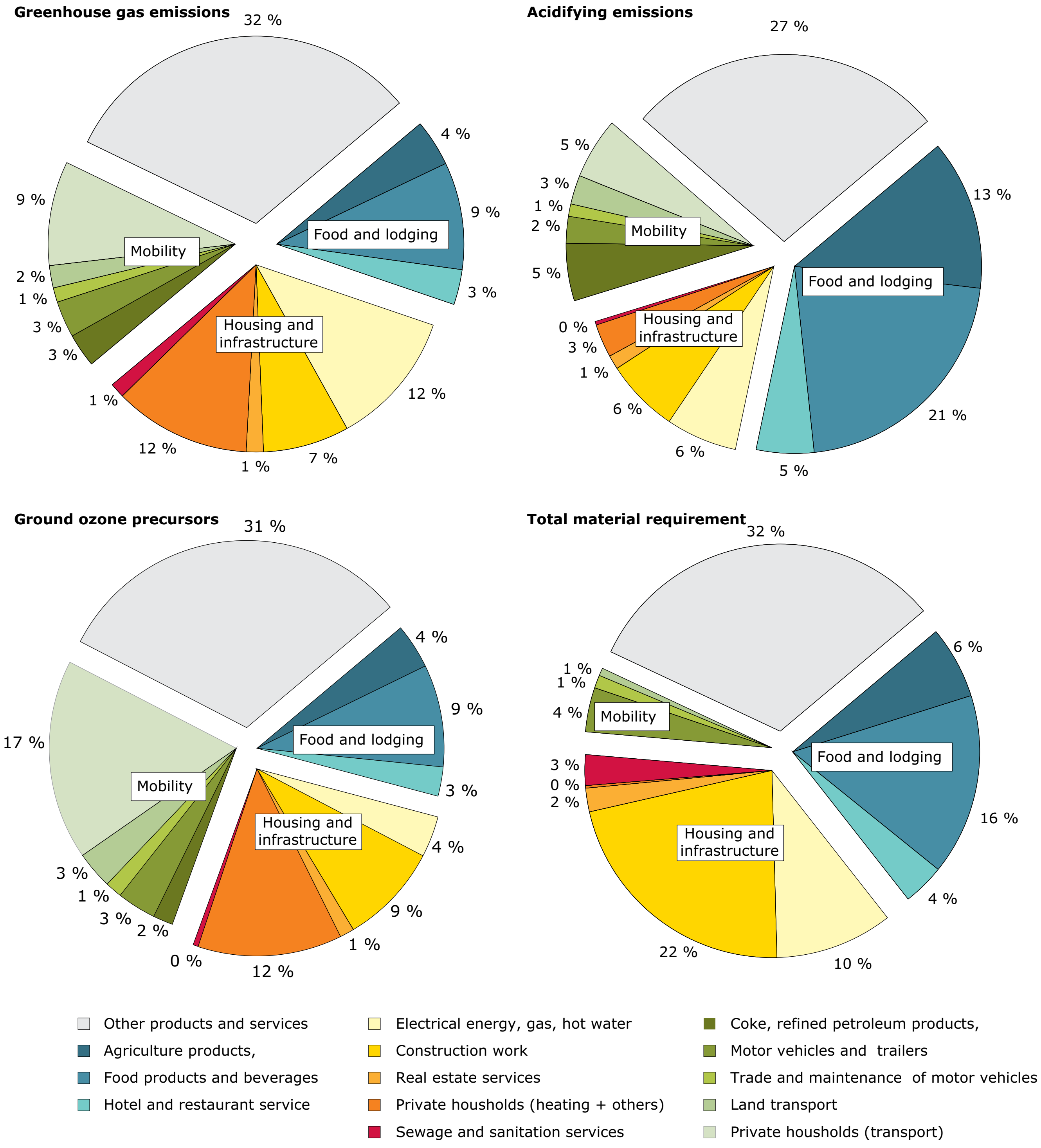
When this allocation is carried out it can be seen that the three consumption areas of Food and lodging, Use of housing and infrastructures and Mobility cause the majority of direct and indirect pressures caused by total consumption (domestic final use) in the 9 EU Member States (Figure 4.3). Approximately 68 % of GHGs, 72 % of acidifying emissions, 69 % of ground ozone precursors and 68 % of TMR can be assigned to these 3 consumption activities.

The results of this work compare well with the findings of other studies using other tools and researching other country groupings. One of these is the EIPRO study (⁴³) commissioned by the European Commission. EIPRO concluded that products from 3 areas of consumption — food and drink, private transportation, and housing — together are responsible for 70–80 % of the various environmental impacts of private consumption. As a result of such study results, the three areas are beginning to be prioritised in SCP-related policy. The Roadmap to a Resource Efficient Europe, for example, includes specific milestones and actions tackling environmental pressures from these three areas.

(⁴²) This approach specially developed for this purpose applies data from the International Energy Agency Database that has been processed within the FP6 project EXIOPOL (www.feem-project.net/exiopol) in order to bridge from the territorial to the residency principle. The distribution key drawn from the EXIOPOL data for the year 2000 has been applied to all years in ETC/SCP calculations.

(⁴³) 'Environmental Impact of PROducts - Analysis of the life cycle environmental impacts related to the final consumption of the EU' (http://susproc.jrc.ec.europa.eu/publications.html). See Tukker et al., 2006.

Figure 4.3 Direct and indirect pressures from domestic final consumption (*) assigned to Food and lodging, Use of housing and infrastructure and Mobility, EU-9, 2005



Note: (*) i.e. total national consumption.

The results for DMI are not reproduced here as they look very similar to those for TMR since it is shares that are being considered here and not absolute levels of pressures.

4.5 Pressures from household consumption

The previous sections looked at direct and indirect pressures associated with final consumption including household and government consumption and capital formation (i.e. investments in machinery and infrastructure).

This section focuses on household consumption in order to aid development of policy aimed directly at households.

Similarly to the previous section, a useful means for analysing household consumption is to split expenditures and associated pressures into consumption shares according to function. In the case of household consumption a classification system has already been developed to split consumption expenditure in this way: the *Classification of individual consumption by purpose* (COICOP) system developed by the UN and adapted for use in the European Union by Eurostat (see Box 4.1).

However, consumption expenditure according to the COICOP and the related environmental pressures as derived from national EE-IOTs do not strictly use the same classification system, although both are part of national accounts, i.e. the CPA classification.

These CPA product groups are not directly transferable to COICOP categories. Several different CPA product groups or parts of them can be relevant to more than one two-digit COICOP category. Unfortunately, there is no standardised way to map aggregated CPA product categories (i.e. at two digit-level) onto aggregated (two-digit) COICOP categories. Eurostat made an attempt in 2009 to develop a standard mapping matrix but the task proved to be unsuccessful. Standard mapping methods exist only for more disaggregated product groups and COICOP categories (e.g. CPA 6-digit and COICOP 4-digit).

Box 4.1 Classification of individual consumption by purpose

The Classification of individual consumption by purpose (COICOP) was developed by the United Nations Statistics Division to classify and analyse individual consumption expenditures incurred by households, non-profit institutions serving households and general government according to their purpose. Eurostat subsequently adapted the COICOP classification to the harmonized index of consumer prices (HICP) of the European Union, and collects and maintains country-level indicators on expenditure within each of these categories for the EU-27.

The COICOP includes 14 upper level (one digit) categories of which the first 12 are relevant to household consumption. The 12 categories are as follows:

01 — Food and non-alcoholic beverages

02 — Alcoholic beverages and tobacco

03 — Clothing and footwear

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

05 — Furnishings, household equipment

06 — Health

07 — Transport

08 — Communications

09 — Recreation and culture

10 — Education

11 — Restaurants and hotels

12 — Miscellaneous goods and services

Each category is further split into a set of two digit categories. For example, the category Transport includes the following two digit categories: 07.1 — Purchase of vehicles, 07.2 — Operation of personal transport equipment, 07.3 — Transport services.

In lieu of such a standard matrix for Europe, the ETC/SCP team developed a transformation matrix which can be found in Appendix B**.** Without robust information allowing for more accurate transformations the matrix is rather simplistic using a many- to-one mapping, i.e. each product group is fully allocated to a single COICOP category.

All electricity use for example (under CPA 40; electrical energy, steam, gas and hot water) is allocated to COICOP category 04 Housing, etc. although a certain share is used for cooking and food storage and could be allocated to 01 Food and beverages. Any such splitting of products could however be seen as arbitrary without being supported by sufficiently detailed data from household surveys, etc. and thus more complex allocations have not been applied. It is important to note that this allocation of pressures according to the rather simplistic transformation matrix leads to some systematic errors in the pressures being allocated to COICOP categories.

Direct pressures from households are allocated as described in Section 4.4.

When pressures caused by private consumption are allocated to these 12 main COICOP areas, food and beverages; housing, water electricity and gas; transport, and furnishings and household equipment dominate (Figure 4.4).

The dominance of the first three is partly due to their also being the three private consumption categories with highest expenditures (Eurostat, 2009a). However, as shown in Figure 4.5 they are also the three COICOP categories along with *furnishings, household equipment* and *restaurants & hotels* with the greatest environmental pressure intensities (pressure per euro spent by consumers) for the five different environmental pressures examined. See Box 4.2 for an explanation of pressure intensities shown in Figure 4.5 and how they were calculated.

It should be noted that the environmental pressure intensities shown in Figure 4.5 should be treated with some caution due to the simplified transformation matrix for allocating pressures to COICIOP categories and certain inconsistencies between data on environmental pressures and expenditures (see Box 4.2).

Decoupling environmental pressures from growth in private consumption can be achieved by reducing the pressure per euro spent (or pressure intensities as we will call it here) within individual consumption categories — through improvements in housing energy efficiency, switching transport expenditure from private cars to public transport, or a shift from spending on quantity to quality in food, furniture, clothing, etc. It can be seen from Figure 4.5 that with a few exceptions (e.g. TMR intensity of food) pressure intensities within consumption categories generally improved between 1995 and 2005.

However, the often large differences in environmental pressure intensities found *between* household expenditure categories (Figure 4.5) highlights a second potential means for decoupling environmental pressures from growth in consumption. That is to channel increasing income towards consumption categories with relatively low environmental pressure intensities.

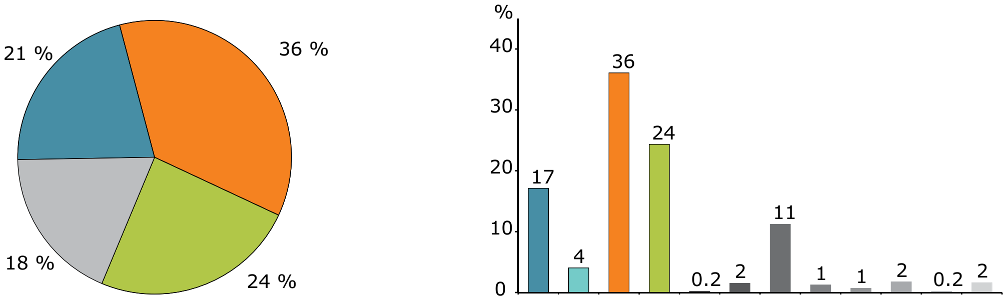
These vary somewhat depending on which environmental pressure is being considered but, as can be seen in Figure 4.5, consumption categories such as education, communication, and recreation and culture, tend to have relatively low pressure intensities. The consumption areas of transport, housing, food and beverages, furnishings, household equipment etc. and restaurants and hotels on the other hand, tend to have high environmental pressure intensities in the five categories of environmental pressures shown here.

It should be noted that the calculations of environmental pressure intensities have been carried out using purchaser prices, rather than basic prices. Taxes including taxes with an environmental objective are included in these purchaser prices. Without the inclusion of environmental taxes, the environmental pressure intensities of transport and housing, in particular, would be more dominant.

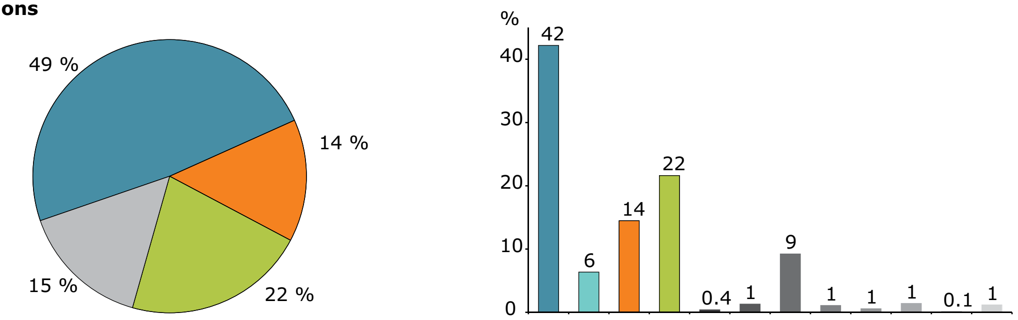
Environmental taxes, *if* applied consistently, might be expected to have a smoothing effect on differences, in environmental pressure intensities across different consumption categories. However, in reality environmental taxes tend to emerge from a number of disassociated political processes with varying objectives and consideration of complex sets of environmental and social factors, and the resulting smoothing effect will not be consistent.

Figure 4.4 Direct and indirect global pressures caused by household consumption distributed amongst 4 broad consumption areas and 12 COICOP categories, EU-9, 2005

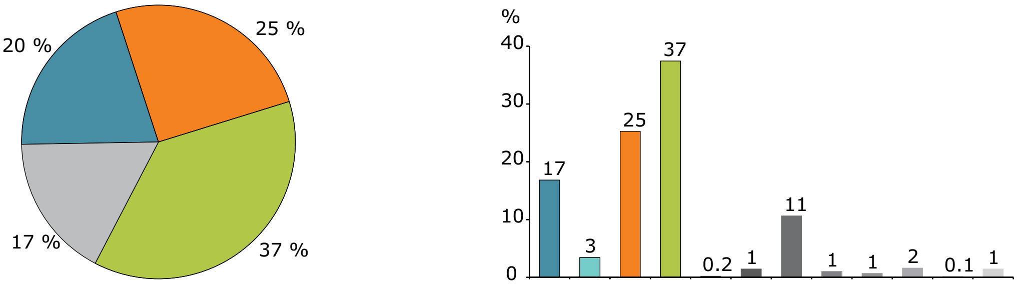
Greenhouse gases



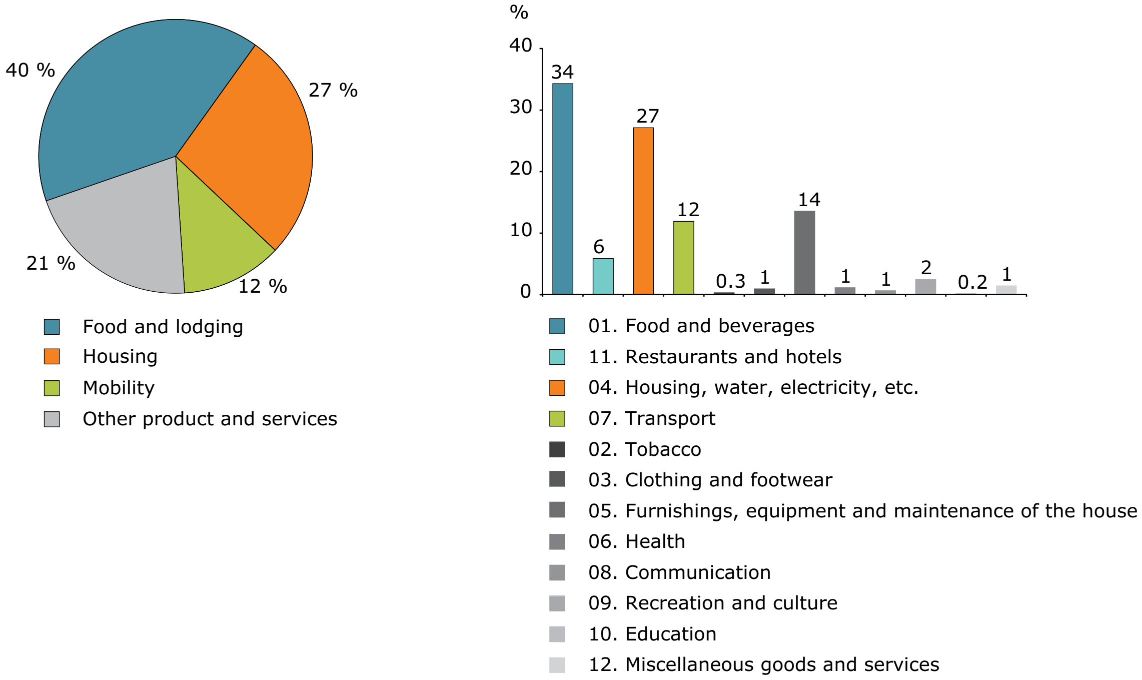
Acidifying emissions



Tropospheric ozone precursors



Total Material Requirement



Note: The results for DMI look very similar to TMR and are not reproduced here.

Figure 4.5 Direct and indirect pressures per euro of expenditure within 12 household consumption categories, EU-8, 1995–2005

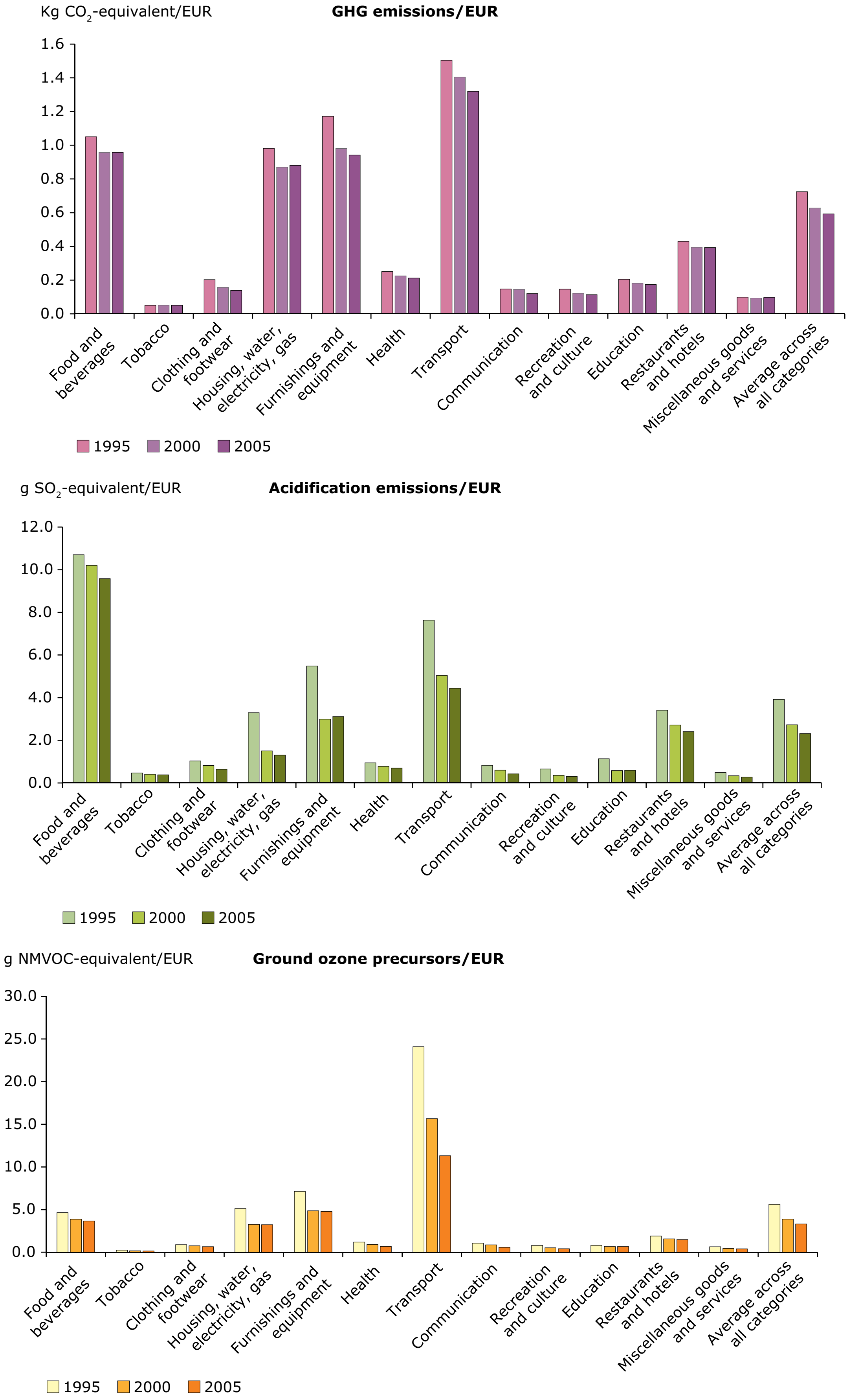
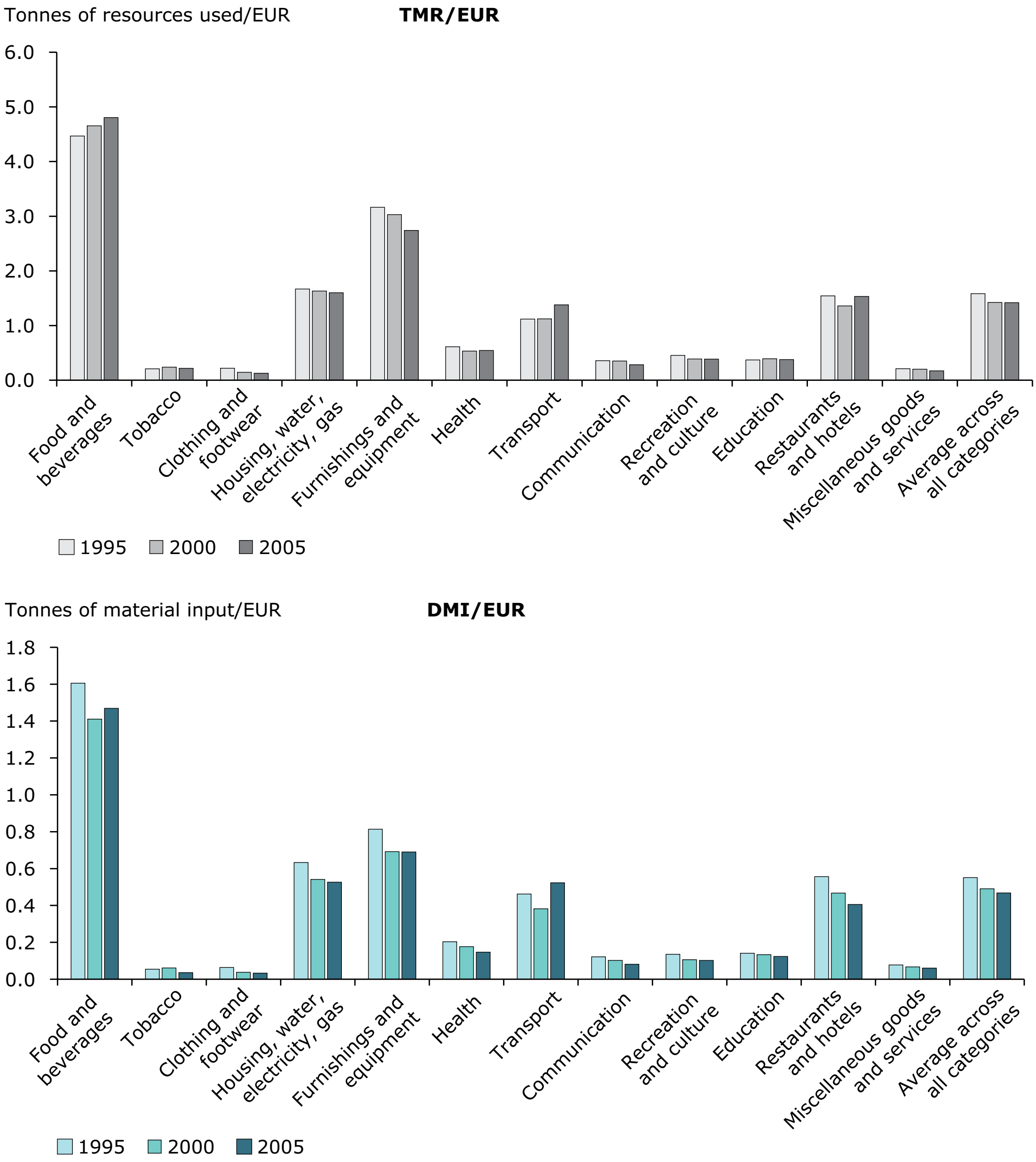


Figure 4.5 **Direct and indirect pressures per euro of expenditure within 12 household consumption categories, EU-8, 1995–2005 (cont.)**



Box 4.2 Pressure 'intensity' of consumption categories

It is interesting to look at how environmental pressures caused by household consumption are split between household consumption categories according to COICOP classification (see Box 4.1) but also how the *environmental pressure intensities* of the various consumption categories differ.

