ETC/SCP working paper 1/2009

Environmental Pressures from European Consumption and Production

A study in integrated environmental and economic analysis

Prepared by:
Stephan Moll and David Watson,
European Topic Centre on Sustainable Consumption and Production

with key contributions from
Isabel van de Sand and Ole Gravgård Pedersen

24 February 2009

Project manager:
Pawel Kazmierczyk
European Environment Agency

Author affiliation

Stephan Moll, formerly of Wuppertal Institute, now of Eurostat
David Watson, Danish Topic Centre on Waste dawat@etc.mim.dk

Context

The majority of the work presented here was carried out by the European Topic Centre on Resource and Waste Management during 2005-2008. The contract period for the ETC/RWM ended at the end of 2008. The project has been continued by the European Topic Centre on Sustainable Consumption and Production (ETC/SCP) which began its first work programme for the EEA in January 2009.

The ETC/RWM and subsequently the ETC/SCP have prepared this Working Paper for the European Environment Agency (EEA) as a contribution to the EEA's work on the use of National Accounts Matrices including Environmental Accounts (NAMEA) for analysing the pressures caused by European consumption and production patterns

Disclaimer

European Topic Centre on Sustainable Consumption and Production
Højbro Plads 4
DK-1200 Copenhagen K
Phone: +45 72 54 61 60
Fax: +45 33 32 22 27
Email: etc@etc.mim.dk
Website: http://waste.eionet.eu.int

Executive Summary

Objectives and Scope

It has become clear that current European consumption and production patterns cannot be transferred to the rest of the world without overstretching global environmental services several times over. The solution to the problem of limited resources and environmental services is clearly not to halt development in emerging economies. Rather it lies in adjusting patterns of consumption and production in Europe and other developed regions to free up resources and environmental services for economic and social development elsewhere.

Achieving the necessary reductions in environmental pressures caused by economic activities in developed countries will be extremely challenging and can't solely be met through efficiency improvements in production processes and product design. It will also require changes in the mix of goods and services we consume. Identifying and encouraging these adjustments are the focus of the policy area of *Sustainable Consumption and Production (SCP)*.

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

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

One tool which has the potential to provide some of the answers to these questions is known as environmentally extended input-output analysis (EE-IOA) of National Accounting Matrices including Environmental Accounts (NAMEA), whose use and application are discussed in this report.

This technical report presents analysis conducted by the European Topic Centre on Resource and Waste Management (ETC/RWM), using data collected by Eurostat and national statistical offices of selected countries. The report aims to:

- *introduce the tool of environmentally extended input-output analysis of NAMEAs and examine its potential for answering key SCP policy questions*
- *make a first use of it in identifying 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

Answering the first policy question above requires both an overview of which economic sectors are directly responsible for key national environmental pressures, but also an understanding of the consumption indirectly driving production and its consequent environmental pressures.

Such a dual approach can provide much of the information necessary to focus policy actions in areas where they are most necessary and can have most effect.

Both perspectives can be obtained through the analysis of tables integrating national economic accounts with environmental data: *national accounting matrices including environmental accounts* (NAMEA). The NAMEAs can be manipulated using *environmentally extended input-output analysis* (EE-IOA) to provide the two different perspectives useful for SCP: a *production perspective* and a *consumption perspective*.

The *production perspective* which is derived directly from the NAMEA matrices, gives a basic picture of direct pressures arising from economic sectors and their economic output both for domestic consumption and export. The inclusion of economic data also allows the *environmental intensity* (environmental pressure per Euro of output) of economic sectors to be compared. Finally, it allows success in decoupling of pressures from economic growth to be assessed for countries and for individual sectors, and can decompose trends in decoupling into different contributing factors.

The NAMEAs can be manipulated using EE-IOA to give a *consumption perspective.* While the production perspective looks at the question 'where and what emissions take place?' 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. Those 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 complimenting the role provided by national emissions inventories.

Hotspots in European production patterns

The NAMEA tables were used directly in their basic form to analyse European production. Suitable NAMEAs were available from Eurostat providing economic and environmental accounts for EU-25 production from 1995 until 2004.

Direct European emissions contributing to four key aggregated pressure categories were examined: *greenhouse gas emissions*, *acidifying emissions*, *emissions of tropospheric ozone precursors* and *domestic material input*.

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 greenhouse gas emissions, 93% of acidifying emissions and 84% of emissions of ground ozone precursors arising from European production. Material extraction is dominated by agriculture and mining industries.

Of the 4 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 of the EU25 economy but together emit 47% and 60% of greenhouse gas 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 17% and 28% respectively between 1995 and 2004 despite an economic growth of 27%. Production-related GHG emissions remained fairly stable 1995-2004.

For all three types of environmental pressure, decoupling appears mostly to have been achieved through improvements in eco-efficiency within 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 only manufacturing achieved absolute decoupling in all three pressures. The transport services industry fared worst with greenhouse gas emissions increasing by 25% between 1995 and 2004.

The European Commission has recently set a target of an 80% reduction in GHG emissions 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 will 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 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 potentially with a negative net effect (e.g. carbon leakage).

Hotspots in European consumption patterns

The consumption perspective concentrates on global environmental pressures caused by all the goods and services consumed in a country. This includes imported goods, but excludes goods produced for the export market. 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 NAMEA matrices from industries to production chains of final products. This requires symmetric national input/output tables. At the time of reporting these tables were only available for 8 EU countries (Denmark, Germany, Hungary, Italy, Netherlands, Spain, Sweden, and the United Kingdom).

A few final consumed product groups contribute significantly (30-40%) to all four environmental pressures embodied in products. These are:

- *construction works* i.e. buildings and infrastructures
- *food products, beverages and alcohol*
- *electricity, gas, steam and hot water* the majority of which is electricity

A further 5 products also accumulate significant environmental pressures:

- *Wholesale and retail services*
- *Products of agriculture, hunting and forestry*

- *Transport equipment*
- *Hotel and restaurant services*
- *Transport, storage and communication services*

The 8 product groups together account for 60-70% of the key environmental pressures caused by consumption but only 40% of consumption expenditure. In other words they have high pressure-intensities. Perhaps surprisingly they include 3 services in addition to 5 material goods. Low pressure-intensive products, however, are dominated by services.

Trends in total pressures activated by national consumption (1995-2000) were analysed in six EU countries with available data. Four of 6 countries saw absolute reductions in air emissions pressures related to consumption, while two achieved only relative decoupling [1]. In all but two countries decoupling was mainly achieved through eco-efficiency improvements in production, rather than by shifts in consumption behaviour to less-intensive products.

Global material extraction, meanwhile, saw little decoupling from consumption growth in the six countries. Material extraction actually increased faster than expenditure in 3 countries due to reduced resource efficiency of production processes.

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[2] which will need to be confirmed by future studies using bottom-up[3] methods. Demand for *Eating & Drinking, Housing & Infrastructures,* and *Mobility* is found to cause around 60-70% of total environmental pressures activated by national consumption in the 8 countries.

The EU Commission has recently adopted a target for an 80% reduction in GHG emissions by 2050 as the EU's contribution to stabilisation of global temperatures at 2^{o}C above pre-industrial levels. Total GHG emissions will, therefore, need to be reduced to around 2 tonnes per capita by 2050. For comparison, each of the key demand areas of *Eating & Drinking, Housing & Infrastructures,* and *Mobility* <u>on their own</u> currently lead to emissions of 1.9-2.5 tonnes of GHGs per capita.

Although in the short/medium term at least some of European's emissions reductions are likely to come from investments in cleaner technologies abroad, in the longer term significant reductions will also be necessary within each of these key consumption areas.