Environmental pressure intensity of a COICOP category for a given pressure type can be defined as the magnitude of the environmental pressure caused directly and indirectly by that consumption category, per euro of spending on that category. Spending one euro on a consumption category with high pressure intensity will lead to greater environmental pressures than 1 euro spent on a category with relatively low pressure intensity.

Seen from the point of view of sustainable consumption assessments it is most interesting to look at pressures per euro of spending at purchaser prices, rather than at basic prices. This includes VAT and other taxes/duties.

Such an intensity calculation is not straightforward due to problems in allocation of pressures calculated using EE-IOA for individual products (as defined using the CPA classification system) to household consumption (COICOP) categories. These issues are described in the main text in Section 4.5.

Two potential methods for calculating pressure intensities were investigated, both of which have consistency issues. The first method is to divide the pressures allocated to each COICOP category using the transformation key given in Appendix B by Eurostat's reported spending on each COICOP category.

The inconsistency here is that the products included under each COICOP category in Eurostat's consumer expenditure data differ somewhat from the products allocated using the transformation matrix in Appendix B. Eurostat's expenditure figures are calculated using a transformation matrix including a high level of disaggregation for both product groups and COICOP categories: This transformation matrix cannot be used for environmental pressures due to lack of disaggregated data. Thus, there is an internal inconsistency within the calculations.

A second method is to make adjustments to Eurostat's expenditure data taking into account the CPA product groups which have actually been assigned to each COICOP group when allocating emissions. The total pressures caused directly and indirectly by a consumption category can then be divided by these adjusted expenditure figures. The inconsistency inherent in this method is rather external; the consumption categories can no longer be described wholly as COICOP categories, containing as they do expenditure on a somewhat different set of product groups (see Appendix B).

For the purposes of this report, the first method was chosen in part for simplicities sake. A more thorough assessment of the relative strengths and weaknesses of the two methods will be carried out prior to finalising the supplementary report on EE-IOA results for the EU-27 as a block in 2013.

4.6 Environmental pressure intensity of final consumption products

Product groups differ significantly in the environmental pressure intensities of their production chains

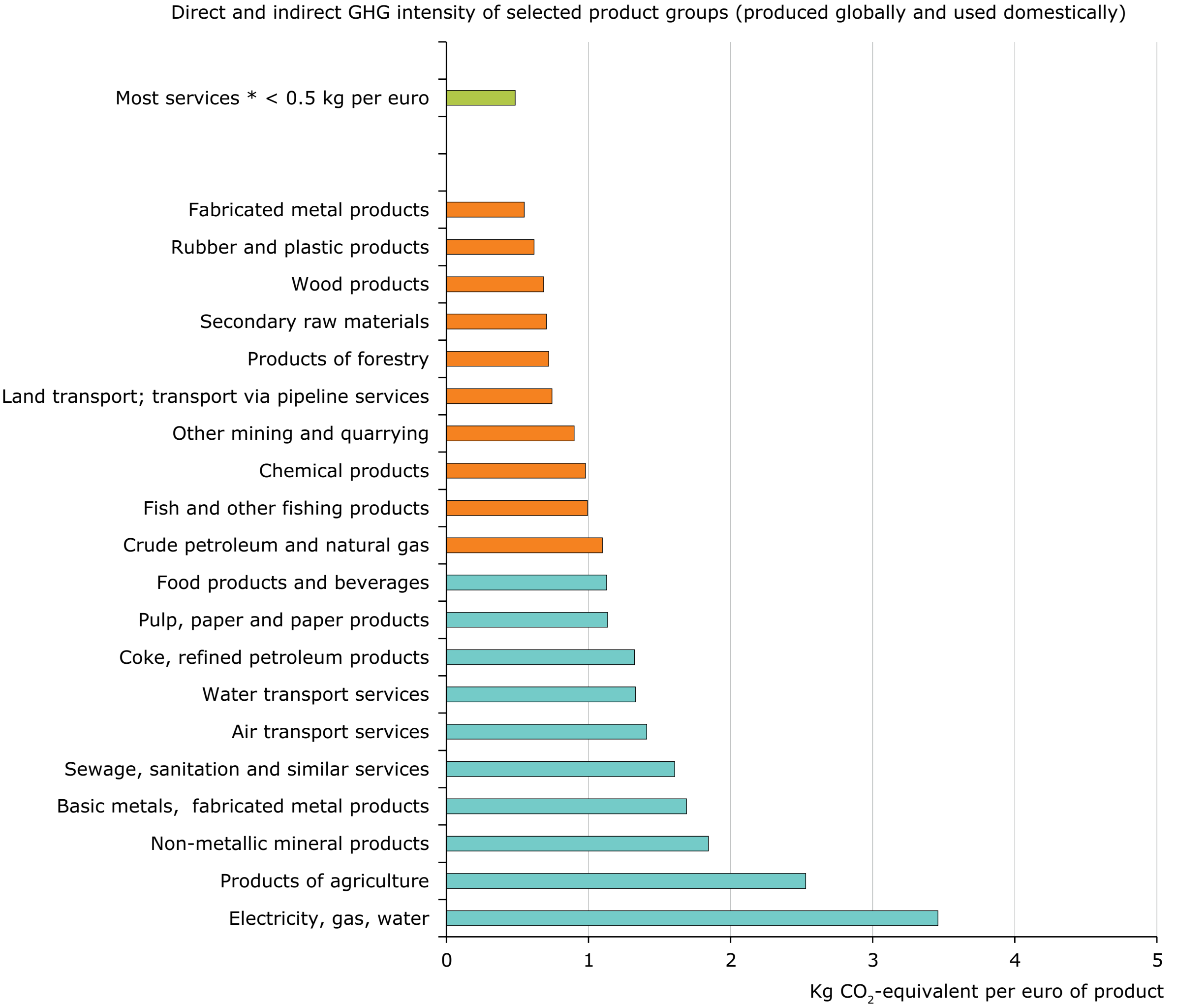
As discussed earlier, the EE-IOA methods can be used to analyse how pressures caused by consumption have changed and how these changes have been influenced by the three main drivers of change: economic growth, changes in the pressure intensity of individual product groups and changes in the mix of products being consumed. This analysis is presented in Section 4.7. The eco-intensity of the production chain of products is a key factor in this analysis and is first discussed below.

Following the brief detour into household consumption (Section 4.5) we return now to total national consumption, i.e. final domestic use by governments, households and gross capital formation.

As seen in Figures 4.1 and 4.2, there can be major differences in the contribution of a product group to total consumption-activated environmental pressures, and its share in total consumption expenditure. These differences are a result of differences in environmental pressure intensity (i.e. environmental pressure per euro of consumption expenditure) of the production chains of the various product groups.

Figures 4.6 and 4.7 compare the GHG emissions intensity and the material intensity of some selected product groups. Only the 20 most pressure-intensive

Figure 4.6 The 20 most GHG emissions-intensive final product groups, EU-9, 2005



Note: * Except water and air transport services and sanitation services.

Product groups are defined at the NACE 60 level, i.e. with all expenditure disaggregated into 60 product groups. The blue bars show the 10 most GHG-intensive product groups; the orange show the next 10 most intensive product groups.

product chains are shown in each case out of a total of 60 product chains. For comparison, an upper pressure intensity for different types of services is shown. For GHGs the intensities range from less than 0.5 kg CO_2-equivalent per euro for most services to 4.1 kg CO_2-equivalent per euro for electricity.

The range of material intensities is much greater, between less than 0.7 kg per euro for most services to 113 kg per euro for 'other mining and quarrying products'. In addition, forestry and agricultural products, basic metals and non-metallic products, electricity and fuels have relatively high material intensities.

In both cases, services, with a few exceptions in the case of GHGs, have comparatively low intensities. In other words, spending EUR 1 for services (excluding transport or sanitation) is better for the environment than spending EUR 1 on chemical or metal products. Therefore decoupling of environmental pressures from growth can in part be achieved by channelling increasing national income towards services rather than material goods.

Though not shown here, a second finding from the EE-IOA was that the same products can have different eco-intensities from country to country. Reasons for these differences can be complex and many of them are non-transferable between countries. However, one key finding is that the eco-efficiency of electricity production has knock-on effects on the eco-efficiency of a large number of product groups. Many Swedish product chains are the most efficient of the 9 countries due to the low use of fossil fuels in electricity production (in Sweden less than 15 % of electricity generation came from conventional thermal electricity plants in 2010 compared to 54.5 % average in EU-27 (44)).

4.7 Decoupling trends in consumption

The EE-IOTs gathered by the EEA and ETC/SCP are valuable in that consistent tables have been gathered for a number of countries over a number of different years. This allows developments in pressures caused by national consumption (domestic final use) to be followed alongside developments in GDP, to see whether or not environmental pressures caused by consumption have been decoupled from growth in expenditure.

> Decoupling trends pressures caused by consumption can be explained by two factors — changes in the *product types* we consume and improvements in *eco-efficiency* of production chains

Decoupling is an essential component of the path to sustainable consumption and production. As described in Section 3.5, decoupling can be relative or absolute: relative decoupling is where an environmental pressure is still growing but at a slower rate than economic output (or in the consumption perspective: expenditure); absolute decoupling occurs if environmental pressures are decreasing despite economic growth.

As described in Section 3.5, EE-IOA methods can also be used to break down the decoupling trends into various contributing factors.

The data available in the EE-IOTs allow decoupling in consumption-activated pressures to be broken down into two factors. These are:

- shifts in the national consumption mix;
- Improvements in eco-efficiency within product group production chains.

The first of these — changes in the consumption mix — is concerned with changes in the types of products consumed domestically (i.e. by government, households and gross capital formation). As described in the last section, when consumption expenditure shifts from pressure-intensive product groups to less intensive product groups this has a positive decoupling effect.

The second factor contributing to decoupling is concerned with improvements within production chains i.e. reductions in pressure intensity along the production chains of a given product group. This second development would lead to decoupling even where the actual types of products being consumed remained the same over time.

Other studies (e.g. Gravgård et al., 2009) have used decomposition analysis to identify further contributing factors to decoupling such as changes in fuel types. For example, a shift from coal to natural gas in electricity production will reduce environmental pressures caused by production chains using electricity even where the energy used

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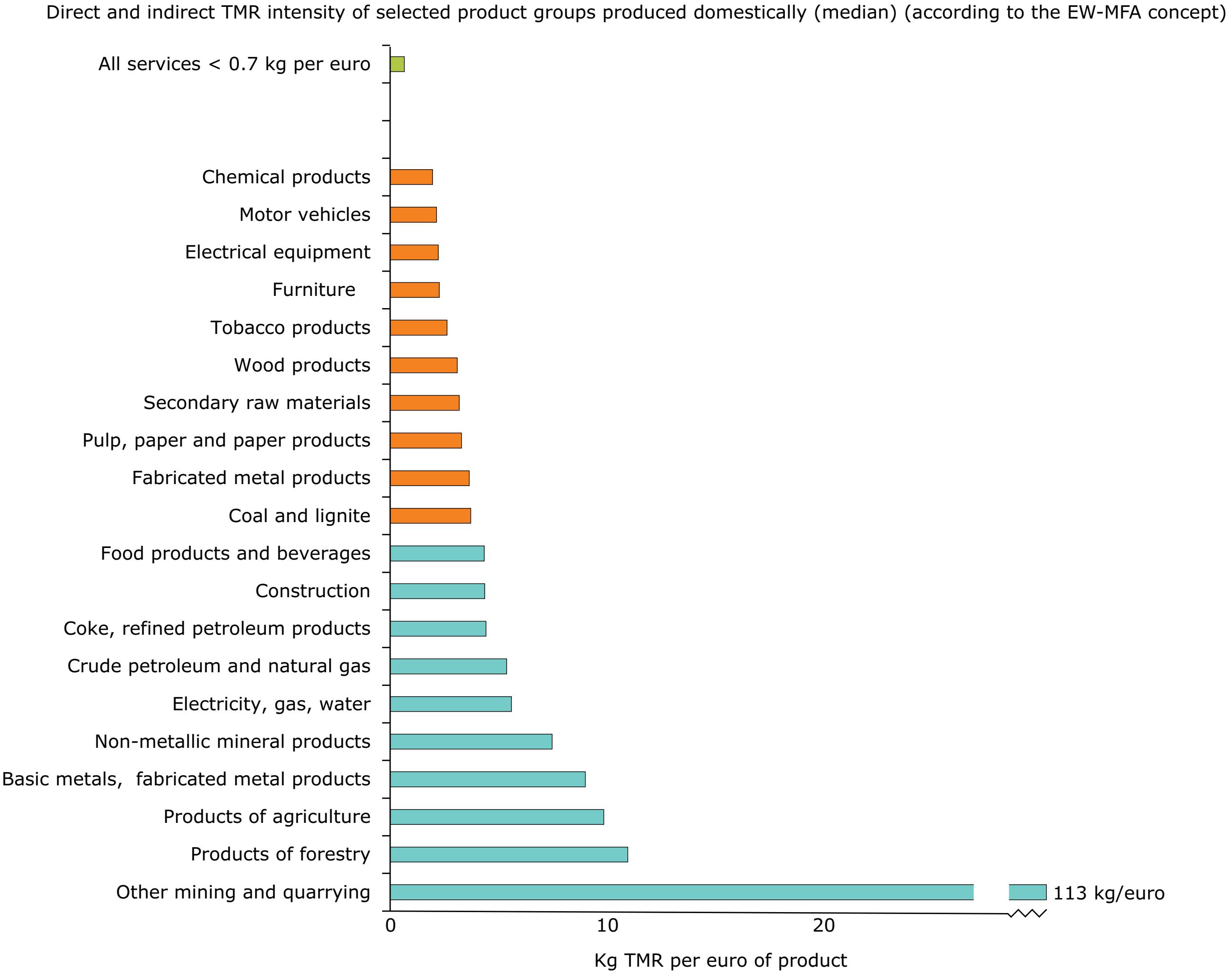
(44) Eurostat (http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Electricity_production_and_supply_statistics). Note though that electricity production from biofuels was not reported separately in the 2010 data, and is included in the conventional thermal electricity production.

Figure 4.7 The 20 most material-intensive (TMR per euro) final product groups, EU-9, 2005



Note: Product groups are defined at the NACE 60 level, i.e. with all expenditure disaggregated into 60 product groups. The blue bars show the 10 most TMR-intensive product groups; the orange show the next 10 most intensive product groups.

by that production chain is unchanged. However, the EE-IOTs available for this current study do not include data on energy carriers.

The EE-IOTs gathered by the ETC/SCP allow developments over 10 years (1995–2005) for 8 EU Member States (45) to be observed.

Figure 4.8 shows developments in GHG emissions in the 8 EU Member States alongside contributions from economic growth and from the two additional factors described above.

The left-hand set of bars in Figure 4.8 show the development in GHGs per capita activated globally by consumption in 8 EU Member States from 1995 to 2005. Four of the eight countries have seen absolute reductions in GHG per capita activated by national consumption (domestic final use).

The second set of bars show how GHGs would have changed if they were fully coupled to growth in consumption expenditure. By comparing growth in consumption to the overall change in pressures in the left hand bars it can be seen that decoupling has taken place in all eight countries. In Italy, Austria, Portugal and Sweden only relative decoupling was achieved.

The two right-hand sets of bars show how changes in the mix of types of goods being consumed and changes in eco-efficiency along individual

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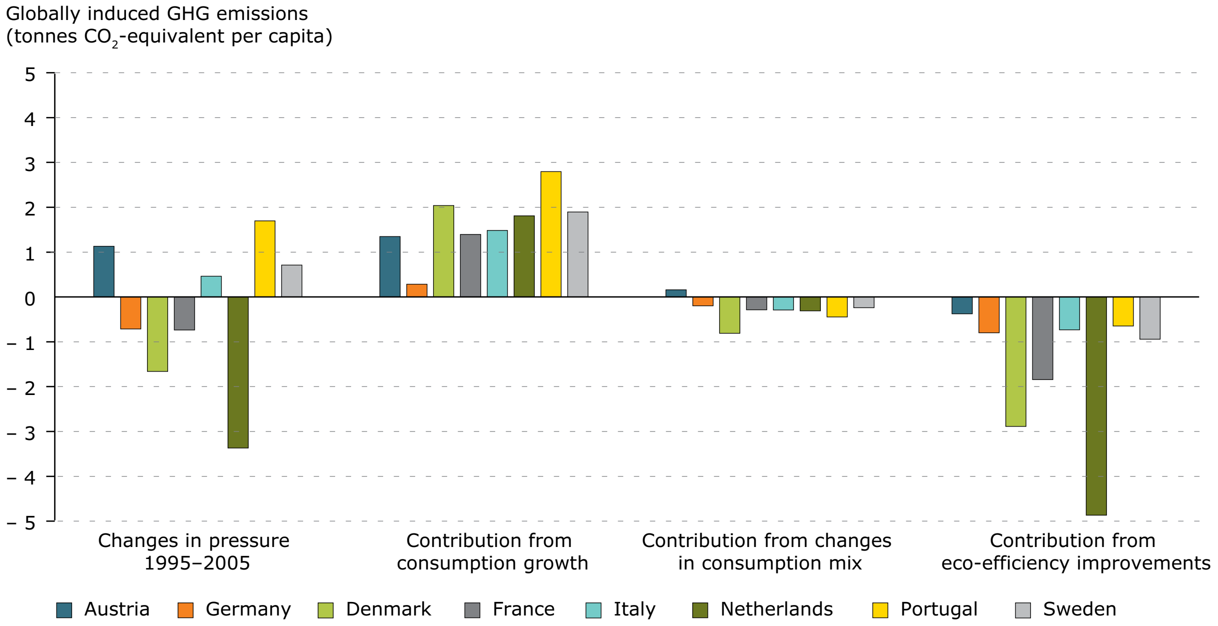
(45) Denmark, Germany, France, Italy, the Netherlands, Austria, Portugal and Sweden.

Figure 4.8 **Changes in global greenhouse gas emissions per capita activated by consumption and main contributing factors in 8 EU Member States, 1995–2005**



Source: ETC/SCP data set.

production chains have contributed to decoupling. The individual bars show how changes in this factor would have changed GHG emissions caused by consumption all other things being equal.

It can be seen that with a single exception, both factors had positive decoupling effect on global GHG emissions caused by consumption in all eight countries between 1995 and 2005. However, for all countries improvements in eco-efficiency of production chains had a significantly stronger decoupling effect than changes in the mix of goods being consumed.

These two factors, and the means by which governments can encourage them, are markedly different. The first is concerned with consumption patterns and consumer choice. Means for encouraging positive change here would include the use of economic instruments, information campaigns or other means to urge consumers to spend their money on less pressure-intensive product groups

The second factor, meanwhile, is concerned with improvements in production processes and encouraging these improvements requires altogether different measures: better regulation, increasing the price of material and energy inputs, encouraging and investing in innovative technologies, etc.

The findings for GHGs suggest that the potential to achieve decoupling through encouraging changes in consumption patterns has yet to be utilised to any great extent.

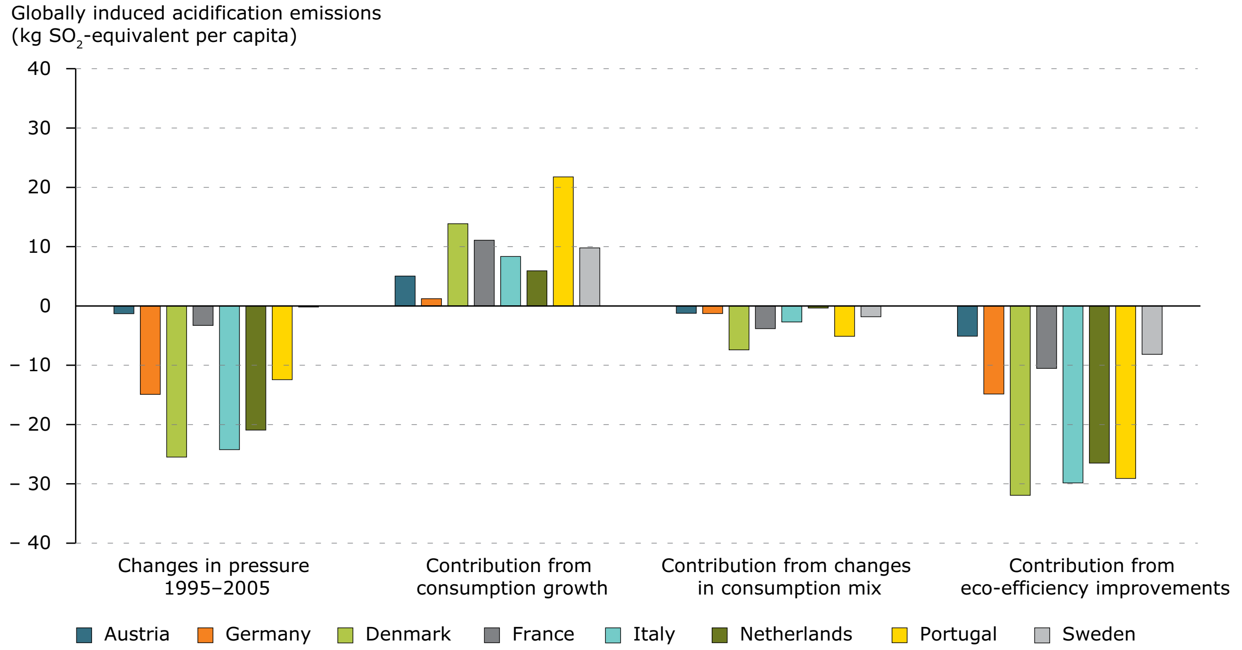
Decoupling of air emissions from growth has mainly been a result of eco-efficiency improvements

Similar results are found for other air emissions-based pressures: for acidification emissions (Figure 4.9) and emissions of ground ozone precursors (Figure 4.10). With one exception, all countries have seen absolute decoupling of pressures from consumption growth. Again, in most cases both consumption mix changes and production cycle efficiency changes have had positive decoupling effects, but the latter has dominated in all but one case.