To identify the most effective actions within the consumption and production systems activated by each demand area, supplementary analytical tools are needed. These include life-cycle analysis, detailed knowledge of efficiency potential in production processes, and in-depth analysis of consumption behaviour and drivers. Such bottom-up studies do not lie within the scope of this report. Such studies may reveal that focusing policy on improving production processes and technology may not always have greatest potential for environmental gain. Actions focused on changing behaviour and altering the drivers of production, may sometimes give greater benefits. In the case of *Eating & Drinking,* for example, reducing the amount of meat, and particularly beef in diets and reducing food wastage may offer greater potential benefits than improvements in agricultural practices.

---

[1] Relative decoupling is where pressures are growing but at a slower rate than the economy.

[2] 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.

[3] NAMEA based analyses are often described as being 'top-down'; taking a starting point in national level accounts. 'Bottom-up' analyses are those taking a starting point in individual households or industries

Decoupling analysis showed that to date most decoupling of environmental pressures appears to have come from technological improvements. To meet the tough challenges ahead a combination of *technological* and *behavioural* based action and policy will be necessary.

Realising the Full Potential

The EE-IOA method proved to be a powerful tool for analysing consumption and production patterns at national and European level. There are some weaknesses to the underlying data, however, which act as barriers to the achievement of the method's full potential.

1. *Outdated data* –Reporting obligations for symmetrical I/O data required for the consumption perspective is 5-yearly with an additional 3 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 US and Japan. This can limit the method's potential in identifying lever points.
3. *Production processes in other countries* –In building the consumption perspective the assumption is made that industrial processes abroad have the same pressure intensities as in the home country. This can lead to significant underestimates in environmental pressures 'embodied' in imported goods.
4. *Environmental scope* – the environmental data held by NAMEAs are mostly limited to air pollutants and greenhouse gases.

European initiatives are currently underway to tackle some of these issues. Eurostat is aiming to extend the environmental scope of NAMEA tables with waste and energy resources, and potentially water in the longer term. The Commission funded EXIOPOL initiative is building up interconnected regional NAMEAs representing 95% of the global economy. This should allow improved estimates of pressures embodied in imports. The model will also include some additional environmental variables.

Neither the level of economic sector aggregation nor the time delays in data reporting are likely to be changed in the short/medium term, however. There is potential for providing approximate up-to-date NAMEAs through 'now-casting' or conversion of annual supply and use tables.

Table of Contents

Tables

Figures

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. The Ecological Footprint provides some indication of the sustainability of resource use both nationally and globally. By 2003 the average global ecological footprint of 2.2 virtual global hectares per person had exceeded the available bio-capacity of 1.8 global hectares (WWF *et al.*, 2006).

BOX 1: Sustainable Consumption and Production – an implementation strategy for sustainable development

Sustainable Consumption and Production is a holistic perspective on how society and the economy can be better aligned with the goals of sustainability. Sustainable Consumption and Production (SCP) 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. 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 process and guards against unforeseen shifting of impacts from one life-cycle stage to another, one geographical area to another or from 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.

The cause of this overstretch is the high per capita use of resources and environmental services resulting from unsustainable consumption and production patterns in developed countries. The ecological footprints of the average American (9.6 global ha per person) and European (4.8 global ha per capita) are significantly higher than the global average and far exceed the available bio-capacity (WWF *et al*. 2006). Similarly European carbon dioxide emissions are more than twice the global average, and 5 times higher than we can afford to emit per global citizen by 2050 if we are to have any chance of meeting the European Council's target of limiting global temperature increases to under 2^{o} C (den Elzen and Meinshausen, 2005).

Current European consumption and production patterns can clearly not be transferred to the rest of the world without overstretching future global environmental services several times over.

The solution to the problem of limited resources and environmental services is not to halt development in emerging economies, since development is needed to meet the social goals of sustainable development. Rather it lies in adjusting patterns of consumption and production in developed countries to free up resources and environmental services for social and economics development elsewhere. A new set of less pressure-intensive patterns can also provide a development blueprint for emerging economies to leapfrog towards. Identifying and encouraging these adjustments are the focus of the policy area of *Sustainable Consumption and Production (SCP)* (see Box 1).