In other words, progress through improved production processes has been significantly greater than gains made through changing consumption patterns.

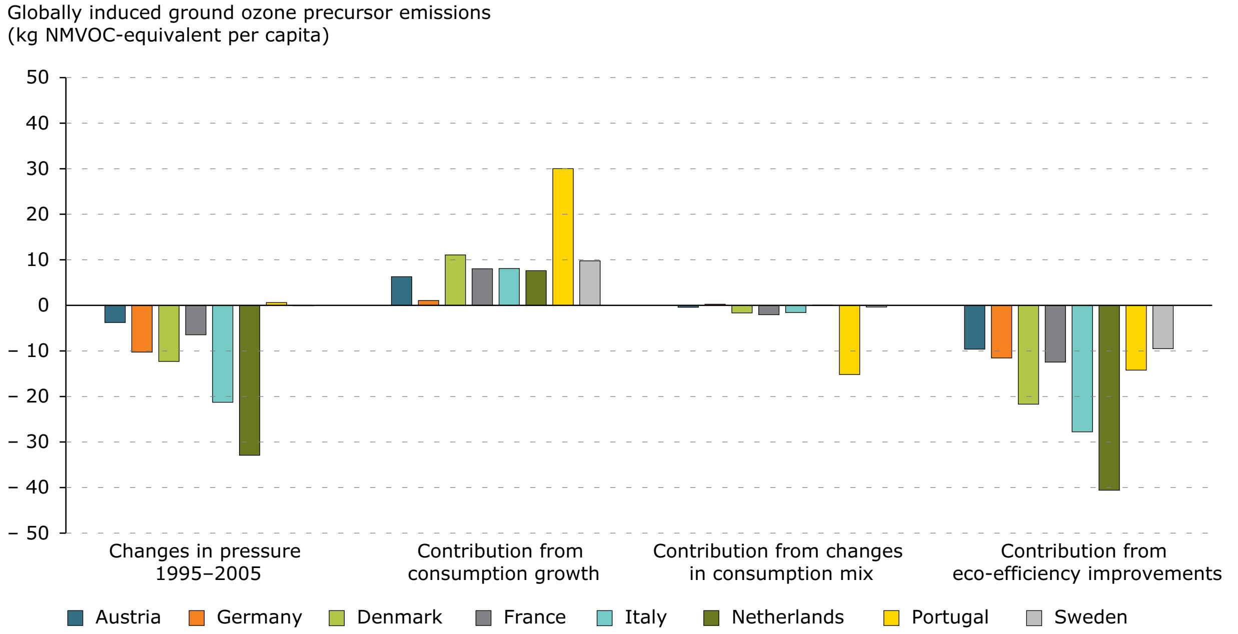
The picture is markedly different for TMR activated by consumption expenditure between 1995 and 2005 (Figure 4.11). Here only one country (Germany) saw absolute decoupling in global material input caused by consumption, in part due to sluggish

Figure 4.9 Changes in global acidifying emissions per capita, activated by consumption and main contributing factors in 8 EU Member States, 1995–2005



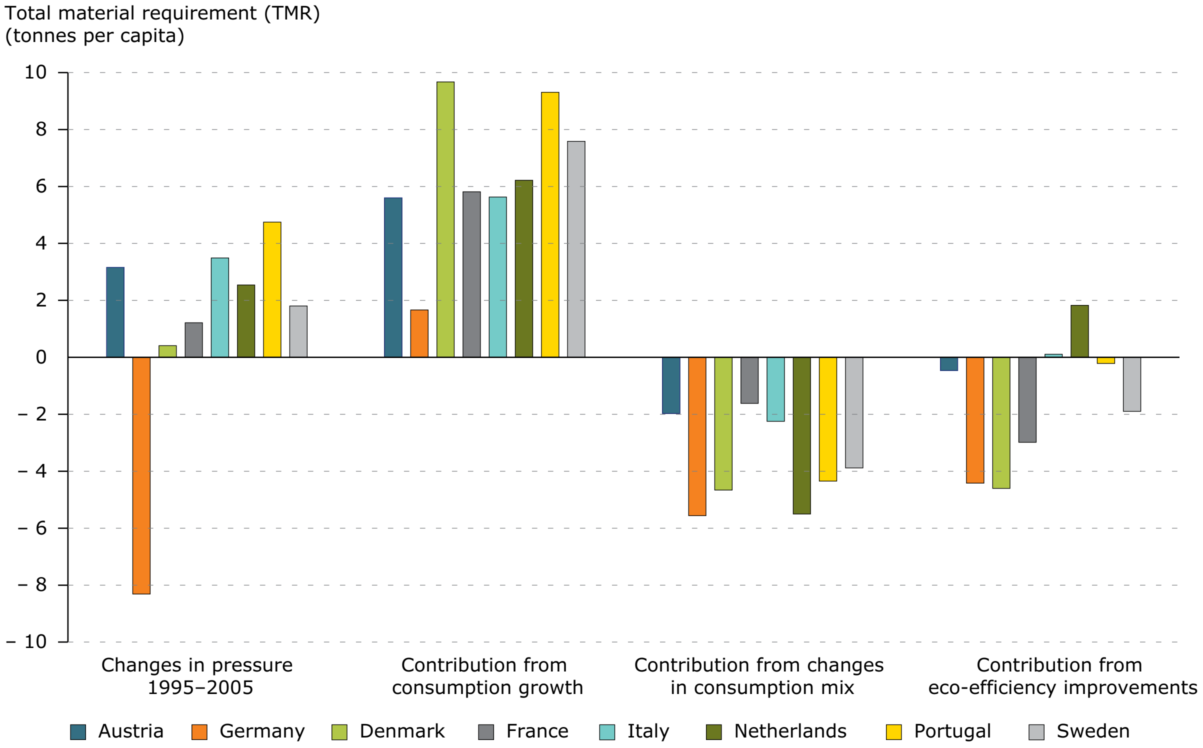
Source: ETC/SCP data set.

Figure 4.10 Changes in global emissions of ground ozone precursors per capita activated by consumption and main contributing factors in 8 EU Member States, 1995–2005



Source: ETC/SCP data set.

Figure 4.11 Changes in total material requirement per capita activated by consumption and main contributing factors in 8 EU Member States, 1995–2005



Source: ETC/SCP data set.

economic growth during this period, but also strong contributions from both eco-efficiency improvements and changing consumption patterns. The other seven countries all saw relative decoupling of TMR from growth in consumption. However, unlike for air emissions, in the case of TMR changes in the mix of goods and services consumed have been the main contributor to decoupling (with the exception of Portugal). Only in Denmark, Germany and France have similar or greater contributions come from resource efficiency improvements along production chains.

EE-IOA-based decomposition analysis can give valuable insights into the main factors behind decoupling or lack of decoupling. Particularly useful is the ability of the method to differentiate between efficiency improvements in production chains on the one hand and changing consumption patterns on the other and the extent to which they complement or conflict with one another in decoupling pressures from growth.

For air emissions and GHGs most of the decoupling seen during the second half of the 1990s was caused by efficiency improvements with changes in consumption patterns having only a modest effect (46). Similar results were found by Baicocchi and Minx (2010) for the United Kingdom between 1992 and 2004.

In the future we will need to make more effort in shifting consumption from high eco-intensive to low eco-intensive products

The European Council confirmed in February 2011 the EU objective of reducing GHG emissions by 80–95 % by 2050 compared to 1990 levels as the European contribution (as part of the group of developed countries) to keeping global temperature increases to 2 °C above pre-industrial levels as agreed under the Copenhagen Accord and Cancun agreements (EC, 2011c; see also den Elzen and Meinshausen, 2005). This will require significantly more rapid decoupling than has been observed so far.

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(46) As noted in Chapter 3, this result may be influenced somewhat by the level of aggregation of the economy given in the NAMEA tables. Studies have shown that increased levels of aggregation can overemphasise the importance of the eco-factor (Hass, 2008).

It seems clear this cannot be achieved alone through efficiency improvements in European industry or investments in efficiency improvements in developing and transition countries and in major trade partners. It will also need a significant contribution from changes in consumption patterns — a shift to less pressure-intensive goods and services.

An important final note on decoupling trends is needed. In Chapter 2 it was described how the EE-IOA method used here can underestimate the pressures caused by national consumption in Europe. This is due to the assumption that pressures embodied in imports are the same as if the imported products had been produced domestically (see Sections 2.6 and 2.7 in the methodology chapter). For imports sourced from BRIC countries with typically less eco-efficient industrial production processes and more impact-intensive energy mixes than EU Member States, this can significantly underestimate embodied pressures (see Rørmose et al., 2009 for Denmark). Per capita pressures caused by consumption could in fact be significantly higher than presented in Section 4.4.

The 'like-domestic-production' assumption for imports can also affect decoupling trends. Trade between Europe and the rest of the world has increased rapidly over the past decades and goods imported from BRIC countries represent an increasing share of domestic final use. If these imports have higher embodied pressures than equivalent goods produced domestically then their increasing share may work against decoupling. Therefore the success in decoupling trends shown in Figures 4.8–4.11 may be overestimated.

Other studies which use country specific data for imports have found significant increases in pressures caused by consumption in EU Member States (Gravgård et al., 2009; Helm et al., 2007).

4.8 Summary of environmental pressures caused by European consumption

Four product groups were identified which together contribute 42 %, 52 %, 37 % and 55 % to GHG emissions, acidifying emissions, ground ozone precursors and total material requirement, respectively, embodied in all consumed products in 9 EU Member States. The four groups — construction works, food products, products of agriculture, forestry and fisheries, and electricity, gas and water services — together represent only 17 % of total consumption expenditure. In other words they are among the most environmental pressure-intensive finally consumed products.

A further 7 product groups added a further 30–40 % of environmental pressures embodied in all consumed products. However, these were much less pressure intensive than the first 4 representing a 42 % share in consumption expenditure.

In addition, private households induce approximately 20 % of environmental pressures directly — mainly associated with the use of fuels for private cars and for heating of houses.

The direct household pressures and indirect pressures embodied in consumed products were assigned further to some broad functional areas of consumption. The allocation has been made according to a number of assumptions (47). Based on these assumptions the demand for three functional consumption areas Food and lodging, Housing and infrastructures, and Mobility were found to cause around 60–70 % of environmental pressures activated by national consumption in the 9 countries. This echoes findings from other European studies including the European Commission funded EIPRO study (Tukker et al., 2006).

Each of these three demand areas on their own lead to global emissions of 1.9–2.5 tonnes of CO_2-equivalents per capita in the 9 countries. In each case this is equivalent to, or more than, the quantity which Europeans will need to budget for all their activities in the long term if we are to meet the 80–95 % reduction target in GHGs by 2050.

An analysis of household consumption also found that consumption of food and beverages; housing, water, electricity and gas; and transport dominate pressures caused by household expenditure, followed by furnishings and household equipment. These four categories along with restaurants and hotels are also the household expenditure categories which cause the greatest pressures per euro spent within the five environmental pressure categories considered in this study.

Analysis showed large differences in environmental pressure intensities of individual product groups.

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(47) On, for example, the proportion of electricity used for different purposes in the home, and the proportion of hotel and restaurant services which can be allocated to food.

Emissions of GHGs per euro spent ranged by a factor of more than 20 between most services at one end of the scale, and electricity and agricultural products at the other. Material use intensity was even more variable ranging by a factor of more than 150.

Two main directions were thus identified for reducing environmental pressures caused by European consumption. Firstly, reducing the pressure-intensities of production chains for key product groups (i.e. technology improvements), and secondly shifting consumption expenditure from pressure-intensive product groups to less intensive groups — mostly represented by services (i.e. a behavioural change).

Decomposition analysis showed that to date most decoupling of environmental pressures from consumption growth has come from technological improvements. To meet the tough challenges ahead in reducing environmental pressures caused by European consumption and production a combination of technological improvement and behavioural change will be necessary.

These two factors, and the means by which policymakers can influence them, are markedly different. Encouraging technological improvements can be achieved through better regulation, increasing the price of material and energy inputs, encouraging and investing in innovative technologies, etc.

Encouraging behavioural change will require an entirely different set of measures (see EEA, 2010e). These would include the use of economic instruments, information campaigns and other means to urge consumers to spend their money on less pressure-intensive product groups.

While much further research is needed to better understand the interplay of various policy instruments and to avoid potential simplistic conclusions, addressing the consumption perspective is critical to achieving the systemic change envisaged in the resource efficiency and green economy initiatives.

5 A tool for SCP — strengths, weaknesses and future development

As outlined in the introduction, this report aimed to:

- present the tool of EE-IOA of EE-IOTs and assess its potential for answering key SCP policy questions;
- make use of the tool and the latest data available in Europe to identify the environmental hotspots and leverage points in European consumption and production;
- identify weaknesses and potential for improvement in the current application of the tool.

Chapter 2 provided an introduction to EE-IOA and outlined its potential as a tool for SCP. The tool was then demonstrated in practice to analyse environmental hotspots in European production and consumption systems. The conclusions for these analyses are given at the end of Chapter 3 (production) and Chapter 4 (consumption).

The EE-IOA method was found to be useful as part of the process of identifying focus points for SCP policy and action to be included in EU-led activities under the Flagship Initiative for a Resource Efficiency Europe and the development of the Roadmap to a Resource Efficient Europe.

When applied to national EE-IOTs, the method can be used to give not only an overview of which economic sectors are responsible for key environmental pressures, but also an understanding of the consumption indirectly driving production and its consequent environmental pressures. Such a dual approach provides much of the information necessary to focus policy actions in areas where they can have the most effect.

The national EE-IOTs in their direct form can be used to complement national emissions inventories in identifying hotpots in national production, i.e. which sectors dominate direct national air emissions and resource use. However, the real power of the tool results from the integration in EE-IOTs of environmental pressures with economic data.

Environmental pressures of individual sectors can be compared to their economic output to give an environmental intensity (environmental pressure per euro output). Trends in decoupling of environmental pressures from economic output can be analysed both at sector level and national level and broken down into some broad underlying causes: structural changes in the production mix (i.e. increase in services at the expense of heavy industry) and improvements in eco-efficiency.

A consumption perspective is gained by the application of EE-IOA to EE-IOTs. Direct pressures from industries are thus allocated to the production chains of final products placing the product in the spotlight. Similar integrated environmental and economic analysis which was applied to industries can then be applied to products.

The product or consumption perspective allows the demand-based drivers of production to be included in the picture, i.e. which products for final consumption cause the greatest pressures along their production cycles. Such a picture gives more information to policymakers, identifying not only the hotspots in production processes but identifying what consumption patterns drive these national production processes and production processes abroad. EE-IOA provides the first insights into where consumption-based policy should be targeted.

The wide range of SCP-related questions that can be answered using EE-IOA of EE-IOTs are summarised in Table 5.1. A number of these analyses were demonstrated in a European context in Chapters 3 and 4 of this report. Many of these questions are directly relevant to the Resource Efficiency Roadmap. Answering the final question in the table will also provide at least the carbon element of the 'Indicator Dashboard' identified in Annex 6 of the Roadmap.

The final objective of this report was to identify weaknesses and potential for further development. Weaknesses or limitations of the tool can be divided into two areas: a) weaknesses in the underlying data,

Table 5.1 SCP and resource efficiency relevant questions that can be answered using EE-IO analysis and NAMEA tables (*)

(Policy) Question	Perspective	Time coverage	Scope
How much do individual industries (incl. private households) contribute to total direct environmental pressures? Ranking and comparison of industries	'Production'	Single year	All industries (incl. Hh) within one economy (national or eu)
Eco- intensities of industries: Which industries are most (least) intensive in terms of environmental pressure per unit output (or per gross value added)?	'Production'	Single year	All industries (incl. Hh) within single economy; or single industry across many economies
How well are individual industries, or a whole economy, decoupling environmental pressures from growth in output?	'Production'	Time series	One industry within one economy (national or eu); or whole economy
To what extent has decoupling of pressures occurred as a result of structural change in an economy (i.e. changes in industry mix), and to what extent as a result of eco-efficiency improvements within industries?	'Production'	Two year points, or time series	One economy
To what extent are differences in national per capita environmental pressures a result of differences in GDP/capita, structural differences in economies and better or worse eco-efficiencies in similar industries?	'Production'	Single year	Across many economies
Which consumed product groups are most responsible for indirect pressures activated by consumption? Ranking and comparison of products	'Consumption'	Single year	All product groups in one economy
Eco- intensities of product groups: Which product groups are most (least) intensive in terms of embodied environmental pressure per euro?	'Consumption'	Single year	All product groups in one economy; one product group across economies
How are indirect environmental pressures distributed across the categories of final use (private household consumption, government consumption, investments, exports)?	'Consumption'	Single year	All final use categories in one economy; one final use category across economies
Have the indirect pressures caused by national consumption been decoupled from growth in consumption expenditure?	'Consumption'	Two year points, or time series	One economy
To what extent has decoupling of indirect pressures from growth in consumption occurred as a result of changes in types of products being consumed, and to what extent as a result of eco-efficiency improvements along the production chain of individual product groups?	'Consumption'	Two year points, or time series	One economy
What is the ratio of indirect environmental pressures caused by national consumption which are emitted domestically compared to those taking place in the rest of the world? (problem shifting)	'Consumption'	Single year	One economy; across economies (can also be broken down by product groups)
How do environmental pressures activated by national consumption compare with environmental pressures activated by national production?	'Consumption' versus 'Production'	Single year	One economy; across economies

Note: (*) The blue rows mark the questions that have been analysed in Chapters 3 and 4.

Source: The table has been derived from Table 14 given in Eurostat, 2009.

b) limitations in the potential of the EE-IOA method. There are solutions to both types of limitation. These are considered in the next two subsections.

Weaknesses in data and methods

Weaknesses in data act as barriers to achieving the full potential of EE-IOA as a tool for SCP

The analysis of national EE-IOTs has proved a potentially powerful tool for SCP analysis. However, some weaknesses in the underlying data and the method using these tables on their own currently act as barriers to the method achieving its full potential. These include the following:

1. ***Outdated data*** — national and EU EE-IOTs require two types of data: economic data and environmental accounts. The environmental accounts and the basic economic accounts required for the production perspective are reported under a gentleman's agreement to Eurostat by countries every two years with a three-year time delay. However, the reporting

obligations for the symmetric input/output tables required to build the consumption perspective are only once every five years with time lags of at least three years. The most up to date symmetrical input-output data are typically 3 to 8 years old and sometimes older. This limits the potential of the method in guiding timely policy.

2. *Level of aggregation* — in the EU, national accounts split economies into between 60 and 120 different economic sectors, compared to several hundreds in Japan and the United States. This can cause errors in analysis of the causes of decoupling trends (overemphasises the role of eco-efficiency improvements) and can limit the method's potential in precisely identifying lever points.

3. *Production processes in other countries* — national EE-IOTs include no data on where imports are sourced or how they are produced. Therefore, when building the consumption perspective it is currently necessary to assume that imported products have the same embodied pressures as if they had been produced in the home country. This can lead to significant underestimates of global pressures activated by consumption, particularly for imports from BRIC countries where environmental intensities of production may be several times higher than in Europe.

4. *International transport* — conceptually, environmental pressures of international transport is considered in EE-IOA through the purchase (e.g. by the retail sector) of domestic transport services and import of transport services. However, there are currently problems with including international transport pressures into the embodied pressures of imports.

5. *Environmental scope* — the catalogue of environmental accounts collected by Eurostat so far comprises only air emissions. For this report the ETC has included resource use from material flow accounts reported to Eurostat. The value of the tool would be increased if this data was extended to include other pressures such as land use, wastes, water, and toxic emissions to water and soil.

6. *Allocating products to consumption activities* — for policy analysis it can be useful to take a step beyond an analysis of the environmental pressures associated with product groups and rather investigate environmental pressures associated with activities like eating and drinking, and mobility, as was done in Chapter 4. Household expenditure is allocated by such functional activities under COICOP classification but there is no standard way for mapping the CPA categories found in national accounts to COICOP categories. Eurostat made an attempt in 2009 to develop a standard mapping matrix by adapting those used at country level but the task proved unsuccessful. Such a matrix needs to be supported by detailed household survey data on the functional use of products (for example, electricity).

7. *Moving away from averages* — information on environmental pressures caused by consumption can only be derived for an 'average' citizen in a country or region using EE-IOTs. This despite the fact that consumption patterns and the drivers that underpin that consumption can vary dramatically across society and between different socio-economic groups. Tailoring consumption-based policy more directly to different consumer groups would benefit from more detailed information on the consumption expenditure of different socio-economic groups.

Overcoming weaknesses in data and methods

Some of the weaknesses above can be overcome with time through improvements in the method and/or underlying data, others through the use of complimentary tools.

It is unlikely that reporting obligations to Eurostat (issue 1) will be changed in the near future to require more regular or timely reporting by national statistics offices of symmetric input/output tables. However, in the shorter term, gaps and time lags can be filled through use of 'now-casting' methodologies using the officially submitted five-yearly tables as the starting point or using annually reported supply and use tables to derive SIOTs. Eurostat has investigated the potential for developing and applying now-casting methods to their environmental accounts but are yet to make any concrete plans for their implementation. There are certainly no plans to now-cast economic input-output data which is central to the temporal coverage of EE-IOTs.

The resolution of IOTs (issue 2) collected by Eurostat (60 industries) is unlikely to be extended in the mid-term. One possible solution would be to use tables provided by selected national statistical institutes which have more detailed industry breakdowns. In addition, the EXIOPOL model produced under contract for the European Commission (see below) has disaggregated IOTs for Europe as a single region into 129 sectors and final products. Disaggregation has focused on sectors of special environmental concern such as the agricultural, food, metal, and energy sectors.

Eurostat and the EEA-ETC/SCP are currently assessing various methods for improving the estimates of pressures embodied in imports (issue 3). The methods range from the more simple solutions such as applying country- or region-dependent adjustment factors to imports, to the much more complex solution of integrating with multiregional input-output tables.