Changing consumption and production patterns will require the involvement by all actors within these systems: government and civil society, business and consumers. 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 known as environmentally extended input-output analysis (EE-IOA), whose use and application are discussed in this report. This tool allows the environmental pressures of a whole economy to be viewed according to two complimentary 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 technical report presents analysis conducted by the EEA's Topic Centre on Resource and Waste Management[4] (ETC/RWM), using data collected by Eurostat and national statistical offices of selected countries. The report aims to:

1. *introduce the tool of environmentally extended input-output analysis of NAMEAs and examine its potential for answering the key SCP policy questions*
2. *make a first use of it in identifying 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*

[4] Since succeeded by the European Topic Centre on SCP

The report is divided into four main sections. The first describes environmental accounts and input output tables, and how these can be manipulated 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.

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 – i.e. *identifying those elements of European production and consumption patterns which are the key causes of environmental pressures* - requires both 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 are most necessary and can have most effect.

Both perspectives can, in principle, be obtained through the analysis of matrices which combine national economic accounts – flows of money – with environmental accounts – i.e. environmental parameters such as material inputs and outputs of air emissions and other waste products. These integrated environmental and economic matrices are termed *national accounting matrices including environmental accounts* (NAMEA) (see Box 2). (see e.g. Moll et al. 2007, de Haan & 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 NAMEA matrices 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 totals of a given environmental pressure are distributed across a country's economic branches. They also provide data on the economic output of each economic branch both for domestic consumption and export.

We term this overview the *production perspective* (see Box 4 in Section 2.5). The tables also include direct pressures from households and government and as such provide an overview of the total *direct* emissions attributable to a country. This picture is similar to the 'territorial' perspective provided by national emissions inventories (see Section 2.4) and the tables can be used in a similar way to identify environmental 'hotspots' in national production.

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

The inclusion of compatible economic data allows the *environmental intensity* (environmental pressure per Euro 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, and can decompose trends in decoupling into different contributing factors (see Chapter 3).

The NAMEAs can be manipulated using some powerful econometric methods termed *environmentally extended input-output analysis* (EE-IOA) to provide a *consumption* *perspective* (see ten Raa, 2005, Miller & Blair 1985, Moll & Acosta 2006, Moll et al. 2007). While the production perspective looks at the question 'where and what emissions take place?' the consumption perspective considers 'what are the consumed products which are 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 caused by an economic sector are re-allocated to the flows of goods and services it sells to other branches and to the final consumer. The indirect pressures accumulated along the full production cycle of final products can then be calculated (i.e. for food - all pressures released and resources used between 'farm and shelf'). Using other methods, direct emissions from households can also be allocated to some final product groups.

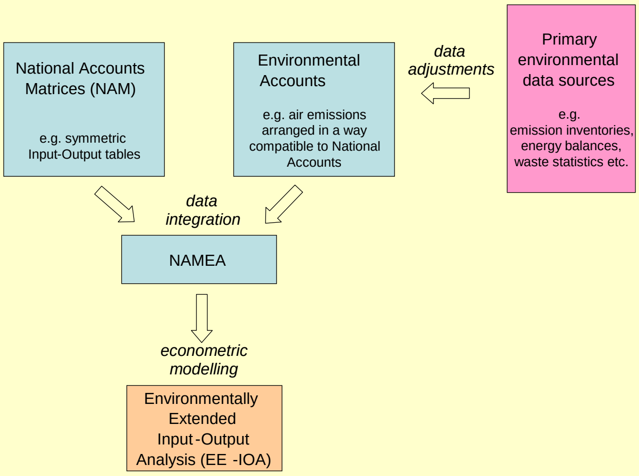
BOX 2 Brief overview of NAMEA Tables

NAMEA tables integrate national environmental accounts with environmental data.

The NAM-part represents the monetary flows between economic branches within a country (i.e. between the food processing industry, the transportation equipment industry, banking and insurance services etc.) and between these and final consumers[5] (government, households and exports). They also include flows of imports for intermediate and final consumption[6]. 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* (IOT) are needed. For the production perspective more readily available gross output data from economic sectors is sufficient.