An example of an MRIO table is the one developed by the EXIOPOL (48) project which uses year 2000 as reference year. The countries specifically covered by the EXIOPOL MRIO model represent 95 % of the global economy for the year 2000, while the remainder of the countries are treated as the 'rest of world'. This model used data on where imported goods originate, and determined pressure coefficients for production processes in Europe's trade partners. This should allow improved estimates of the pressures embodied in imports including those resulting from international transportation (issue 4). The EXIOPOL database, which is to be disseminated in the near future, is known as 'EXIOBASE'. A mechanism for continual maintenance, updating and improvement of the database is currently being established (49). As a successor to EXIOPOL, the recently initiated CREEA project (50) has the objective of improving the EXIOBASE and extending it with an additional year; 2007.

In the meantime, Eurostat completed in 2011 a single region EE-SUT/IOT (51) for the EU-27 as a whole covering the period 2000–2007, which can be used to analyse environmental pressures caused by European consumption. Since all trade between EU member countries is included within the EE-IOT, imports are here of less importance than for an individual EU country — they comprise solely imports from the rest of the world. In this way, errors resulting from the 'like-domestic-production' assumption are expected to be less significant but will still exist within the consumption analysis. The EEA will publish results from EE-IOA of this new data in a supplementary report in 2013.

With respect to environmental scope (issue 5), Eurostat is currently developing energy accounts and water accounts. The European Parliament has also requested the development of forestry accounts and ecosystem accounts. Energy and water accounts are the most advanced with a pilot questionnaire on energy accounts having been developed during the final quarter of 2011.

The goals of EXIOPOL also included introducing land use, energy commodities and water consumption into the model.

Supplementing EE-IOA with other tools

EE-IOA can guide policy towards the broad hotspots in consumption and production patterns

Identifying potential actions requires supplementary methods

The EE-IOA of NAMEA tables can address many SCP-relevant questions (See Table 5.1). However, development of effective policy measures and instruments to tackle unsustainable consumption and production patterns would benefit from a deeper analysis of consumption and production systems.

The macro-scale information provided by EE-IOA can identify broad hotspots in consumption and production patterns. However, these need to be combined with other tools and information sources to investigate these in more detail and to pinpoint specific actions for reducing environmental pressures. Such information can include life-cycle analyses (LCA), detailed knowledge of production processes and consumption behaviour analysis.

To further disaggregate production processes, LCA process data can be used. Hybrid LCA and EE-IOA models have been developed by a number of research programmes and are documented for example by Hawkins et al. (2007) and Yi et al. (2007). Hybrid methods combine advantages of LCA (accurate and specific data) with those of EE-IOA (ready available, complete and consistent data) (Wiedmann et al., 2009). Such studies can identify in more detail, the specific production processes with high overall environmental pressures and pressure intensities in Europe.

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(48) See http://www.feem-project.net/exiopol/index.php.
(49) See http://www.exiobase.eu/.
(50) See http://www.creea.eu.
(51) Environmentally extended supply and use table/input-output table.

For further analysis of the consumption activities which cause high environmental pressures, other types of information are necessary. As identified under issue 6, the consumption perspective as created by EE-IOA of NAMEA tables includes only indirect pressures caused by purchase of goods and services, i.e. 'from cradle to shelf'. Direct pressures arising from households cannot be allocated to final product groups using NAMEA tables. Here household surveys, LCA data and other tools are needed to identify problematic products and services. Household survey data are needed to better allocate products to specific consumption activities.

The Institute for Prospective Technological Studies, Joint Research Centre, has already made studies on the technological potential for improvements in the three consumption areas of food and drink, mobility and housing through the Environmental Improvement of Products (IMPRO) programme. These studies used combinations of LCA and EE-IOA information (52). Further IMPRO studies looked at policy options for achieving these technical improvements. However, these studies should be supplemented and referenced by studies on the gains that can be made through behavioural change.

Finally, as discussed under issue 7 above, results of the EE-IOA given in this report only provide information on environmental pressures caused by the average citizen of a country. The development of effective policy focused on reducing the environmental impacts of consumption could benefit from more disaggregated information on the environmental pressures caused by different socio-demographic groups. These groups can be characterised by their expenditure patterns, their attitudes to the environment, type of living space, etc.

Studies disaggregating environmental pressures according to socio-demographic groups have been carried out in the United Kingdom (Dawkins et al., 2010; Experian, 2009) and more recently in Sweden, but have yet to be carried out elsewhere in Europe.

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(52) See http://susproc.jrc.ec.europa.eu/activities/IPP/impro.html.

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Appendix A: Detailed description of the methodology used for the EE-IOA calulations presented in the report

Appendix A presents a short description of the analytical tools applied in the study. Section A.1 presents the general structure of monetary input-output tables and the information contained therein. Section A.2 refers to the structure of the Environmentally-Extended Input-Output-Tables. Section A.3 presents the Static Open Input-Output Model (Leontief model). Section A.4 describes models for re-attribution of domestic and global environmental pressures associated with industrial production to the final use of products produced domestically and imported. Section A.5 concerns structural decomposition analysis, by means of which the main drivers of changes in environmental pressures are investigated. In this sense, these changes are explained by changes in production volume, changes in consumption patterns, and changes in technological improvements in efficiency.

A.1 Monetary input-output tables

Monetary IOTs contain rather comprehensive information on intermediate and final use of products produced domestically and imported.

Monetary IOTs are part of the SNA. The concepts and definitions, on which they are based, are thus identical with those of the annual SNAs.

IOTs provide a detailed view on the production of goods and services, their use, as well as the generation of income resulting from production processes. Thus, IOTs give a quantitative picture of the interrelations of production and consumption activities both within a national economy and with the rest of the world. IOTs show, for instance:

- how the total supply (53) of the industries' output is used as inputs to other industries or for final use (54) (55);
- how each industry receives inputs from other industries and uses factor inputs (56).

In other words, IOTs are used to present the economic production structure of national economies. On this base, it is possible to calculate the direct and indirect effects of changes in final demand, prices and wages on the entire economy as well as its single components. The analysis of these direct and indirect effects allows the identification of interdependencies between consumption and production within the national economy that are relevant for policymaking. Further, they can be used to make (simple) projections of economic developments and to make cross-country comparisons of economic production structures and consumption structures.

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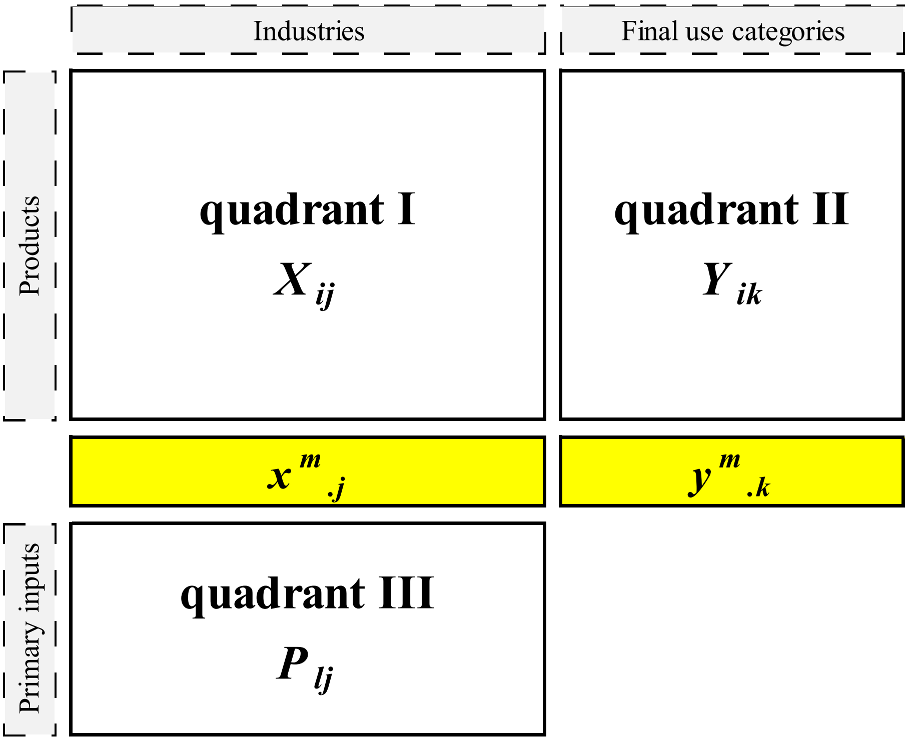
(53) Total supply includes domestic production and imports.

(54) Final use categories can be split into domestic final use (private consumption, government consumption and investment, i.e. fixed capital formation, change in inventories) and exports.

(55) IOTs can be of either the 'industry-by-industry' type or the 'product-by-product' type — see Box A.1 for more details.

(56) Factor inputs of production comprise labour and capital that are needed to transform the intermediate products into output.

Figure A.1 Simplified IOT scheme



A.1.1 A general simplified IOT scheme

Monetary IOTs comprise three quadrants as illustrated in Figure A.1.

Quadrant I (X_{ij}) is a square matrix called intermediate matrix or transformation matrix and shows the intermediate transactions of products between industries. Column *j* of quadrant I shows the use of **products** *i* (rows) used by **industry** *j* (columns) for intermediate consumption. For consistency, this notion of columns as industries and rows as products will be used within the remaining text (apart from Section 4.6.6). However, it should be noted that this is a simplification and that there are a number of different IOTs. These are described in more detail in Box A.1.

Quadrant II (Y_{ik}) is located to the right of quadrant I, and shows the final use of industries' output. It is called the final demand matrix. The columns of quadrant II represent the different components of final demand, which include household consumption, government consumption, capital formation and exports. The first column, 'private household consumption', shows for example how much output from each industry has been consumed by households.

A row across quadrants I and II shows how much output of a particular domestic product is used for further production, domestic final consumption, and for export to other countries. Thus, the sum of row *i* across quadrants I and II is the total output of industry *i*.

The imports are located as two row vectors directly below quadrants I and II, respectively (shown with dashed line). The first vector (m_{1j}) shows the total imports used by each industry, and the second one (m_{1k}) the value of imports used by each final use category.

Quadrant III (P_{lj}) is located below quadrant I. It is called the primary input matrix and shows for the producing entities (columns) the value added components they generate (rows). The components of value

Box A.1 'Product' and 'industry' notation in input-output tables

The Input-Output Framework of Eurostat (see ESA 95) provides symmetric input-output tables (SIOT). In contrast to supply and use tables which are presented annually, SIOTs are presented by Eurostat every five years. The SIOT describe the domestic production processes and the transactions in products within the national economy in detail. Two different options for presentation exist: (1) industry-by-industry transactions, and (2) product-by-product transactions.

For the type 'product-by-product', the output of one product is used as input to produce other products, or for final use. For the type 'industry-by-industry', the output of an industry (i.e. products) are used by other industries for production, or for final use. In practice the tables are very similar since the outputs of an industry would all be allocated to the same group of products, i.e. outputs of the construction industry would all also fall under the group of products 'products of the construction industry'. However, in few cases one single industry may produce products that fall within two or more broad product groups.

National SIOTs are dominantly compiled according to an industry-by-industry structure, although some countries compile them by the product-by-product structure (or even both).

The SIOTs provided by Eurostat comprise both types, although the 'product-by-product' type dominates.

The calculations carried out for this report are based on both types, according to the availability of national SIOTs. For didactic reasons, we refer in the following explanations mostly to product-by-industry tables (as derived as combined supply and use tables). In Section 0 we refer for simplicity to industry-by-industry tables (while the imports are of course presented by product groups). However, these differences are solely related to the way of presentation, and are not intended to describe differences in the model basically applied.

added are production taxes less subsidies, compensation of employees (labour), consumption of fixed capital (i.e. depreciation of investments such as machineries), and profits (net operating surplus). The latter, is part of the total factor inputs needed to transform the intermediate products into output, and represents the return to the invested capital.

The sum of column *j* across quadrants I and III is the total input into industry *j* that is necessary to produce its total output.

By definition, total input into an industry (column-sum) equals the total output (row-sum) of the same industry in monetary terms.

A.1.2 Representation of imports within input-output tables

There are several possibilities to represent imports in the IOTs. The most important ones can be summarised by the following three types (57):

- Type 0: Separate and detailed tables for imports, where the imports are classified according to foreign industries in the same way as domestic outputs are classified;
- Type I: Accounted by separate row vectors, i.e. 'total imports classified by purchaser only'; Type I is obtained by calculating column sums of Type 0 tables.

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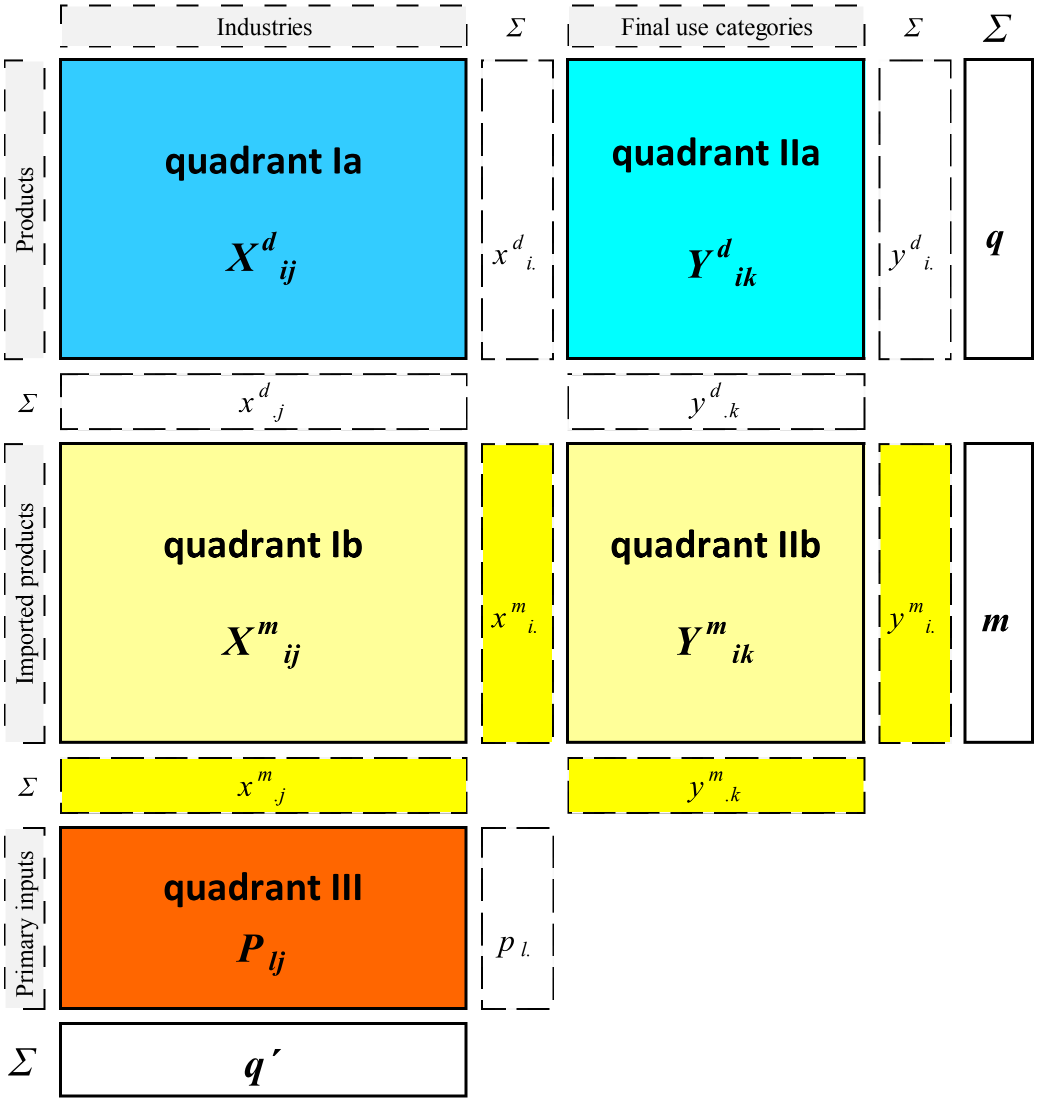
(57) Holub and Schnabl (1994) differentiate several variants of IOTs, in which the imports are more or less explicitly represented. These variants have been developed by the UN and are applied by the ESA.

Figure A.2 IOT scheme showing domestic products and imports by separate tables (Type 0)



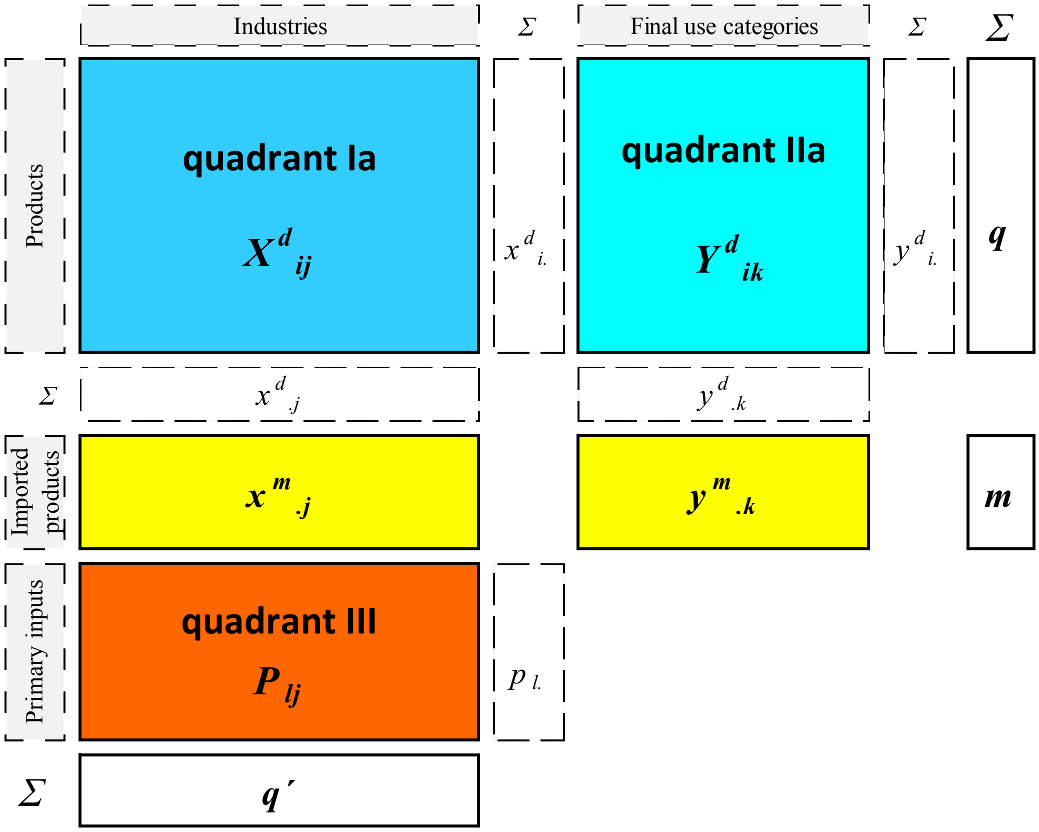
- Type II: Detailed inputs of imports (Type 0) are added to the domestic inputs industry by industry, i.e. the inputs of imports are not shown explicitly, but are included in the total use. Type II is obtained by calculating cell by cell sums of Type 0 imports and inputs of domestic production.

Type 0 is the most comprehensive variant and from this Type I and Type II can easily be derived. Figure A.2 shows the IOT scheme according to Type 0 ([58]).

In variant Type 0, the imports are represented by origin (producing industry) and according to their use by industries (intermediate use), and final use components (e.g. private household consumption). Thus, such an import matrix contains comprehensive information with regard to the structure of use, and the values of product groups imported.

([58]) Modified after UN (1999), Table 6.4, p. 159.

Figure A.3 IOT scheme with imports classified by purchaser (Type I)



By including the detailed Type 0 information on imports, Figure A.1 is expanded into Figure A.2 and shows five quadrants as follows:

- Quadrant Ia [X^d_{ij}]: *Matrix of domestic intermediate production* shows the transactions between the industries, i.e. the supply and use of intermediate products for domestic production. For example, domestically produced output from the steel industry used by the domestic automobile manufacturing industry;
- Quadrant Ib [X^m_{ij}]: *Matrix of imported intermediate consumption* shows the intermediate use of imports by delivering foreign and domestic using industries. It includes, for instance, tyres imported from the Brazilian rubber industry and used by the domestic automobile manufacturing industry;
- Quadrant IIa [Y^d_{ik}]: *Matrix of domestic final demand* shows the final demand of output from domestic industries. It includes, for instance, domestically produced automobiles bought by private households;
- Quadrant IIb [Y^m_{ik}]: *Matrix of imported final demand* presents the final use of imports by delivering foreign industries. It includes, for instance, Japanese cars, which are bought by private households;
- Quadrant III [P_{lj}] remains as in the simplified scheme in Figure A1 and presents the components of value added for each producing entity.

Type I presents the total imports by using industries and final demand categories, without the differentiation by foreign industry. Variant Type I is generated from Type 0 by aggregation of the import matrices (quadrants Ib and IIb) from *i* rows to one row vector. These row vectors x_{1j} and y_{1k} are located directly below quadrants Ia and IIa, respectively. As the quadrants Ia, Ib, and III remain the same, the descriptions of these quadrants for Type 0 apply accordingly for Type 1. Figure A.3, which basically is the same as Figure A.1, shows the IOT scheme according to Type I (59).

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(59) Modified after Holub and Schnabl (1994).

Type II presents the imports and the products produced domestically within a single quadrant, for intermediate use and final use, respectively. Figure A.4 shows the IOT scheme according to Type II (60). Type II is derived from Type 0 by addition of the corresponding matrices, i.e.:

- the addition of *matrix of domestic intermediate production* (quadrant Ia) and the *matrix of imported intermediate products* (quadrant Ib) (61), and
- the addition of *matrix of domestic final demand* (quadrant IIa) and the *matrix of imported final demand* (quadrant IIb), respectively (62).

This leads to the quadrants I with matrix X^T_{ij} and II with matrix Y^T_{ik} (Figure A.4). X^T_{ij} (quadrant I) is a matrix that presents the applied production technology, because it shows for each industry all intermediate inputs (regardless of whether they are domestically produced or imported) that are used for the production of the outputs of that industry. Similarly, Y^T_{ik} (quadrant II) is a matrix that presents the total final use of products, regardless of whether they are domestically produced or imported.

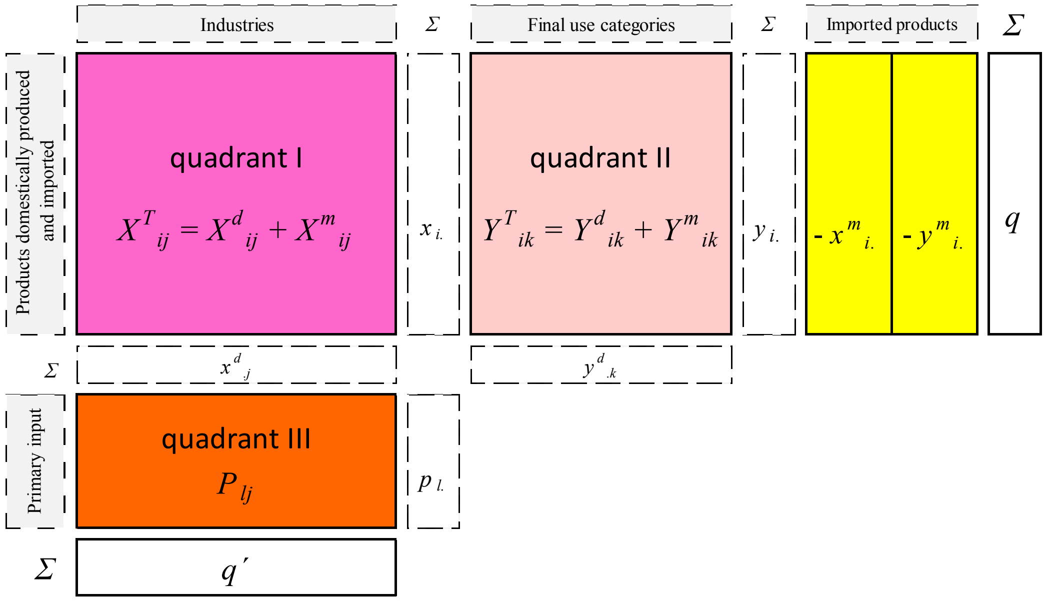
By adding up domestic output and imports, the row sums in a type II matrix no longer represent the total domestic production (vector *q*). The rows include now also the imports (vector *m*). Therefore, in order to achieve a balance between inputs and outputs, it is necessary to add a correction matrix (see yellow vectors in Figure A4). This correction consists of the subtraction of the imports as column vectors $-x^m_{i.}$ and $-y^m_{i.}$ In other words the vectors in the pink matrix contain the negative values of imports by product group.

A.2 Environmentally-extended input-output tables

EE-IOTs integrate economic data with environmental data (air emissions, resource use) according to the SNA.

EE-IOTs are an element of the UN System of Integrated Environmental and Economic Accounts (SEEA) introduced by the UN and others (63). An EE-IOT is a monetary IOT (cf. Section A.1) extended by

Figure A.4 IOT scheme classifying imports by commodity (Type II)



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(60) UN (1999), Table 6.2, p. 159.

(61) This means that the imports are assigned to those industries, which produce the same (or at least similar) products; then, the imports are distributed along with the domestically produced goods among the users (consumers).

(62) Matrix addition means adding components of the matrices, component by component (i.e. cell-by-cell).

(63) United Nations, Eurostat, International Monetary Fund, Organisation for Economic Co-operation and Development and World Bank (2003): Handbook of National Accounting — Integrated Environmental and Economic Accounting 2003, United Nations publications Series F, n° 61, rev. 1, New York.

environmental accounts. These accounts represent environmental pressures, i.e. physical data on direct inputs and outputs from and to the environment broken down by industries (⁶⁴) and final demand categories, such as private households, where relevant.

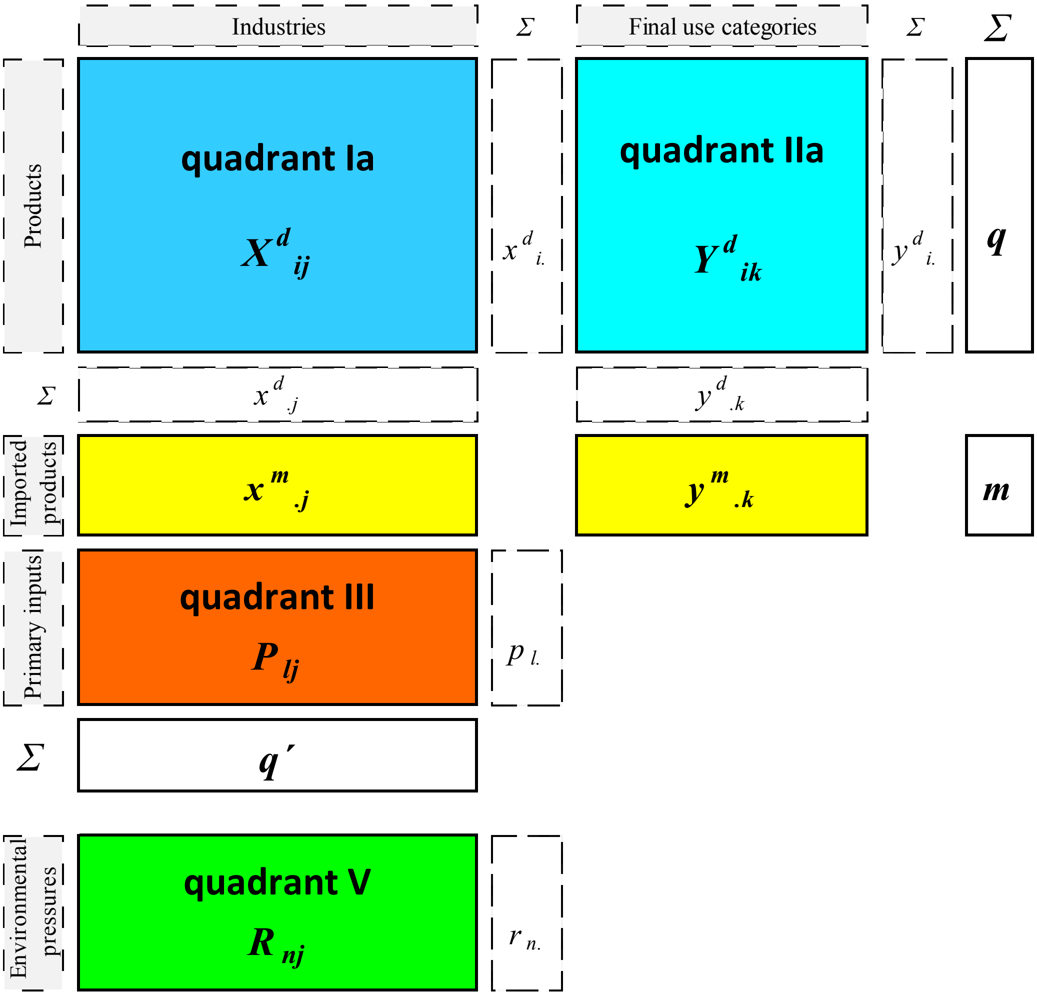
Generally, primary data from environmental statistics (such as air emissions, water, waste, resource use, energy and land use) do not apply classifications and accounting rules that are compatible with the IOTs. Hence, primary environmental data need to be adjusted to the classifications and accounting principles of national accounts before used as extensions of IOTs. Once this adjustment is carried out, economic data (in monetary units) and environmental data (in physical units) are integrated by EE-IOTs.

Although still rather limited, the availability of environmental accounts is gradually increasing; Eurostat provides regular updates of both air emission accounts and MFAs based on data transmissions from member countries. Within the environmental accounts air emission accounts (sometimes called NAMEA Air) are the most advanced.

A.2.1 EE-IOT schemes as used in this study

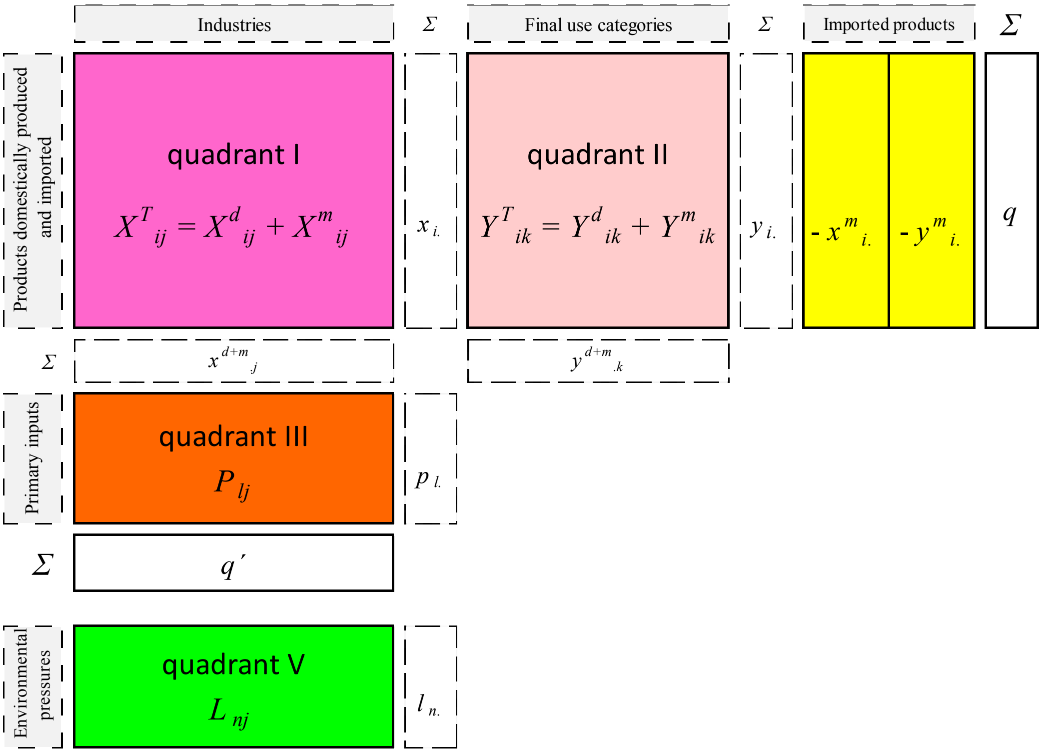
In order to generate an EE-IOT, it is necessary to combine one of the variants of IOTs as introduced in Section A.1 with compatible environmental accounts. Figure A.5 shows the EE-IOT scheme according to

Figure A.5 EE-IOT scheme as used for material resources in this study, variant Type I (see text)



(⁶⁴) The term industry does not only refer to manufacturing industry, but also to services.

Figure A.6 EE-IOT as used for air emissions in this study, variant Type II (identical to Figure 2.3 given in the main report)



variant Type I, while Figure A.6 shows the EE-IOT of applied production technology according to variant Type II. The schemes of the EE-IOT used within this study (65) refer to variant Type II for air emissions and to variant Type I for resource and material use, respectively.

The upper part of the EE-IOT schemes contains the monetary IOTs, which has been described in Section A.1, while the lower part of the EE-IOT schemes contains the environmental accounts, such as environmental pressure variables (rows) by industry (columns) (66).

The difference between the two schemes is limited to the IOT (see Section A.1 in this appendix), as it refers to the treatment of imports. In particular, in the case of quadrant I the inclusion of the imports as part of intermediate use has important implications with regard to the environmental effects (i.e. higher/lower environmental pressures) resulting from the applied production technology (Figure A.6).

The environmental pressures caused directly by the domestic industries are dependent on the production technology. Nevertheless, they are independent from the means used to represent the production technology. Since the inclusion of the imports into quadrant I is solely a matter of representation of production technology (but does not affect the volume of the direct environmental pressures by industries), the environmental accounts are equivalent in both schemes.

Variant Type II represents the actually applied production technology; therefore, it is considered here as standard variant. Where the application of variant Type II is constrained due to characteristics of the calculation of environmental accounts, the other variants can be seen as options according to the purpose of the analysis.

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(65) Information on how this system can be derived from T-accounts is given in the report, Section 2.2.

(66) The coverage of the final use categories is dependent from the type of environmental accounts, e.g. air emissions accounts provide data for households, only.

Box A.2 Economy-wide material flow accounts (EW-MFAs) and derived indicators

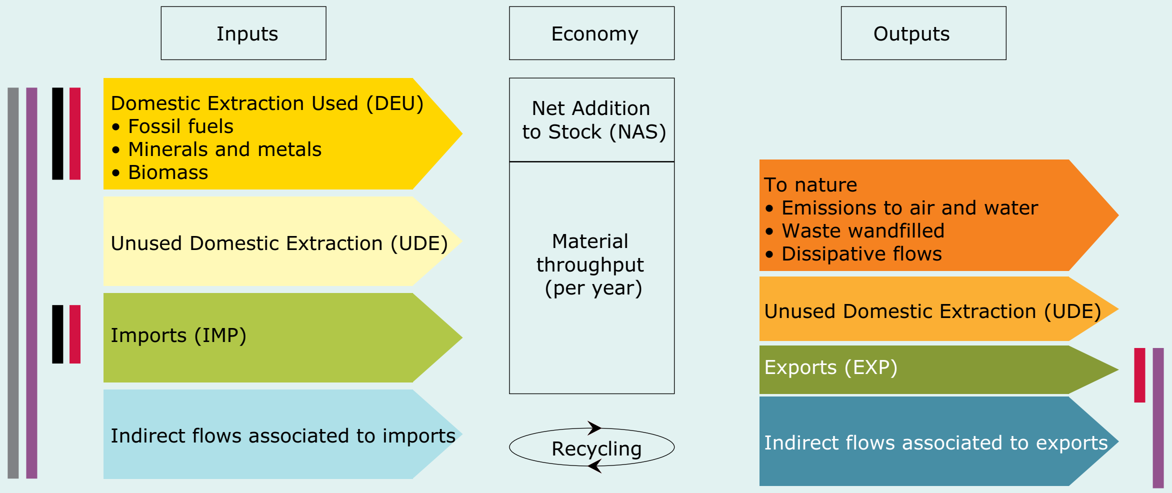
To monitor economy-wide material flows, Eurostat has applied an accounting methodology and a number of indicators that describe the material throughput and material stock additions in a (national) economy expressed in tonnes. EW-MFAs account for all extraction of biomass, fossil fuels, metal ores and metals, and industrial minerals, as well as the imports and exports of all goods, but exclude water and air. The most frequently used MFA indicators, often given in tonnes per capita, are:

- **Domestic Extraction Used (DEU)** that sums all natural resources that are extracted in a given country and used in the economy;

- **Direct Material Input (DMI)** that measures the input of materials into the economy, that is DEU plus physical imports of goods (IMP);

- **Domestic Material Consumption (DMC)** that equals DMI minus exports (EXP) and thus represents the domestic material consumption of an economy;

- **Total Material Requirement (TMR)** is also used in this paper to the extent possible in order to include hidden or indirect material flows (i.e. the material rucksack) associated with both domestic material extraction (Unused Domestic Extraction, UDE) and the materials imported (Raw Material Equivalents, RME, and the unused extraction abroad).



DMI = DEU + IMP
TMR = DMI + UDE + indirect flows associated to imports

DMC = DEU + IMP – EXP
TMC = TMR – EXP – indirect flows associated to exports

Available data of air emissions accounts refer to the air emissions caused by the domestic industry (including private households) only. In contrast, there are normally no data on air emissions associated with the production of the imports (air emissions embedded in imports). Based on the assumption that the imports are produced according to the same production technology as applied domestically, it is necessary to apply the EE-IOT of Type II, in order to calculate the global air emissions induced by total final use (domestic production plus imports).

Economy-wide material flow accounts (EW-MFAs) provide data on resource and material use in a different way. Available data refer to resource and material use by product groups for the whole economy. This includes the domestic extraction used, unused extraction, the imported materials and their hidden flows.

In order to generate the environmental accounts that can be connected with the IOA model, it is necessary to allocate the imports to the industries and to the final use categories. By doing so for DMI and TMR, the direct environmental pressures associated with imports are already accounted within the EW-MFA accounts according to the conceptual characteristics of EW-MFA (see Box A.1 in this appendix).

Obviously, application of variant Type II would require further adjustments in order to avoid deviations from given EW-MFA indicators. By application of variant Type I, such possible deviations are avoided.

A.2.2 Input coefficients

A column *j* across quadrants (67) I (X_{ij}) and III (P_{lj}) presents all inputs that are required by industry *j* to produce its total output x_j. Hence, such a column of inputs can be interpreted as a specific 'recipe' for this industry — with each input (cell) constituting an 'ingredient'. Assuming a linear relationship between such 'ingredients' (i.e. inputs) and output, 'specific quantities per unit output' can be calculated. They are called input coefficients. Thus, an input coefficient is the ratio of a certain intermediate input or primary factor to the total output, i.e. an input coefficient expresses how much input (in monetary terms) is needed to produce one unit of output. The sum of all input coefficients within a column thus equals 1.

Input coefficients can be calculated for all columns across quadrants I and III. The results are input coefficient matrices, i.e. one input coefficient matrix of quadrant I and one of quadrant III.

Depending on the IOT/EE-IOT scheme (cf. Sections A.1.2 and A.2.1), different input coefficient matrices in relation to quadrant I can be derived as follows:

- For variant Type II, the corresponding input coefficient matrix is calculated by taking into account domestically produced and imported intermediate inputs (technological coefficient matrix). It is denoted as $\boldsymbol{A}_{tec}$ in the following.
- For variant Type I, the corresponding input coefficient matrix is calculated by taking into account the domestically produced intermediate inputs, only (domestic coefficient matrix). It is denoted in the following as $\boldsymbol{A}_{dom}$.

A.2.3 Environmental pressure intensities

So far, we considered in Section A.2.2 only input coefficients inherent to the IOT scheme, i.e. intermediate inputs and components of value added (so-called primary inputs). However, within an EE-IOT there are other variables that emerge due to production activities and that can be related to the output by industry in a similar way to the calculation of the input coefficients. Considering the environment as the source for natural inputs, such as material resources, energy or land, for the industries, the variables refer to the input side of production. Considering the environment as a sink with an absorption capacity (for example, for absorbing air emissions or wastes generated by the industries in conjunction with their production activities), the variables refer to the output side of production. These variables represent the environmental accounts located in quadrant V (X_{ij}) of an EE-IOT, and are called environmental pressures within this report. Environmental pressures are usually expressed in physical units such as tonnes, kilojoules or hectares.

The quotient of (a) the above-described variables by industry and (b) the output by industry can be calculated — in analogy to the input coefficients (cf. Section A.2.2). By doing so, these coefficients represent the direct environmental pressure intensities per unit output of an industry, or in short environmental pressure intensities. The units of the environmental pressure intensities are thus expressed in physical units per monetary unit, (for example, tonnes/euro, kilojoules/euro, etc).

---

(67) For simplification, we refer in the following to a composite quadrant I (Type II); however, the explanations also hold accordingly for the case where imports appear by separate row vectors (Type I).

An example is to relate material resource use which is required by an industry to the total output of that industry. The calculated coefficient shows how much resources are needed for the production of a unit output of that industry. Another example is to relate for a certain industry the CO_2 emitted to the total output. The calculated coefficient then indicates how much CO_2 is emitted per unit of output of that industry.

A.3 Static open input-output model

The static open input-output model is a linear production model, for which the final demand is disconnected from the technologically interrelated productive industries. The term 'open' means that the final demand is completely exogenously determined, and does not change by the modelling. The model is termed 'static' as all variables within the model refer to the same period, and it does not support analyses regarding the development of variables over time ([68]).

Accordingly, the static open input-output model enables the calculation of the direct and indirect production induced by changes in final demand for products. In general, changes in final demand for a certain product (see Box A.1) do not only affect the output of the respective industry (direct production), but also the output of any other industry (indirect production). For instance, if the final demand for motor vehicles increases, more tyres, steel and glass also need to be produced. These increases in the production of tyres, steel and glass trigger likewise the output of further industries, such as electricity, mining, etc. The static open input-output model enables the determination of the total production by each industry, which is activated by the increase in final demand for a certain product.

This relation of cause-effect can be represented by the following linear equation:

$$\boldsymbol{q} = \boldsymbol{A} \cdot \boldsymbol{q} + \boldsymbol{y} \qquad \text{(eq. 1)}$$

where:

$\boldsymbol{q}$: production output

$\boldsymbol{A}$: input coefficient matrix

$\boldsymbol{y}$: final demand

This is equal to:

$$\boldsymbol{q} = (\boldsymbol{I} - \boldsymbol{A})^{-1} \cdot \boldsymbol{y} \qquad \text{(eq. 2)}$$

where: $(\boldsymbol{I} - \boldsymbol{A})^{-1}$:Leontief inverse matrix

A particular feature of equation 2 is the so-called Leontief inverse matrix $(I - A)^{-1}$. The components L_{ij} of this matrix represent the result of the manifold and complex interactions between all industries. The component L_{ij} shows how much production output by industry i is required directly and indirectly, to enable industry j to generate one unit of its production output.

By summing up column j of the Leontief inverse matrix to one scalar, a Leontief-multiplier is calculated. Hence, the Leontief-multiplier for industry j shows the total production output of all industries (including industry j itself) required in order to produce one unit of its production output for final demand.

Depending on the input coefficient matrix, according to variant Type II or Type I of IOT/EE-IOT (Section A.1 and A.2) that are used, different Leontief inverse matrices are derived. A Leontief inverse matrix derived from the technological coefficient matrix (variant Type II of IOT/EE-IOT) will be denoted as $(\boldsymbol{I} - \boldsymbol{A}_{tec})^{-1}$, while one derived from the domestic coefficient matrix (variant Type 0 and Type I of IOT/EE-IOT) will be denoted as $(\boldsymbol{I} - \boldsymbol{A}_{dom})^{-1}$.

([68]) Holub and Schnabl (1994).

A.4 Re-attribution models

A.4.1 Introduction to re-attribution models

Re-attribution models are models which use the logical structure of static open input-output models (69) in order to connect final demand categories with:

a) primary input categories: This concerns re-attribution of variables that are included in the IOT scheme as components of the primary input matrix, e.g. primary input categories such as gross value added in euro;
b) other policy-relevant variables, like environmental pressures: This concerns re-attribution of variables that are outside the IOT scheme (quadrant V of EE-IOT) and that generally are measured by units other than monetary ones, e.g. air emissions (such as CO_2) in tonnes.

While in the first case — for example, for gross value added — the results of the modelling (i.e. the re-attributed gross value added) can be interpreted as gross value added content of final demand, in the second case — for example for CO_2 emissions — the results of the modelling are to be interpreted as CO_2 emissions induced by final demand.

Furthermore, the re-attribution models (70) can be differentiated by three kinds of re-attribution, all of them potentially applied for both primary input categories, and other policy-relevant variables (see above):

- direct re-attribution (also termed simple attribution), applying output-coefficients;
- direct and indirect re-attribution to final demand (i.e. the standard type re-attribution);
- direct and indirect re-attribution to production-transformations (sub-systems).

The application of these three kinds of re-attribution can be recognised within the following three re-attribution models (Sections A.4.2–A.4.4).

A.4.2 The standard re-attribution model

In a more narrow sense, the term re-attribution is restricted to the standard type re-attribution (cf. overview in Section A.4.1) that concerns direct and indirect re-attribution to final demand. In the following, all explanations refer to this standard type of re-attribution models.

The starting point for deriving re-attribution models is the direct link between the environmental pressures and the production output. For a single industry, this link can be expressed by the following equation:

$$g_j = gt_j / q_j \qquad \text{(eq. 3)}$$

where:

g_j: environmental pressure intensity (i.e. direct environmental pressure per unit output of industry j)

gt_j: environmental pressure caused by production of industry j

q_j: production output of industry j

---

(69) The static open input-output model is often called basic Leontief model.