The EA-part of a NAMEA represents environmental flows, i.e. physical data on direct inputs and outputs to and from the environment, for each economic branch. The EA-part must follow the accounting principles and structures of the NAM-part in order to allow integration.into the NAMEA. Most primary data sources of environmental statistics do not fulfil this requirement and employ classifications and accounting rules which aren't 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 when integrating them into a NAMEA (see section 2.3).

The scheme below provides an overview of how NAMEAs are derived. The NAMEA forms the data basis for environmentally extended input-output analyses.



Source: Eurostat 2009

---

[5] The correct term used in National Accounts is *categories of final use*.

[6] The correct term used in National Accounts is intermediate and final *use*.

Those product groups which cause the majority of environmental pressures can be identified and the eco-intensity (environmental pressure per Euro) of different product groups compared. The eco-intensity of a product group can also be monitored over time.

A further output of this tool is in the analysis of the full production chain for any product-group to identify which parts of that chain are responsible for the most environmental pressures. This analysis can identify where product-orientated policy should be focused.

Finally, the consumption perspective also allows direct and indirect *global* environmental pressures caused by *total national consumption* to be estimated, giving a complementary perspective to more traditional monitoring of direct *territorial* pressures presented by emissions inventories[7]. This perspective can be informative for national governments interested in measuring their country's global 'footprint'.

The next two sections give some more detail on how NAMEAs are constructed from national accounts and environmental information.

Section 2.5 gives an overview of differences between national GHG emissions inventories for reporting under the UNFCCC, and total GHG emissions as identified in NAMEA tables. Section 2.6 then describes how NAMEAs and EE-IO analysis are used to create the *Production* and *Consumption* perspectives.

Finally, Section 2.7 provides an overview of data employed in this project.

2.2 A brief introduction to National Accounts

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. GDP is just one indicator derivable from a comprehensive data framework called *System of National Accounts* (SNA). Further prominent indicators derivable from SNA include national income, gross value added of industry branches, trade balance, net savings etc.

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 (SNA) was established internationally under the auspices of the United Nations. The first version was published in 1953, followed by revisions in 1968 and 1993[8] and it is under continuous development. The European System of Accounts (ESA) is the equivalent system used by members of the European Union[9]. It was most recently updated in 1995 and is broadly consistent with the 1993 SNA.

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

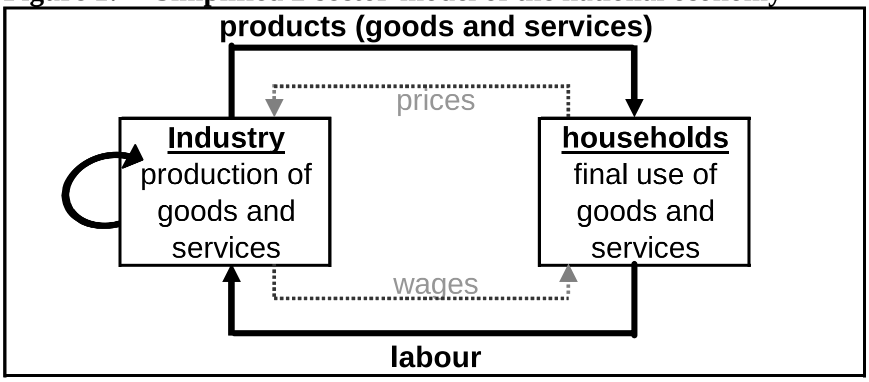
[7] The territorial perspective is similar to a production perspective with the addition of direct pressures from households

[8] See http://unstats.un.org/unsd/sna1993/introduction.asp

[9] See http://circa.europa.eu/irc/dsis/nfaccount/info/data/esa95/en/titelen.htm

The most simplified presentation of a national economy is the 2-sector-model comprising industry and households[10]. Industry represents the production of products (goods and services[11]) and households represent the primary final use of these products. The two components are mutually connected via transactions: physical and monetary flows. In Figure 1 physical flows are represented by a bold arrow; monetary flows by a dotted arrow. There is a physical flow of products from the production system to the private households. The reciprocal monetary flow is the purchase price private households pay for these products. The physical flow from private households to the production system comprises the labour force private households provide. The reciprocal monetary flow is the compensation of this labour through wages.