(70) A re-attribution model is not a prognosis tool; rather, all the analysis-components used in a re-attribution model stem from the same time base (usually the year for which the IOT/EE-IOT is computed).

The calculation of the direct environmental pressure intensity for all industries can be achieved by applying the following equation [71]:

$$g = \langle q \rangle^{-1} \cdot gt' \qquad \text{(eq. 4)}$$

where: g: environmental pressure intensities by industry (column vector)

$\langle q \rangle^{-1}$: inverse of the diagonalised production output vector (matrix)

gt': environmental pressure by industry (column vector)

That is equivalent to writing:

$$gt' = \langle g \rangle \cdot q \qquad \text{(eq. 5)}$$

where: gt': environmental pressure by industry (column vector)

$\langle g \rangle$: diagonalised vector of environmental pressure intensities by industry (matrix)

q: production output by industry (column vector)

Finally, the re-attribution model can be derived by replacing the production output by industry in equation 5 with the production output by industry in equation 2 (static open input-output model):

$$gt = \langle g \rangle \cdot (I - A)^{-1} \cdot y \qquad \text{(eq. 6)}$$

Furthermore, environmental pressure multipliers can be determined according to equation 7:

$$gm = g \cdot (I - A)^{-1} \qquad \text{(eq. 7)}$$

where: gm : environmental pressure multiplier by industry (row vector)

$$gt = gm \cdot y \qquad \text{(eq. 8)}$$

Equation 6 represents the general equation for the re-attribution model. According to this equation, the environmental pressure by industry is:

- explained through an ex ante model rather than through a merely definitional equation (equations 3 and 5);
- linked to A (the matrix of applied technologies by the industries) and y (the vector/matrix of final consumption of produced product groups) through the Leontief's production function;
- estimated on the basis of environmental pressure multipliers by industry or product groups, so that all direct and indirect effects along the production chain are taken into account.

Also here, the Leontief inverse is dependent on the selection of the input coefficient matrix that can be calculated according to variant Type II or Type I of IOT/EE-IOT (A_{tec} and A_{dom}, respectively). This means that also the multipliers differ for variant Type II or Type I.

Here, two re-attribution models are distinguished:

- attribution by final demand categories (Section A.4.3);
- attribution by finally demanded products (Section A.4.4);

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(71) In the following text, transposed vectors are marked with symbol '; capital letters indicate matrices, while non-capital letters indicate vectors (or diagonalised vectors).

A.4.3 Re-attribution to final demand by final demand categories

Final demand in equation 6 can be expressed by the entire final demand matrix ***Y*** with dimension (*i,k)*; assuming that the number of the product groups is *i* = 59, and the number of categories of final demand is *k* = 6. The numbers reflect the dimensions of the IOT used for the analysis in this report ([72]). Then, the following re-attribution model results (the squared brackets indicate in the following the dimensions of the matrices or vectors):

$$Gt^{*c} = \langle g \rangle \cdot (I - A)^{-1} \cdot Y \qquad \text{(eq. 9)}$$

[59,6] [59,59] [59,59] [59,6]

The environmental pressure matrix resulting from the re-attribution has the dimensions [59,6]. This environmental pressure matrix shows how much of an environmental pressure per product group is directly and indirectly induced by the total of each of the six different categories of final demand, i.e. private household consumption, government consumption, exports, etc.

A.4.4 Re-attribution to final demand by products

This re-attribution model is given by equations 7 and 8. For this purpose, the diagonal vector ***gm*** is multiplied by the final demand matrix ***Y***.

$$Gt^{*r} = \langle gm \rangle \cdot Y \qquad \text{(eq. 10)}$$

[59,6] [59,59] [59,6]

The environmental pressure matrix resulting from the re-attribution has the dimensions [59,6], i.e. broken down by 59 product groups and six categories of final demand. This environmental pressure matrix shows how the environmental pressure, which is directly and indirectly induced by the total final demand of each product group, is distributed by final use categories. This study applies re-attribution models as expressed by equation 10.

A.4.5 Domestic versus global re-attribution

The EE-IOT schemes as used in this study (see Figure A.5 and Figure A.6) lead to two different Leontief inverse matrices and different final use matrices. Hence, we can distinguish a domestic-oriented model and a global-oriented model, corresponding to the variants Type I and Type II, respectively (cf. Section A.3).

A.4.5.1 The domestic-oriented model

The domestic-oriented model quantifies the direct and indirect effects on, for example, production, value added, or emissions induced by the final demand of products domestically produced. This can be expressed by the following equation (see equation 10):

$$Gt^{*rYdom} = \langle gm_{dom} \rangle \cdot Y_{dom} \qquad \text{(eq. 11)}$$

where: $gm_{dom} = g \cdot (I - A_{dom})^{-1}$

Y_{dom} : matrix of final demand of products produced domestically

A_{dom} : domestic coefficient matrix

---

(72) The IOTs used for this report are based on NACE rev 1.1 that distinguishes 60 industries and 60 product groups (NACE A60, CPA P60), respectively. However, as the reported IOTs do generally not include data for product/industry group 'extraterritorial organisations', the dimensions of the IOTs in the following are reduced to 59 by 59.

By employing Y_{dom} and A_{dom}, this domestic-oriented model strictly considers only patterns of domestic intermediate production and final consumption of the domestic production, i.e. it neither considers the intermediate use, nor the final use of imported products. This domestic-oriented model re-attributes the domestic environmental pressures, only, i.e. those environmental pressures which result from domestic production.

In this study, the domestic-oriented model has been applied for the re-attribution of global resource and material use associated with domestic production, which in the case of TMR also includes all hidden flows (e.g. ecological rucksack) to final consumed products (73).

In other words, the method has been used for estimating the TMR and DMI associated with final consumption where presented in the figures in Chapter 4 of the main report.

A.4.5.2 The global-oriented model

The global-oriented model quantifies the direct and indirect effects on, for example, production, value added, or emissions induced by the final demand of products globally produced. This can be expressed by the following equation (see equation 10):

$$Gt_g^{*rYtot} = \langle gm_{tec} \rangle \cdot Y_{tot} \qquad \text{(eq. 12)}$$

where: $gm_{tec} = g \cdot (I - A_{tec})^{-1}$

Y_{tot} : matrix of final demand of products produced globally (domestic and imported products)

A_{tec} : technological coefficient matrix

By employing Y_{tot} and A_{tec} this global-oriented model considers the technological production patterns, i.e. it does consider — in contrast to the domestic-oriented model — also the intermediate use and the final use of imported products. This global-oriented model re-attributes the global environmental pressures due to total domestic final use, i.e. the environmental pressures which result from domestic production and production of imported products.

In this study, the global-oriented model has been applied for re-attribution of air emissions caused by global production. In other words, the method has been used for estimating the GHG emissions, tropospheric ozone precursors and acidifying emissions associated with final consumption products where presented in the figures in Chapter 4 of the main report.

A.4.5.3 Methodological limitations of the models applied

Evidently, these models can only approximate the global direct and indirect environmental pressures. It implies that input-structure, energy-mix and emission factors (and factors of other environmental pressures), etc. are assumed to be the same independent of where intermediate and final goods originate, i.e. the assumption is implicitly made that imported products induce the same direct and indirect environmental pressures as if the respective product would have been produced domestically according to technological production patterns. This assumption is called domestic production technology assumption because it is implicitly assumed that products, which are imported, were produced with the same technology (A_{tec}) as the products which are produced domestically. This does not accurately represent conditions in the real world, and interpretations of the results should be made with this in mind.

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(73) In order to estimate the total resource use caused by total final use, it is necessary to add the resource use associated with the imports for final use (not covered by the model).

An alternative and somewhat more correct interpretation of the environmental pressures calculated by equations 11–14 is that these environmental pressures would have occurred, if all products including the imported ones were produced in the country and with application of the average technology and emission factors (and factors of other environmental pressures). Hence, these environmental pressures can be interpreted as those environmental pressures, which are avoided domestically through the import of intermediate and final products.

Considerations on how embedded environmental pressures can be better accounted for are discussed in the report in Section 2.7.

Furthermore, the model results should be treated with some caution because of the following potential inaccuracy: the model makes implicitly the assumption that the supply of EUR 1 of semi-finished products from, for example, the chemical industry to the agricultural industry induces the same amount upstream of environmental pressure as EUR 1 of semi-finished products, which the chemical industry supplies to the vehicle manufacturing industry. This does not always correspond completely with the reality, as the car industry and agriculture generally use chemicals with differing environmental pressure intensities (pressure per euro).

A.4.6 Further explanations on the application of EE-IOA on material flows

As described in the report in Chapter 1, this report builds on former analyses of the ETC/SCP. For this study, the method was further enhanced related to the implementation of material flows data in EE-IOA. This was necessary because the information contained in the EW-MFAs requires special treatment when used for EE-IOA purposes. In the following, the application of EE-IOA on EW-MFAs is explained by illustrating how material flows should be treated in order to calculate the material resource use directly and indirectly induced by the total final demand.

A.4.6.1 Concepts and definitions

The material that enters the economic system for further processing comprises the DEU (74), and the Imports (IMP) (75). They form together the DMI (76) (see Box A.1).

Adding the material resources used indirectly for providing the material imports, and unused extraction, e.g. overburden from mining activities and unused residuals of biomass extraction, to the DMI results in the TMR. In other words, the TMR includes the DMI, the UDE and the Hidden Flows of the Imports (HFIMP).

The system boundaries of the EW-MFA indicators are the geographical borders of the national economy, to which they refer. This means that the EW-MFA indicators (DMI and TMR) cannot be used for a region/aggregate (group of countries like the EU) without carrying out corrections on bilateral trade between the single economies of the region/aggregate.

According to EW-MFA definitions:

- for the DMI, the imports consist only of the pure mass being further used in the economy (both for domestic production and for final use);
- the share of the TMR referring to the IMP (i.e. the 'foreign TMR' of an economy) consists of the imports (pure mass) and the hidden flows associated with these direct imports (HFIMP);

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(74) DEU sums all raw materials that are extracted in a given country and used in the economy.

(75) Although the imports are covered by EW-MFAs, the perspectives by economic sector and final product, respectively, required a higher resolution of trade flows than provided by EW-MFAs. For this purpose, the database ComExt was used (see report, Section 2.8).

(76) The compilation of material input data followed the nomenclature and categorisation of materials listed in the handbook for economy-wide material flow accounting published by the Statistical Office of the European Union (Eurostat, 2001).

- the hidden flows of imports (HFIMP) comprise both the extraction used abroad, which is required for the production of the imports, and the unused extraction associated with it.

A.4.6.2 Source of data

Sources for data on the resource use and material input (TMR, DMI), respectively, have been Eurostat, and the Wuppertal Institute (WI). Eurostat provides data on DEU and imports in physical terms. The WI was the source for data comprising the UDE and the HFIMP. The database resulting from merging these different sources has been an MFA database for the calculations.

In more detail, the data sources are as follows (77):

- DEU: Eurostat MFAs (env_ac_mfa) at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_mfa&lang=en
  Data for 1995 are not available in this database and were therefore compiled from national material flow data of the Federal Statistical Office and FAOSTAT;
- UDE: was partly compiled from national material flow data of the Federal Statistical Office and partly from own database of WI, RG 3;
- IMP: data were taken from Eurostat external trade database ComExt at:
  http://epp.eurostat.ec.europa.eu/newxtweb/
  Data are reported in a mass unit of 100 kg. All data at HS6-digits level were used except code 271600 (electrical energy) which was taken from Eurostat energy statistics (nrg_105a) in units of Gigawatt hours (GWh) at:
  http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_105a&lang=en;
- HFIMP: was derived using multipliers from the data base of WI, FG3.

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(77) For countries, for which data on DEU was not sufficiently available in the Eurostat database, the Wuppertal Institute database was used.

A.4.6.3 *Specification of EW-MFA indicators in the context of EE-IOA*

The following equations were applied in this study to calculate *DMI* and *TMR* caused by total final consumption:

$$DMI_{DI} + DMI_{PR} = DMI_{FU} = DMI$$

$$TMR_{DI} + TMR_{PR} = TMR_{FU} = TMR$$

where:

DMI_{DI}	Direct material input, which refers to the products imported directly for final use, i.e. pure mass of imports.
DMI_{PR}	Direct material input caused by the domestic production of goods and services. In the framework of EE-IOA, DMI_{PR} can be interpreted from two perspectives: • Regarding the production perspective, DMI_{PR} refers to the domestic extraction and imports used by the domestic industry in order to produce goods and services both for intermediate use and for final use; • Regarding the consumption perspective, DMI_{PR} represents the *DMI* caused directly or indirectly by the final use of the products, which are produced domestically. Thus, the DMI_{PR} by product group can be split into two components: the direct DMI_{PR} and the indirect DMI_{PR}. The direct DMI_{PR} component of each product group refers to the *DMI* embodied in the products for final use produced domestically, i.e. practically the mass of the products produced domestically for final use. The indirect DMI_{PR} component of each product group refers to the *DMI* embodied in all intermediate inputs, which were required along the domestic production chain, in order to enable the domestic production for final use. Hence, the DMI_{PR} for each product group produced domestically for final use is the result of the accumulation of the corresponding 'direct' and 'indirect' DMI_{PR}.
DMI_{FU}	Direct material input caused by final use of goods and services that are produced domestically or imported. Thus, DMI_{FU} is equal to the *DMI* of the whole economy. The DMI_{FU} is calculated as sum of the DMI_{PR} and the DMI_{DI}. In the following texts and graphs, it is termed *DMI* 'according to the EW-MFA concept' (78).
TMR_{DI}	Total material requirement associated with the products imported directly for final use, i.e. mass of imports and their hidden flows.
TMR_{PR}	Total material requirement caused by the domestic production of goods and services for final use. In the framework of EE-IOA, the TMR_{PR} can be interpreted from two perspectives: • Regarding the production perspective, the TMR_{PR} refers to the resource use, i.e. *DMI* and its hidden flows, caused by the domestic industries due to the production of goods and services for intermediate use and for final use; • Regarding the consumption perspective, TMR_{PR} represents the resource use caused directly or indirectly by the final use of products produced domestically. Thus, the TMR_{PR} by product group can be split into two components: the direct TMR_{PR} and the indirect TMR_{PR}. The 'direct' TMR_{PR} component of each product group comprised the share of global resources used directly for the domestic production for final use. The 'indirect' TMR_{PR} component of each product group refers to the share of resources associated to all intermediate inputs, which are required along the domestic production chain in order to enable the domestic production for final use. Hence, the TMR_{PR} for each product group produced domestically for final use is the result of the accumulation of the corresponding direct and indirect TMR_{PR}.
TMR_{FU}	Total material requirement caused by final use of goods and services, produced domestically and imported. Thus, TMR_{FU} is equal to the *TMR* of the whole economy. The TMR_{FU} is calculated as sum of the TMR_{PR} and the TMR_{DI}. In the following texts and graphs, it is termed *TMR* 'according the EW-MFA concept'.

The specific indicators listed above are visualised separately for *DMI* and *TMR* by Figure A.7 and Figure A.8, respectively.

Outlook on DMI/TMR**

In contrast to the DMI_{FU} and TMR_{FU} (according to EW-MFA, see above), an estimation of the *DMI** and the *TMR**, respectively, of a national economy includes all the total material resources, which are associated with the imports. The difference is caused by the estimation methods that are applied: the method applied for the calculation of the *DMI* and *TMR* is in practice based on LCA methodology — in accordance with the framework of EW-MFAs. Accordingly, the *DMI* or *TMR*, respectively, do not fully cover the material resources, which are associated with the production processes including all the intermediate products required for the production of the imported product groups.

An enhanced estimation procedure of the *DMI* and *TMR* (resulting in 'enhanced' indicators *DMI** and *TMR**, respectively) caused by total final use, i.e. final use of products produced domestically and imported, could be gained by applying an EE-IOA model on (national data on) DEU and on UDE. Such an advanced procedure would allow for estimating the material resource use associated with all intermediate inputs required for the

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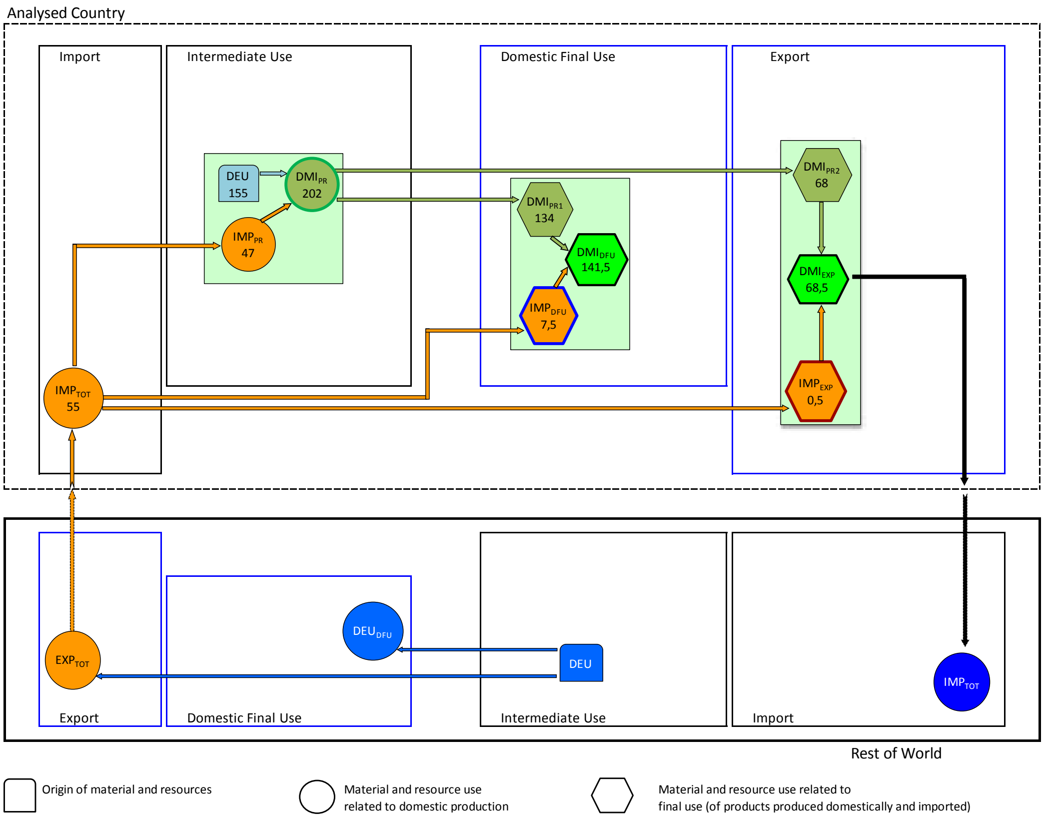
(78) The difference between the DMI_{FU}/TMR_{FU} ('according to the EW-MFA concept') and an 'extended' *DMI*/TMR** that can be estimated by means of the application of variant Type II should be noted (see Section 'Outlook on *DMI*/TMR**').

production of the imports. However, applying such an advanced procedure is not possible until the data required for that has become available in sufficient quality. In this context, further efforts are required to provide such data in sufficient quality.

Figure A.7 DMI flow chart: Direct material input induced by domestic intermediate use, domestic final consumption and exports



DEU : Domestic extraction used

DEU_{DFU} : Domestic extraction used caused by domestic production for domestic final use

DMI_{DFU} : Direct material input caused by domestic final use

DMI_{EXP} : Direct material input for domestic production caused by export

DMI_{PR} : Direct material input for domestic production

DMI_{PR1} : Direct material input caused by domestic production for domestic final use

DMI_{PR2} : Direct material input caused by domestic production for export

IMP_{DFU} : Imports for domestic final use

IMP_{EXP} : Imports for re-export

IMP_{PR} : Imports for domestic production

IMP_{TOT} : Import

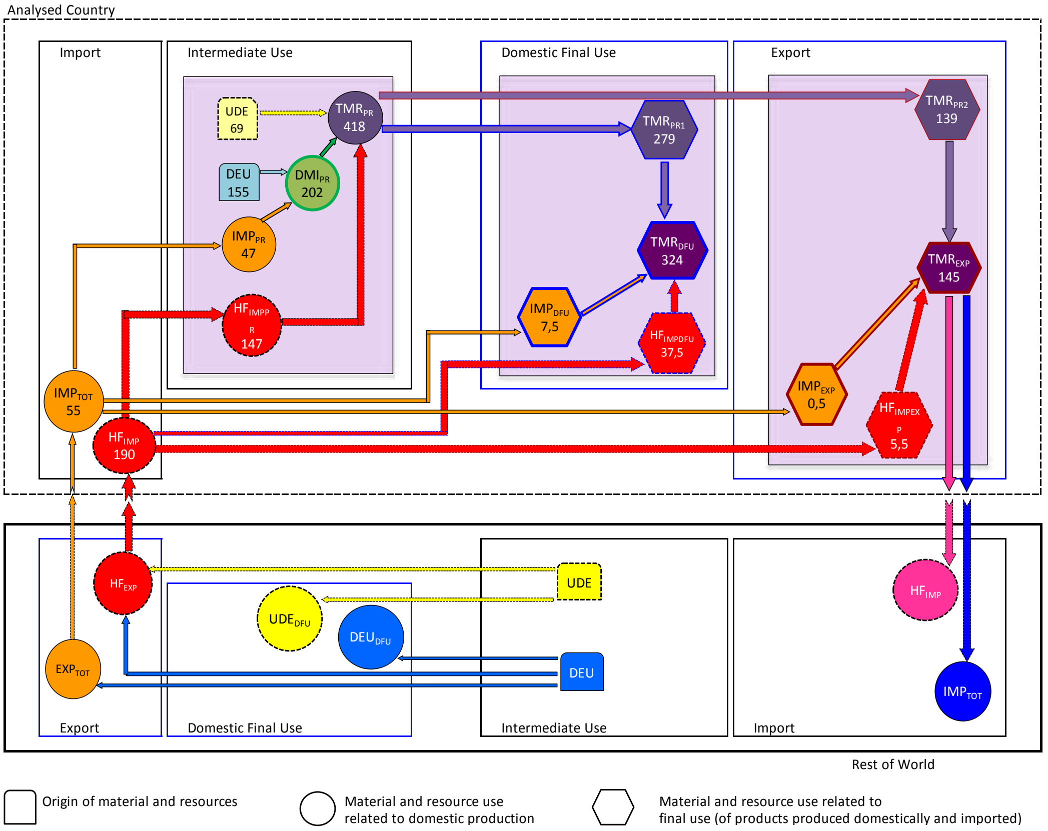
DMI_{PR2} : Direct material input caused by domestic production for export

EXP_{TOT} : Export

DMI_{DFU} ≈ DMC

Note: For illustration, figures are provided for the example of Portugal, 2005, in million tonnes.

Figure A.8 TMR flow chart: total material requirement induced by domestic intermediate use, domestic final consumption and exports



DEU : Domestic extraction used

DEU_{DFU} : Domestic extraction used caused by domestic production for domestic final use

DMI_{DFU} : Direct material input caused by domestic final use

DMI_{EXP} : Direct material input for domestic production caused by export

DMI_{PR} : Direct material input for domestic production

DMI_{PR1} : Direct material input caused by domestic production for domestic final use

DMI_{PR2} : Direct material input caused by domestic production for export

EXP_{TOT} : Export

HF_{EXP} : Hidden flows of the exports

HF_{IMP} : Hidden flows of the imports

HF_{IMPDFU} : Hidden flows of the imports for domestic final use

HF_{IMPEXP} : Hidden flows of the imports for re-export

HF_{IMPPR} : Hidden flows of the imports for domestic production

IMP_{DFU} : Imports for domestic final use

IMP_{EXP} : Imports for re-export

IMP_{PR} : Imports for domestic production

IMP_{TOT} : Import

TMR_{DFU} : Total material requirement caused by domestic final use

TMR_{EXP} : Total material requirement caused by export

TMR_{PR} : Total material requirement caused by domestic production

TMR_{PR1} : Total material requirement caused by domestic production for domestic final use

TMR_{PR2} : Total material requirement caused by domestic production for export

UDE : Unused domestic extraction

UDE_{DFU} : Unused domestic extraction caused by domestic production for domestic final use

DMI_{DFU} ≈ DMC

TMR_{DFU} ≈ TMC

Note: For illustration, figures are provided for the example of Portugal, 2005, in million tonnes.

A.4.6.4 Applied input-output models

Input-output models applied in this study for the calculation of *DMI* and *TMR* caused by the domestic production of goods and services for final use:

$$DMI_{PR} = \langle dmi\_intensity\_dom \rangle * (I - A_{dom})^{-1} * Y_{dom} = \langle dmi\_mutiplier_{dom} \rangle * Y_{dom}$$

$$TMR_{PR} = \langle tmr\_intensity\_dom \rangle * (I - A_{dom})^{-1} * Y_{dom} = \langle tmr\_multiplier_{dom} \rangle * Y_{dom}$$

where:

<dmi_intensity_dom> : DMI input intensity (i.e. material use caused 'directly' per euro produced domestically)

<tmr_intensity_dom> : TMR intensity (i.e. material resource use caused 'directly' per product produced domestically

$(I - A_{dom})^{-1}$: Leontief inverse of domestic production

Y_{dom} : Matrix of final use of goods and services produced domestically (i.e. domestic production for final use)

$\langle dmi\_mutiplier_{dom} \rangle$: Diagonal matrix of the DMI multiplier by product group produced domestically, i.e. the quantity of domestic extraction used and intermediate inputs imported needed 'directly' and 'indirectly' per product produced domestically

$\langle tmr\_mutiplier_{dom} \rangle$: Diagonal matrix of the TMR multiplier by product group produced domestically, i.e. quantity of resource use (DMI + HF) caused 'directly' and 'indirectly' per product produced domestically

A.4.6.5 DMI and TMR caused by total final consumption: Calculating 'according to the EW-MFA concept', i.e. by means of using a mix-approach

The equations applied in this study for the calculation of *DMI* and *TMR* caused by total final consumption of imported and domestic produced goods and services are:

$$DMI = DMI_{FU} = DMI_{PR} + DMI_{DI} = \langle dmi\_mutiplier_{dom} \rangle * Y_{dom} + \langle dmi\_intensity\_imp \rangle * Y_{imp}$$

$$TMR = TMR_{FU} = TMR_{PR} + TMR_{DI} = \langle tmr\_mutiplier_{dom} \rangle * Y_{dom} + \langle tmr\_intensity\_imp \rangle * Y_{imp}$$

where:

<dmi_intensity_imp> : Diagonal matrix of the DMI intensity of imported product groups, i.e. *DMI* quantity associated 'directly' to each unit product imported. It represents the pure mass of the imports

<tmr_intensity_imp> : Diagonal matrix of the *TMR* intensity of imported product groups, i.e. material resource use quantity associated 'directly' to each unit product imported

Y_{imp} : Matrix of final use of products imported (i.e. direct imports for final use)

These formulas ensure that the (re-)attribution of the *DMI* and *TMR* to the product groups for final use is fully compatible with the (original) *DMI* and *TMR* according to the EW-MFA concept. The formulas consist of two components:

- The first component refers to the re-assignment of DMI_{PR} or TMR_{PR} respectively, to the product groups which were produced domestically for final use; for this purpose, the EE-IOA model of domestic production was applied (see Section A.4.6.4);
- The second component refers to *DMI* or *TMR*, respectively, associated directly to the imported product groups for final consumption (i.e. DMI_{DI} or TMR_{DI}); for this purpose, a simple distribution model was applied.

A.4.6.6 Numerical model example of a complete sequence of working steps related to the application of the EE-IOA model

When applying the EE-IOA model, a sequence of working steps is required. In the following, the sequence of working steps applied is shown by a numerical model example. In this example, the calculations refer solely to DMI; however, it can also be applied accordingly on TMR. All figures are fictional as the example is designed for illustrative purposes only.

The overall procedure is illustrated by seven phases, which are generally composed of single steps.

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(1) Data preparation: IOTs and environmental extensions

Monetary data (in million euro): Input-output table. It comprises the matrix of domestic production (green/violet), the matrix of imports (yellow), and the gross value added (white)

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$	∑	PH	EXP	FU	∑
$PG_1 / I_1 / S_1$	3	5	5	**13**	10	7	**17**	**30**
$PG_2 / I_2 / S_2$	10	5	25	**40**	0	0	**0**	**40**
$PG_3 / I_{13} / S_3$	2	0	8	**10**	30	20	**50**	**60**
∑	**15**	**10**	**38**	**63**	**40**	**27**	**67**	**130**

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$	∑	PH	EXP	FU	∑
$PG_1 / I_1 / S_1$	2	3	2	**7**	2	0	**2**	**9**
$PG_2 / I_2 / S_2$	1	1	2	**4**	3	5	**8**	**12**
$PG_3 / I_{13} / S_3$	2	7	4	**13**	1	5	**6**	**19**
∑	**5**	**11**	**8**	**24**	6	10	**16**	**40**

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$	∑
GVA_{c1}	4	6	8	**18**
GVA_{c2}	6	13	6	**25**
∑	**10**	**19**	**14**	**43**

$PG_j / I_j / S_j$: Product groups, industries or sectors respectively
GVA_k : Gross Valued Added category
PH : Private Households
EXP : Exports
FU : Final Use

EW-MFA data: DEU (in million tonnes)

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
DEU	8	4	10

IMP: Imports of the whole economy (in million tonnes)

	Total
$PG_1 / I_1 / S_1$	42
$PG_2 / I_2 / S_2$	66
$PG_3 / I_{13} / S_3$	70
∑	**178**

=

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$	∑
$PG_1 / I_1 / S_1$	**42**	0	0	**42**
$PG_2 / I_2 / S_2$	0	**66**	0	**66**
$PG_3 / I_{13} / S_3$	0	0	**70**	**70**
∑	**42**	**66**	**70**	**178**

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(2) Distribution of physical imports among industries and final use components

Monetary import structure matrix

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$	∑	PH	EXP	FU	∑
$PG_1 / I_1 / S_1$	0,222	0,333	0,222	**0,778**	0,222	0,000	**0,222**	**1,000**
$PG_2 / I_2 / S_2$	0,083	0,083	0,167	**0,333**	0,250	0,417	**0,667**	**1,000**
$PG_3 / I_{13} / S_3$	0,105	0,368	0,211	**0,684**	0,053	0,263	**0,316**	**1,000**

Distribution of physical imports:

Due to missing physical IOT, the monetary import structure has been applied for the distribution

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$	∑	PH	EXP	FU	∑
$PG_1 / I_1 / S_1$	9	14	9	**33**	9	0	**9**	**42**
$PG_2 / I_2 / S_2$	6	6	11	**22**	17	28	**44**	**66**
$PG_3 / I_{13} / S_3$	7	26	15	**48**	4	18	**22**	**70**
∑	**22**	**45**	**35**	**103**	**30**	**46**	**75**	**178**

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(3) Calculation of DMI by industries (product groups) and final use components

DMI related to intermediate use and final use (DMI = DEU + IMP)

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$	∑	PH	EXP	FU	∑
DMI	**30**	**49**	**45**	**125**	**30**	**46**	**75**	**200**

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(4) *Environmentally-extended input-output table*

Environmentally-extended input-output table for domestic production

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$	IO	PH	EXP	FU	q_d
$PG_1 / I_1 / S_1$	3	5	5	**13**	10	7	**17**	**30**
$PG_2 / I_2 / S_2$	10	5	25	**40**	0	0	**0**	**40**
$PG_3 / I_{13} / S_3$	2	0	8	**10**	30	20	**50**	**60**
II	**15**	**10**	**38**	**63**	**40**	**27**	**67**	**130**
IMP	**5**	**11**	**8**	**24**				
GVA	10	19	14	**43**				
q_d	**30**	**40**	**60**	**130**				

DMI	**30**	**49**	**45**	**125**	**30**	**46**	**200**

DMI : External parameter (extension: Direct Material Input)

DMI caused by production of domestic industries: 125; DMI caused by final use of products produced domestically: 75 (both values rounded).

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(5) *Calculation of matrices required for the input-output analysis*

Matrix of domestic intermediate production

X_d =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
$PG_1 / I_1 / S_1$	3	5	5
$PG_2 / I_2 / S_2$	10	5	25
$PG_3 / I_{13} / S_3$	2	0	8

Diagonal matrix of domestic output

$< q_d >$ =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
$PG_1 / I_1 / S_1$	**30**	0	0
$PG_2 / I_2 / S_2$	0	**40**	0
$PG_3 / I_{13} / S_3$	0	0	**60**

Inverse of the diagonal matrix of domestic output

$< q_d >^{-1}$ =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
$PG_1 / I_1 / S_1$	**0,033**	0	0
$PG_2 / I_2 / S_2$	0	**0,025**	0
$PG_3 / I_{13} / S_3$	0	0	**0,017**

Matrix of domestic production for final use (final use of product groups produced domestically)

Y_d =

	PH	EXP	FU
$PG_1 / I_1 / S_1$	10	7	**17**
$PG_2 / I_2 / S_2$	0	0	**0**
$PG_3 / I_{13} / S_3$	30	20	**50**
∑	**40**	**27**	**67**

Diagonal matrix of domestic production for final use (i.e. domestic final use and exports)

$< y_d >$ =

$PG_1 / I_1 / S_1$	**17**	0	0
$PG_2 / I_2 / S_2$	0	**0**	0
$PG_3 / I_{13} / S_3$	0	0	**50**

Input coefficients of domestic production

A_d =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
$PG_1 / I_1 / S_1$	0,100	0,125	0,083
$PG_2 / I_2 / S_2$	0,333	0,125	0,417
$PG_3 / I_{13} / S_3$	0,067	0,000	0,133
∑	**0,500**	**0,250**	**0,633**

Unit matrix

I =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
$PG_1 / I_1 / S_1$	**1**	0	0
$PG_2 / I_2 / S_2$	0	**1**	0
$PG_3 / I_{13} / S_3$	0	0	**1**

= + Unit matrix – input coefficients matrix of domestic production

$(I - A_d)$ =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
$PG_1 / I_1 / S_1$	0,900	-0,125	-0,083
$PG_2 / I_2 / S_2$	-0,333	0,875	-0,417
$PG_3 / I_{13} / S_3$	-0,067	0,000	0,867

Leontief inverse of domestic production

$(I - A_d)^{-1}$ =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
$PG_1 / I_1 / S_1$	1,189	0,170	0,196
$PG_2 / I_2 / S_2$	0,496	1,214	0,631
$PG_3 / I_{13} / S_3$	0,091	0,013	1,169
$\sum$	**1,776**	**1,397**	**1,996**

Diagonal matrix of the multipliers by product group

q_{d}_mult =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
$PG_1 / I_1 / S_1$	1,776	0	0
$PG_2 / I_2 / S_2$	0	1,397	0
$PG_3 / I_{13} / S_3$	0	0	1,996
$\sum$	**1,776**	**1,397**	**1,996**

Total domestic output required for the domestic production for final use — interpretation by row:
Direct and indirect domestic output required for the production of the goods and services used finally.

$^{r}Q_d$ =

	PH	EXP	FU
$PG_1 / I_1 / S_1$	18	12	**30**
$PG_2 / I_2 / S_2$	0	0	**0**
$PG_3 / I_{13} / S_3$	60	40	**100**
∑	**78**	**52**	**130**

$^{r}Q_d = <q_{d}\_\mathrm{mult}> * Y_d$

Total domestic output content of final use components — interpretation by column:
Direct and indirect domestic output required in order to ensure that the total demand of each final use component can be satisfied.

$^{c}Q_d$ =

	PH	EXP	FU
$PG_1 / I_1 / S_1$	18	12	**30**
$PG_2 / I_2 / S_2$	24	16	**40**
$PG_3 / I_{13} / S_3$	36	24	**60**
∑	**78**	**52**	**130**

$^{c}Q_d = (I - A_d)^{-1} * Y_d$

---

(6) Estimation of DMI induced by final use of product groups, which are produced domestically

DMI induced by domestic production

DMI =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
DMI	**30**	**49**	**45**

Direct material input intensity, i.e. material use that is induced 'directly' per unit output produced domestically

dmi_int =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
$dmi_{PG1/2/3}$	1,007	1,232	0,751

Diagonal matrix of DMI per unit output produced domestically (direct intensity)

<dmi_int> =

	dmi_{PG1}	dmi_{PG2}	dmi_{PG3}
dmi_{PG1}	1,007	0	0
dmi_{PG2}	0	1,232	0
dmi_{PG3}	0	0	0,751

DMI associated directly to domestic intermediate use and final use

$^{D}DMI_d$ =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$	∑	PH	EXP	FU	∑
$^{D}DMI_{PG1}$	3	5	5	**13**	10	7	**17**	**30**
$^{D}DMI_{PG2}$	12	6	31	**49**	0	0	**0**	**49**
$^{D}DMI_{PG3}$	2	0	6	**8**	23	15	**38**	**45**
∑	17	11	42	**70**	33	22	**55**	**125**

$^{D}DMI = <dmi\_int>*X_d + <dmi\_int>*Y_d$

Direct and indirect DMI induced by the domestic production of a unit output for the final use:

Matrix of multipliers related to the DMI per EUR 1 million (direct and indirect DMI intensity)

dmi_inv =

	$PG_1 / I_1 / S_1$	$PG_2 / I_2 / S_2$	$PG_3 / I_{13} / S_3$
$^*dmi_{PG1}$	1,196	0,171	0,197
$^*dmi_{PG2}$	0,612	1,496	0,778
$^*dmi_{PG3}$	0,069	0,010	0,878
∑	**1,877**	**1,676**	**1,853**

$\text{dmi\_inv} = \langle\text{dmi\_int}\rangle * (I - A_d)^{-1}$

The column sums represent the DMI multipliers of domestic production, i.e. DMI embodied directly and indirectly in a unit domestic production for the final use. These will be represented by the letter 'm'.

Diagonal matrix of the DMI multipliers of domestic production

Direct and indirect DMI intensity per EUR 1 million domestic production

<dmi_mult> =

	$^m dmi_{PG1}$	$^m dmi_{PG2}$	$^m dmi_{PG3}$
$^m dmi_{PG1}$	**1,877**	0	0
$^m dmi_{PG2}$	0	**1,676**	0
$^m dmi_{PG3}$	0	0	**1,853**
∑	**1,877**	**1,676**	**1,853**

---

(7) *Calculation of DMI induced by final use of product groups (domestically produced and imported) according to the 'EW-MFA concept'*

Direct and indirect DMI induced by final use of product groups produced domestically, i.e. direct and indirect DMI caused by domestic production for final use — interpretation by row

$^{r*}\mathbf{DMI}_d$ =

	PH	EXP	FU
$^*DMI_{PG1\_d}$	19	13	**32**
$^*DMI_{PG2\_d}$	0	0	**0**
$^*DMI_{PG3\_d}$	56	37	**93**
$\sum$	**74**	**50**	**125**

$^{r*}DMI_d = \langle dmi\_mult \rangle * Y_d$

Imports for final use, i.e. the quantity of product groups, which are directly imported for final use (taken from phase 2 above)

$^{D}\mathbf{DMI}_{imp}$ =

	PH	EXP	FU
DMI_{PG1_i}	9	0	**9**
DMI_{PG2_i}	17	28	**44**
DMI_{PG3_i}	4	18	**22**
$\sum$	**30**	**46**	**75**

DMI induced by final use of product groups (i.e. produced domestically and imported), interpretation by row

$^{r*}\mathbf{DMI}$ =

	PH	EXP	FU
$^*DMI_1$	28	13	**41**
$^*DMI_2$	17	28	**44**
$^*DMI_3$	59	55	**115**
$\sum$	**104**	**96**	**200**

$^{r*}DMI = {}^{r*}DMI_d + {}^{D}DMI_{imp}$

DMI content of final use produced domestically — interpretation by column

Direct and indirect DMI induced by the total demand of each final use component

$^{c*}\mathbf{DMI}_d$ =

	PH	EXP	FU
$^{*d}\mathbf{DMI}_{PG1}$	18	12	**30**
$^{*d}\mathbf{DMI}_{PG2}$	29	20	**49**
$^{*d}\mathbf{DMI}_{PG3}$	27	18	**45**
∑	**74**	**50**	**125**

$^{c*}DMI_d = dmi\_inv{*}Y_d$

DMI content of final use of product groups (produced domestically and imported) — interpretation by column

$^{c*}\mathbf{DMI}$ =

	PH	EXP	**FU**
$^{*}\mathbf{DMI}_1$	27	12	**40**
$^{*}\mathbf{DMI}_2$	46	47	**93**
$^{*}\mathbf{DMI}_3$	31	36	**67**
∑	**104**	**96**	**200**

$^{c*}DMI = {}^{c*}DMI_d + {}^{D}DMI_{imp}$

A.5 Structural de-composition analysis

In this study, structural de-composition analyses were conducted to explain developments over time.

De-composition analysis is a means for analysing the extent to which individual contributing factors have caused changes in, for example, direct pressures resulting from a country's production, or direct and indirect pressures caused by a country's final use over time (of one particular country or region).

A.5.1 Methodological introduction

The method of structural de-composition analysis is a means to analyse the difference of a variable ***x*** over time by two or more explaining variables ***a***, ***b***, ***c*** …. In other words, the differences of ***x*** are decomposed into several explaining effects. The contribution of several explaining variables ***a***, ***b***, ***c*** … to explain the difference of ***x*** is quantified.

The starting point is the case where ***x*** is determined by two explaining variables ***a*** and ***b***.

$$x = f(a,b) \qquad \text{(eq. 13)}$$

We assume a multiplicative relationship between the two explaining variables ***a*** and ***b***:

$$x = a \cdot b \qquad \text{(eq. 14)}$$

The total differential of equation 14 is:

$$\mathrm{d}x = \mathrm{d}a.b + a.\mathrm{d}b \qquad \text{(eq. 15)}$$

This differential can be approximated by differences:

$$\Delta x = \Delta a.b + a.\Delta b \qquad \text{(eq. 16)}$$

where: Δx : difference of variable *x*, for instance, between two reference years.

In the equation shown above, the difference between two reference years Δ***a*** is weighted by the earlier reference year's value of ***b***. However, there are several possibilities for applying this weighting. A commonly applied approach is the central difference assumption. This implies that the difference Δ***a*** between two reference years is weighted by those two reference years' average of ***b***.

It follows the following equation:

$$\Delta x = \Delta a.\overline{b} + \overline{a}.\Delta b \qquad \text{(eq. 17)}$$

where: $\overline{b}$: the average of a variable between two reference years;

Δa : the difference of variable ***a*** between two reference years.

If more than two explaining variables are considered, a so-called joint effect will appear, i.e. a kind of residual item. For example, Δ***x*** can be expressed as follows in the case of three explaining variables:

$$\Delta x = \Delta a.\overline{b}.\overline{c} + \overline{a}.\Delta b.\overline{c} + \overline{a}.\overline{b}.\Delta c + residual \qquad \text{(eq. 18)}$$

This joint effect is that part of the difference (change) Δ***x*** that cannot be explained by the explanatory variables ***a***, ***b***, and ***c***.

There are further methodological approaches, which have been proposed to avoid any joint effect. The problem can be looked at as follows (see also Jensen and Olsen, 2003)

We look at the differences between reference year A and reference year B:

$$\Delta x = a_B b_B c_B - a_A b_A c_A \qquad \text{(eq. 19)}$$

$$= a_B b_B c_B - a_A b_B c_B + a_A b_B c_B - a_A b_A c_A$$

$$= \Delta a\, b_B c_B + a_A b_B c_B - a_A b_A c_B + a_A b_A c_B - a_A b_A c_A$$

$$= \Delta a\, b_B c_B + a_A \Delta b_B c_B + a_A b_A \Delta c$$

According to equation 19, we have a complete de-composition of the change in x, i.e. there is no joint effect or residual in the de-composition. Obviously, this de-composition is not unique. Other de-compositions could have been chosen as well, since:

$$X = abc \qquad \text{(eq. 20)}$$

$$' = cba$$

$$' = acb$$

$$' = bca$$

$$' = bac$$

$$' = cab$$

This means that in the case of three determinants there are 3! = 6 possible de-composition forms; in the general case with n determinants we find n! possible de-composition forms. For example, equation 21 would be another complete de-composition form of Δx.

$$\Delta x = \Delta c\, b_B a_B + c_A \Delta b_B a_B + c_A b_A \Delta a \qquad \text{(eq. 21)}$$

Dietzenbacher and Los (1998) suggest that all such de-composition forms are calculated, and that the weights attached to the diverse Δ are then calculated as averages of the weights from the n! forms. They further suggest that the standard deviations of the results are published together with the means. The calculations carried out in a Danish study (Jensen & Olsen, 2003) showed that a very significant variation results from the diverse individual de-composition forms. This underlines the importance to apply some kind of average in the calculation.

It can be shown that some of these n! de-composition forms result in the same weights. This allows reducing the number of de-compositions to $2^{(n-1)}$. For example, if 6 determinants exist, 32 different weights result from the 720 de-composition forms.

In the case of three determinants with six de-composition forms, only the following weights for Δa need to be calculated, as the two first weights correspond to two de-composition forms, each:

$$b_A c_A,\ b_B c_B,\ b_A c_B \text{ and } b_B c_A \qquad \text{(eq. 22)}$$

Then, the average weight attached to Δa is:

$$(2(b_A c_A) + 2(b_B c_B) + b_A c_B + b_B c_A) / 6 \qquad \text{(eq. 23)}$$

Even with the reduction in the number of different forms, it is necessary to carry out a significant number of calculations. Therefore, Dietzenbacher and Los (1998) and de Haan (2001) have suggested that the calculation of so-called mirror images can be calculated instead of all the different weights. Using mirror-images has the advantage that the variance of the results is reduced considerably, and that the results are quite close to the result, which is found if all de-composition forms and all possible weights are included.