Figure 1: Simplified 2-sector-model of the national economy



The SNA (and ESA) principally records only the physical flows. In other words, only the bold arrows in Figure 1 are accounted for. However, these physical flows are represented in monetary values rather than the original physical units of tonnes of goods or numbers of employees and hours worked. For example, the flow of products is expressed in Euro by multiplying the volume of goods by the unit price.

An important insight which can be derived from Figure 1 is that the production of goods and services and final use of products are closely related. In a closed economy they are in fact two sides of the same coin[12].

The flows as shown in Figure 1 can also be presented in a T-account where the left column shows the production of goods and services and the right column shows how these products are used.

Figure 2 shows the T-account for domestic production. The left column presents the resources needed to generate the output from domestic production. Two generic inputs are required. First intermediate products are needed to generate the final product for consumption. For instance, the domestic car manufacturing industry needs steel, tyres, glass, electricity etc. to be able to assemble finished cars. These intermediate products come either from other domestic production units or are imported. Secondly, the industry needs so-called *factor* inputs such as labour and machines. These are recorded under the item ‘gross value added’. The costs of intermediate products and factor inputs (value added) together give the cost of the final goods to the producing company.

---

[10] This is a very simplistic image. It neglects further important sectors of the national economy such as e.g. government and financial corporations.

[11] Note: “products” is the superior term comprising “goods” and “services”

[12] i.e. in the global economy or other closed economies. In national economies many goods and services are provided to and from outside the system.

The right column shows how this output from domestic production is used. A certain part of the domestically produced output 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 and government. A secondary part of the output is used to build up the physical capital stock of machinery, buildings and infrastructures (termed ‘gross capital formation’). A third portion of the output is exported and although this is described as final use in the accounts, exported goods comprise 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.

Figure 2: Simple T-account for domestic production

Resources	Use
Use of intermediate products from domestic production	Use of intermediate products from domestic production
Purchase of imported intermediate products	Final use (of mainly finished products) from domestic production:
Gross value added: - compensation of employees - profits - indirect taxes less subsidies - depreciation	- final consumption expenditure - gross capital formation - stock changes - exports
= Output (from domestic production)	= Output (from domestic production)

The two sides of the T-account presented in Figure 2 should be exactly balanced i.e. both columns should add up to the same total quantity. Again, it shows two sides of the same coin: everything produced is also used, be it intermediate use or final use.

If the right column of the T-account in Figure 2 is rotated by 90° to overlap with the left hand column we obtain the basic shape of an Input-Output table shown in Figure 3. Now, the intermediate use parts of both sides of the initial T-account are overlapping. Monetary values of imports for final use (light blue) are added in underneath the final use cell. These comprise products imported for final use in the home country.

Eurostat’s Input-Output tables disaggregate production into 60 distinct economic sectors. Each sector is represented by both a column and row. The columns show the inputs required by each sector for their production, while the rows represent the outputs of that branch, comprising both intermediate products for use by other branches (left hand side) and final products for consumption by households and government and for export.