The mirror images correspond to the groupings indicated above. Thus, ***abc*** and ***cba*** are mirror images. In this case, we would — as one option — calculate the weights for $\Delta \boldsymbol{a}$ as $(\boldsymbol{b}_B \boldsymbol{c}_B + \mathrm{c}_\mathrm{A} \mathrm{b}_\mathrm{A}) / 2$, the weight of $\Delta \mathbf{b}$ as $(\boldsymbol{a}_A \boldsymbol{c}_B + \boldsymbol{c}_A \boldsymbol{a}_B) / 2$, and the weight of $\Delta \boldsymbol{c}$ as $(\boldsymbol{a}_A \boldsymbol{b}_A + \boldsymbol{b}_B \boldsymbol{a}_B) / 2$.

A.5.2 Development of direct domestic industrial emissions and material inputs — focusing on the development in production patterns

In the following, the direct environmental pressures by industry branches are subject to this structural de-composition analysis. The development of the pressures is analysed for selected countries (Figures 13–15 in the report).

Three factors that contribute to changes in pressures over time are identified:

- changes in the specific pressure intensities of individual industries, i.e. technology in a wider sense;
- changes in the structure of the economy, i.e. the relative importance of each industry;
- changes in the size of the economy, i.e. total economic output.

The basic equation in matrix notation is:

$$Gx = \boldsymbol{ga}' \cdot \boldsymbol{q}^c \cdot Q \qquad \text{(eq. 24)}$$

$$[1,1]' \quad [1,59]'[59,1]'[1,1]$$

with Gx : total pressures by all industry branches (scalar)

$\boldsymbol{ga}'$: row-vector of direct pressures input coefficients (= $\boldsymbol{g}' \cdot \langle \boldsymbol{q}^{-1} \rangle$)

$\boldsymbol{q}^c$: column-vector of share of individual industries in total output, i.e. composition of output (= $\boldsymbol{q}' \cdot Q^{-1}$)

Q : total output (scalar)

The difference equation is:

$$\Delta Gx = \Delta \boldsymbol{ga}' \cdot \boldsymbol{q}^c \cdot Q + \boldsymbol{ga}' \cdot \Delta \boldsymbol{q}^c \cdot Q + \boldsymbol{ga}' \cdot \boldsymbol{q}^c \cdot \Delta Q + \text{joint effect} \qquad \text{(eq. 25)}$$

In conclusion, equation 27 decomposes the development in industry emissions (Gx) into the following effects:

[1] $\Delta \boldsymbol{ga}' \cdot \boldsymbol{q}^c \cdot Q$: industry pressure-intensity effect

[2] $\boldsymbol{ga}' \cdot \Delta \boldsymbol{q}^c \cdot Q$: production patterns effect

[3] $\boldsymbol{ga}' \cdot \boldsymbol{q}^c \cdot \Delta Q$: output-scale effect

[4] *residual* : joint effect

A.5.3 Development of direct and indirect domestic industrial emissions and material inputs — focusing on the differences in final use patterns

In this section, the temporal differences in domestic final use are subject to structural de-composition analysis. Emphasis is given on the final use patterns, i.e. which product groups are finally used and how the latter ones induce pressures. This type of analysis has been applied for temporal comparisons of the consumption perspective (Section 4.7 in the main report).

In a first equation, only domestic industrial pressures are considered. Three factors can be identified which can contribute to changes in pressures over time:

- changes in the production-cycle–wide pressure-intensities of finally used product groups;
- changes in the composition of final demand by product group;
- changes in the size of total domestic final use.

The basic equation in matrix notation is:

$$Gx = [\boldsymbol{ga'}\,(\boldsymbol{I} - \boldsymbol{A}_{dom})^{-1}] \cdot \boldsymbol{y}_{dom}{}^{c} \cdot Y_{dom} \qquad \text{(eq. 26)}$$

[1,1] [1,59] [59,1] [1,1]

where

G_X : total pressures by industries per capita (scalar)

$[\boldsymbol{ga'}\,(\boldsymbol{I} - \boldsymbol{A}_{dom})^{-1}]$: row-vector of direct and indirect domestic pressures per unit final use of product groups domestically produced

$\boldsymbol{y}_{dom}{}^{c}$: column-vector of the composition of domestic final use, i.e. share of product groups in total domestic final use

Y_{dom} : final use of domestic production, per capita (scalar)

In Section 4.7 in the report, such structural de-composition analysis has been performed for the reference years 1995 and 2005: Figures 4.8–4.11 do show absolute changes, and the contribution of the single components. While this has been done for each country individually, the graphs compile the results for the calculations of eight individual countries. In this form, the graphs allow country comparisons for the results of the structural de-composition analysis.

Appendix B: Transformation matrix used for mapping environmental pressures from CPA to COICOP categories

Consumption expenditure and related environmental pressures as derived from national EE-IOTs use the Statistical Classification of Products by Activity (CPA (79)) code, i.e. a product classification system with a structure parallel to the NACE system, which is used for national accounts. Consequently, the model used provides results for 60 product groups, according to 60 distinct product categories (CPA two-digit categories). However, for analysing environmental pressures from household consumption (Section 4.5), expenditure and associated pressures of all consumed product groups are to be split into consumption categories according to function (80). In the case of (final) consumption by households, the *Classification of individual consumption according to purpose* (COICOP) (81) has been developed by the UN and adopted by Eurostat to class consumption expenditure. For the analyses of the effects associated with consumption by households in the framework of the EE-IOA, the COICOP categorisation was applied in this report.

The COICOP is structured hierarchically in three levels: Each upper level category is split into a set of middle level (twodigit) categories, which are again split by a set of lower level categories. For example, the one-digit category *Transport* includes the following two digit categories: 07.1 – *Purchase of vehicles*, 07.2 – *Operation of personal transport equipment*, and 07.3 – *Transport services*; while for example the two-digit category *Purchase of vehicles* includes the following three-digit categories: 07.1.1 – *Motor cars*, 07.1.2 – *Motor cycles*, 07.1.3 – *Bicycles*, and 07.1.4 – *Animal drawn vehicles*.

The original COICOP classification includes altogether 14 upper level categories (two-digits), of which the first 12 are relevant to household consumption. These 12 categories are as follows:

01 – Food and non-alcoholic beverages

02 – Alcoholic beverages and tobacco

03 – Clothing and footwear

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

05 – Furnishings, household equipment

06 – Health

07 – Transport

08 – Communications

09 – Recreation and culture

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(79) CPA is the classification of products at the level of the European Union. The term products covers both goods and services. 'The CPA product categories are related to activities as defined by the *Statistical classification of economic activities in the European Community*' (NACE) by the assignment of any CPA product to one single NACE activity (Eurostat Glossary, 02.02.2012).

(80) Of course, both expenditures and pressures ideally ought to follow the same attribution to COICOP categories. However, in this report that rule has been suspended due to data constraints, see. Box 4.2.

(81) The COICOP classification has been developed by the United Nations Statistics Division; the recent version was adopted in 1999. Actually, COICOP allows classifying and analysing individual consumption expenditures according to their purpose incurred not only by households, but also by non-profit institutions serving households, and by general government. For further information see Box 4.1 in the main report.

10 – Education

11 – Restaurants and hotels

12 – Miscellaneous goods and services

The detailed structure of the full COICOP is shown in Table B.1.

In general, each CPA two-digit category can be directly attributed to a certain COICOP group. However, in some cases, this is not possible. Thus, the COICOP categories had to be modified where necessary to allow such a basic approach for attribution. The modification of COICOP groups comprise, amongst others:

- Since the original COICOP group 'Food and non-alcoholic beverages' (COICOP 01) cannot cover alcoholic beverages, a modified COICOP group 'Food and non-alcoholic beverages' was generated that includes alcoholic beverages;
- Leather and leather products (CPA 19) have been fully assigned to Clothing and footwear (COICOP 03), although other uses can be considered as significant.

The resulting modified set of twelve COICOP categories are as follows (the modified categories are marked with *); the corresponding CPA two-digit categories are listed in square brackets:

01* – Food and beverages (including alcoholic beverages)	[01,05,15]
02 – Tobacco (excluding alcoholic beverages)	[16]
03* – Clothing and footwear (including all leather products)	[18,19]
04 – Housing, water, gas, electricity and other fuels	[02,10,11,12,13,14,20,31,37,40,41,45,70,90]
05 – Furnishings, household equipment and routine maintenance of the house	[17,24,25,26,28,29,30,32,36,51,52,71,]
06 – Health	[33,85]
07 – Transport	[23,34,35,50,60,61,62,63]
08 – Communications	[64]
09 – Recreation and culture	[21,22,72,91,92]
10 – Education	[80]
11 – Restaurants and hotels	[55]
12 – Miscellaneous goods and services	[27,65,66,67,73,74,75,93,95]

The transformation matrix between the CPA two-digit categories , which were used for analytical purposes in the main report, and the modified COICOP categories is shown in Table B.2.

Table B.1 COICOP Classification on four digit levels

01-12 — INDIVIDUAL CONSUMPTION EXPENDITURE OF HOUSEHOLDS

- **01 — FOOD AND NON-ALCOHOLIC BEVERAGES**
  - **01.1 — FOOD**
    - 01.1.1 — Bread and cereals (ND)
    - 01.1.2 — Meat (ND)
    - 01.1.3 — Fish and seafood (ND)
    - 01.1.4 — Milk, cheese and eggs (ND)
    - 01.1.5 — Oils and fats (ND)
    - 01.1.6 — Fruit (ND
    - 01.1.7 — Vegetables (ND)
    - 01.1.8 — Sugar, jam, honey, chocolate and confectionary (ND)
    - 01.1.9 — Food products n.e.c (ND)
  - **01.2 — Non-alcoholic beverages**
    - 01.2.1 — Coffee, tea and cocoa (ND)
    - 01.2.2 — Mineral waters, soft drinks, fruit and vegetable juices (ND)
- **02 — ALCOHOLIC BEVERAGES, TOBACCO AND NARCOTICS**
  - **02.1 — Alcoholic beverages**
    - 02.1.1 — Spirits (ND)
    - 02.1.2 — Wine (ND)
    - 02.1.3 — Beer (ND)
  - **02.1 — Alcoholic beverages**
    - 02.2.0 — Tobacco (ND)
  - **02.3 — Narcotics**
    - 02.3.0 — Narcotics (ND)
- **03 — CLOTHING AND FOOTWEAR**
  - **03.1 — Clothing**
    - 03.1.1 — Clothing materials (SD)
    - 03.1.2 — Garments (SD)
    - 03.1.3 — Other articles of clothing and clothing accessories (SD)
    - 03.1.4 — Cleaning, repair and hire of clothing (S)
  - **03.2 — Footwear**
    - 03.2.1 — Shoes and other footwear (SD)
    - 03.2.2 — Repair and hire of footwear (SD)
- **04 — HOUSING, WATER, ELECTRICITY, GAS, AND OTHER FUELS**
  - **04.1 — Actual rentals for housing**
    - 04.1.1 — Actuals rentals paid by tenants (S)
    - 04.1.2 — Other actual rentals (S)
  - **04.2 — Imputed rentals for housing**
    - 04.2.1 —Imputed rentals of owner-occupiers (S)
    - 04.2.2 — Other imputed rentals (S)
  - **04.3 — Maintenance and repair of the dwelling**
    - 04.3.1 — Materials for the maintenance of the dwelling (ND)
    - 04.3.2 — Services for the maintenance and repair of the dwelling (S)

Abbreviations used: (ND) non-durable goods; (SD) semi-durable goods; (D) durable goods; (S) services.

Table B.1 COICOP Classification on four digit levels (cont.)

04.4 —Water supply and miscellaneous services relating to the dwelling
04.4.1 — Water supply (ND)
04.4.2 — Refuse collecting (S)
04.4.3 — Other services relating to the dwelling n.e.c (S)
04.5 — Electricity, gas and other fuels
04.5.1 — Electricity (ND)
04.5.2 — Gas (ND)
04.5.3 — Liquid fuels (ND)
04.5.4 — Solid fuels (ND)
04.5.5 — Heat energy (ND)
05 — FURNISHING, HOUSEHOLDS EQUIPMENT AND ROUTINE HOUSEHOLD MAINTENANCE
05.1 — Furniture and furnishings, carpets and other floor coverings
05.1.1 — Furniture and furnishings (D)
05.1.2 — Carpets and other floor coverings (D)
05.1.3 — Repair of furniture, furnishings and floor covering (S)
05.2 — Household textiles
05.2.0 — Household textiles (D)
05.3 — Household appliances
05.3.1 — Major household appliances whether electric or not (D)
05.3.2 — Small electric household appliances (SD)
05.3.3 — Repair of household appliances (S)
05.4 — Glassware, tableware and household ustensils
05.4.0 — Glassware, tableware and household ustensils (SD)
05.5 — Tools and equipment for house and garden
05.5.1 — Major tools and equipment (D)
05.5.2 — Small tools and miscellaneous accessories (SD)
05.6 — Goods and services for routine household maintenance
05.6.1 — Non durable household goods (ND)
05.6.2 — Domestic services and household services (S)
06 — HEALTH
06.1 — Medical products, appliances and equipment
06.1.1 — Pharmaceutical products (ND)
06.1.2 — Other medical products (ND)
06.1.3 — Therapeutic appliances and equipment (D)
06.2 — Outpatient services
06.2.1 — Medical services (S)
06.2.2 — Dental services (S)
06.2.3 — Paramedical services (S)
06.3 — Hospital services
06.3.0- Hospital services (S)
07 — TRANSPORT
07.1 — Purchase of vehicles
07.1.1 — Motor cars (D)
07.1.2 — Motor cycles (D)
07.1.3 — Bicycles (D)
07.1.4 — Animal drawn vehicles (D)

Abbreviations used: (ND) non-durable goods; (SD) semi-durable goods; (D) durable goods; (S) services.

Table B.1 COICOP Classification on four digit levels (cont.)

07.2 — Operation of personal transport equipment
07.2.1 — Spare parts and accessories for personal transport equipment (SD)
07.2.2 — Fuels and lubricants for personal transport equipment (ND)
07.2.3 — Maintenance and repair of personal transport equipment (ND)
07.2.4 — Other services in respect of personal transport equipment (S)
07.3 — Transport services
07.3.1 — Passenger transport by railway (S)
07.3.2 — Passenger transport by road (S)
07.3.3 — Passenger transport by air (S)
07.3.4 — Passenger transport by sea and inland waterway (S)
07.3.5 — Combined passenger transport (S)
07.3.6 — Other purchased transport services (S)
08 — COMMUNICATION
08.1 — Postal services
08.1.0 — Postal services
08.2 — Telephone and telefax equipment (D)
08.2.0 — Telephone and telefax services (S)
08.3 — Telephone and telefax services (S)
09 — RECREATION AND CULTURE
09.1 — Audio-visual, photographic and Information equipment
09.1.1 — Equipment for the reception, recording and reproduction of sound and pictures (D)
09.1.2 — Photographic and cinematographic equipment and optical instruments
09.1.3 — Information processing equipment (D)
09.1.4 — Recording media (D)
09.1.5 — Repair of audio-visual, photographic equipment and information processing equipment (S)
09.2 — Other major durables for recreation and culture
09.2.1 —Major durables for outdoor recreation (D)
09.2.2 — Musical instruments and major durables for indoor recreation (D)
09.2.3 — Maintenance and repair of other major durables for recreation and culture (S)
09.3 — Other recreational items and equipment, gardens and pets
09.3.1 — Games, toys and hobbies (SD)
09.3.2 — Equipment for sport, camping and open-air recreation (SD)
09.3.3 — Gardens, plants and flowers (ND)
09.3.4 — Pets and related products (ND)
09.3.5 — Veterinary and other services for pets (S)
09.4 — Recreational and cultural services
09.4.1 — Recreational and sporting services (S)
09.4.2 — Cultural services (S)
09.4.3 — Games of chance (S)
09.5 — Newspapers, books and stationary
09.5.1 — Books (SD)
09.5.2 — Newspapers and periodicals (ND)
09.5.3 — Miscellaneous printed matter (ND)
09.5.4 — Stationary and drawing materials (ND)
09.6 — Packages holidays
09.06.0 — Package holidays (S)

Abbreviations used: (ND) non-durable goods; (SD) semi-durable goods; (D) durable goods; (S) services.

Table B.1 COICOP Classification on four digit levels (cont.)

10 — EDUCATION
10.1 — Pre-primary and primary education
10.1.0 — Pre-primary and primary education (S)
10.2 — Secondary education
10.2.0 — Secondary education (S)
10.3 — Post-secondary non- tertiary education
10.3.0 — Post-secondary non-tertiary education (S)
10.4 — Tertiary education
10.4.4.0 —Education not definable by level
10.5 — Education not definable by level (S)
10.5.0 — Education not definable by level (S)
11 — RESTAURANTS AND HOTELS
11.1 — Catering service
11.1.1 — Restaurants, cafés and the like (S)
11.1.2 — Canteens (S)
11.2 — Accommodation services
11.2.0 — Accommodation services (S)
12 — MISCELLANEOUS GOODS AND SERVICES
12.1 — Personal care
12.1.1 — Hairdressing salons and personal grooming establishments (S)
12.1.2 — Electric appliances for personal care (SD)
12.1.3 —Other appliances, articles and products for personal care (ND)
12.2 — Prostitution
12.2.0 — Prostitution (S)
12.3 — Personal effects n.a.o.
12.3.1 — Jewellery, clocks and watches (D)
12.3.2 —Other personal effects (SD)
12.4 — Social protection (S)
12.4.0 — Social protection (S)
12.5 — Insurance
12.5.1 — Life insurance (S)
12.5.2 — Insurance connected with the dwelling (S)
12.5.3 — Insurance connected with health (S)
12.5.4 — Insurance connected with transport (S)
12.5.5 — Other insurance (S)
12.6 — Financial services n.a.o.
12.6.1 — FISIM (S)
12.6.2 — Other financial services n.e.c (S)
12.7 — Other services n.a.o
12.7.0 — Other services n.e.c (S)

Note: (ND) non-durable goods; (SD) semi-durable goods; (D) durable goods; (S) services.

Source: Eurostat, 2005.

Table B.2 Transformation matrix CPA — modified COICOP categories

	Modified COICOP categories 2-digits		CPA 2-digits
01	Food and beverages *	01	Products of agriculture, hunting and related services
04	Housing, water, electricity, gas and other fuels *	02	Products of forestry, logging and related services
01	Food and beverages *	05	Fish and other fishing products, services incidental of fishing
04	Housing, water, electricity, gas and other fuels *	10	Coal and lignite, peat
04	Housing, water, electricity, gas and other fuels *	11	Crude petroleum and natural gas, services incidental to oil and gas extraction excluding surveying
04	Housing, water, electricity, gas and other fuels *	13	Metal ores
04	Housing, water, electricity, gas and other fuels *	14	Other mining and quarrying products
01	Food and beverages *	15	Food products and beverages
02	Tobacco	16	Tobacco products
05	Furnishings, household equipment and routine maintenance of the house *	17	Textiles
03	Clothing and footwear *	18	Wearing apparel, furs
03	Clothing and footwear *	19	Leather and leather products
04	Housing, water, electricity, gas and other fuels *	20	Wood and products of wood and cork (except furniture), articles of straw and plaiting materials
09	Recreation and culture	21	Pulp paper and paper products
09	Recreation and culture	22	Painted matter and recorded media
07	Transport	23	Coke, refined petroleum products and nuclear fuels
05	Furnishings, household equipment and routine maintenance of the house *	24	Chemicals, chemical products and man-made fibres
05	Furnishings, household equipment and routine maintenance of the house *	25	Rubber and plastic products
05	Furnishings, household equipment and routine maintenance of the house *	26	Other non-metallic mineral products
12	Miscellaneous goods and services *	27	Basic metals
05	Furnishings, household equipment and routine maintenance of the house *	28	Fabricated metal products, except machinery and equipment
05	Furnishings, household equipment and routine maintenance of the house *	29	Machinery and equipment n.e.c
05	Furnishings, household equipment and routine maintenance of the house *	30	Office machinery and computers
04	Housing, water, electricity, gas and other fuels *	31	Electrical machinery and apparatus n.e.c
05	Furnishings, household equipment and routine maintenance of the house *	32	Radio, television and communication equipment and apparatus
06	Health	33	Medical, precision and optical instruments, watches and clocks
07	Transport	34	Motor vehicles, trailers and semi-trailers
07	Transport	35	Other transport equipment
05	Furnishings, household equipment and routine maintenance of the house *	36	Furniture, other manufactured goods n.e.c
04	Housing, water, electricity, gas and other fuels *	37	Secondary raw materials
04	Housing, water, electricity, gas and other fuels *	40	Electrical energy, gas, steam and water
04	Housing, water, electricity, gas and other fuels *	41	Collected and purified water, distribution services of water
04	Housing, water, electricity, gas and other fuels *	45	Construction work
07	Transport	50	Trade, maintenance and repair services of motor vehicles and motorcycles, retail sale of automotive fuel
05	Furnishings, household equipment and routine maintenance of the house *	51	Wholesale trade and commission trade services, except of motor vehicles and motorcycles
05	Furnishings, household equipment and routine maintenance of the house *	52	Retail trade services, except of motor vehicles and motorcycles, repair services of personal and household goods
11	Restaurants and hotels	55	Hotel and restaurant services

Table B.2 Transformation matrix CPA — modified COICOP categories (cont.)

Modified COICOP categories 2-digits		CPA 2-digits	
07	Transport	60	Land transport, transport via pipeline services
07	Transport	61	Water transport services
07	Transport	62	Air transport services
07	Transport	63	Supporting and auxiliary transport services, travel agency services
08	Communication	64	Post and telecommunication services
12	Miscellaneous goods and services *	65	Financial intermediation services, except insurance and pension funding services
12	Miscellaneous goods and services *	66	Insurance and pension funding services, except compulsory social security services
12	Miscellaneous goods and services *	67	Services auxiliary to financial mediation
04	Housing, water, electricity, gas and other fuels *	70	Real estate services
05	Furnishings, household equipment and routine maintenance of the house *	71	Renting services of machinery and equipment without operator and of personal and household goods
09	Recreation and culture	72	Computer and related services
12	Miscellaneous goods and services *	73	Research and development services
12	Miscellaneous goods and services *	74	Other business services
12	Miscellaneous goods and services *	75	Public administration and defence services, compulsory social security services
10	Education	80	Education services
06	Health	85	Health and social work services
04	Housing, water, electricity, gas and other fuels *	90	Sewage and refuse disposal services, sanitation and similar services
09	Recreation and culture	91	Membership organisation services
09	Recreation and culture	92	Recreational, cultural and sporting services
12	Miscellaneous goods and services *	93	Other services
12	Miscellaneous goods and services *	95	Private households with employed persons

Note: COICOP categories marked by a star are the modified ones (see text).

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