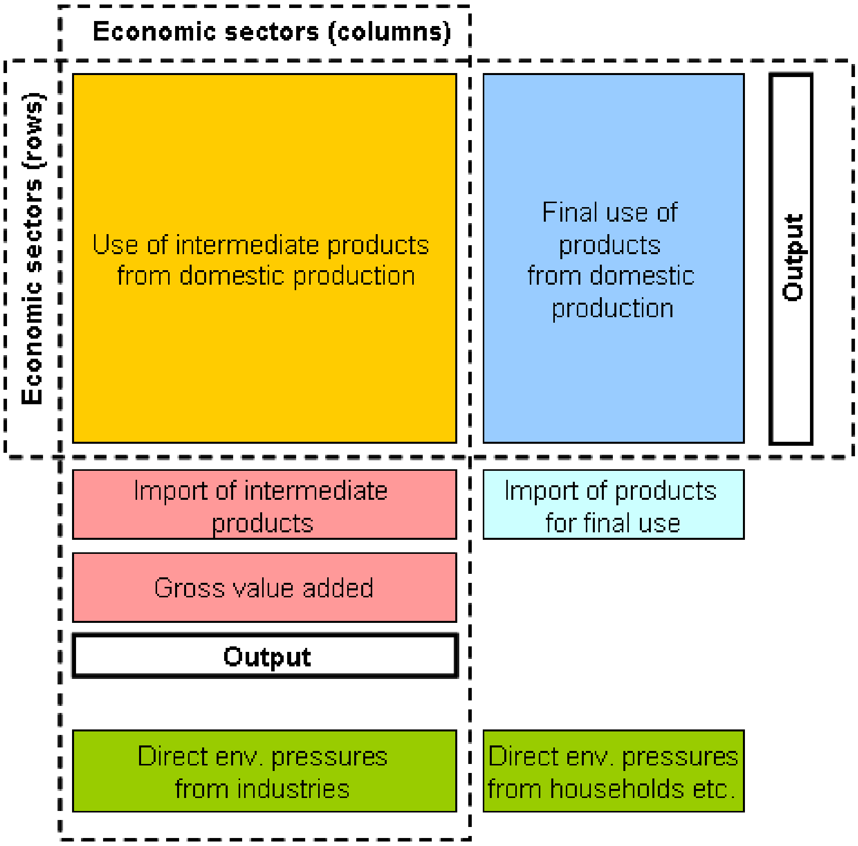
Thus the 60 by 60 intermediate matrix shown in yellow shows the monetary flows of intermediate products exchanged between the 60 different economic branches i.e. use of electricity by the food processing industry, or use of outputs of the rubber industry in the car manufacturing industry. The dark blue area of the tables shows the end destination of final products from each economic branch (households, government, export). Finally the pink parts of the table show inputs to each economic branch other than the domestically produced intermediate goods.

To create the final NAMEA, 'environmental pressures' (shown in green in Figure 3) are added underneath the economic matrices. They represent environmental inputs to, and outputs from, the economic branches (left hand side) and economic pressures emitted directly by households (right hand side). The environmental extension part may include several categories of environmental pressures. Typically, NAMEAs include key air pollutants and greenhouse gases but can also include material inputs in tonnes and outputs of some toxic waste materials.

Environmental pressure data split by industry are added to the economic input/output table to give the NAMEA

The scheme in Figure 3 represents a final NAMEA, i.e. *National Accounting Matrix including Environmental Accounts*. The green parts are the EA, the remainder represents the NAM.

Figure 3: Simplified scheme for a NAMEA matrix



2.3 From environmental statistics to Environmental Accounts

The EEA, based on previous works by OECD and others, has established the DPSIR framework as a working principle for their provision of environmental information Therein, three types of environmental data can be distinguished:

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

Of these, 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 induced by human activities. They comprise the input of materials (such as e.g. minerals, fuels, biomass, water etc.), land and energy, and the output of waste emissions to air, soil and water. Those environmental pressure variables, unlike environmental states or impacts, can be assigned to economic actors in NAMEA tables.

Statistics on environmental pressures are recorded in various data formats. As shown by the scheme in Figure 3 those environmental pressure statistics need to be adjusted to accounting principles and structures of the System of National Accounts (SNA). Such adjusted environmental pressure statistics are termed *Environmental Accounts*[13].

This project employs some of the more important environmental pressure variables for which specific statistics exist:

- emissions of greenhouse gases and air pollutants as recorded in emission inventories
- material inputs as recorded in economy-wide material flow accounts

Methodological guidelines for *emission inventories* for greenhouse gases and air pollutants have been established under the umbrella of two international conventions. With the Convention on Long Range Transboundary Air Pollution (CLRTAP) standards were developed to represent national data on emissions of a number of important air pollutants. The United Nations Framework Convention on Climate Change (UNFCCC) triggered the establishment of harmonised greenhouse gas inventories. The EEA is the responsible body collecting these inventory data from national authorities and compiling aggregated EU inventories (e.g. EEA, 2006; EEA, 2008). The classification systems of both conventions have been harmonised recently 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 2009). Eurostat compiles air emission accounts under its work programme on Environmental Accounts.

Material inputs are recorded in *economy-wide material flow accounts*[14] (EW-MFA) for which Eurostat has established compilation standards (see Eurostat 2001 and Weisz et al. 2005). 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 domestic extraction used (DEU) – i.e. the extraction of material resources within national boundaries – can easily be linked to the economic classifications used in National Accounts.

[13] The term *Environmental Accounts* is used here to denote that environmental variables are organised in a SNA-compatible data format.

[14] Some prominent environmental pressure indicators can be derived from economy-wide material flow accounts, such as e.g. Direct Material Input (DMI), Direct Material Consumption (DMC) or Total Material Requirement (TMR).

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

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 as possible to a particular industry. In SNA, industries (economic units) are defined and classified using NACE classification. 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 Environmental Accounts and National Emissions Inventories

The boundary for National Emissions Inventories is the territorial border.

For NAMEAs the scope is all nationally registered businesses– even those situated in other countries

Although, as described above, the air emissions elements of Environmental Accounts in national NAMEAs are derived from national air emissions inventories, there are some important differences between NAMEAs and national emissions inventories both in their scope, and what the objectives are behind them.

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, the Convention on Long Range Transboundary Air Pollution)
- 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 effectives 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 3).

BOX 3: 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.

NAMEA accounting principles on the other hand follow national accounting systems which defines 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 of included in NAMEAs are restricted to a national *economic* boundary.

In NAMEAs, 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 NAMEA 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 NAMEA.

Of key importance, NAMEAs, 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 1 below shows the main differences in the scope of environmental pressures included in national NAMEA tables and national air emissions inventories: in the case of GHG emissions:

Table 1: Differences in scope of air emissions included in NAMEAs and in national emissions inventories

	GHG emission inventories	**NAMEA**
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	Emissions within the economic territory of the country covered, i.e: • Emissions of entities registered in the country (e.g. ships, residents)

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 we are doing 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.

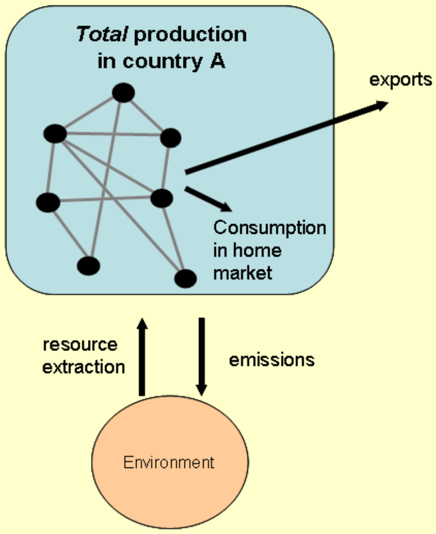
2.5 Obtaining the consumption and production perspectives

Two different perspectives of the economy can be derived from the NAMEAs. 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 3), i.e. industries, government and households. In this perspective it is the environmental performance of different economic sectors which is in focus. The *consumption perspective* estimates the pressures arising along the international production chains of all products consumed nationally, and compares the environmental pressures caused by different product groups. In this perspective it is the environmental pressures 'embodied' in consumed product groups which are of interest. Direct pressures arising during the consumption of these products can also be added in using other methods to give a full picture of which product groups are leading to greatest direct and indirect pressures. See Box 4 for a comparison of the two perspectives.

BOX 4: The production and consumption perspectives

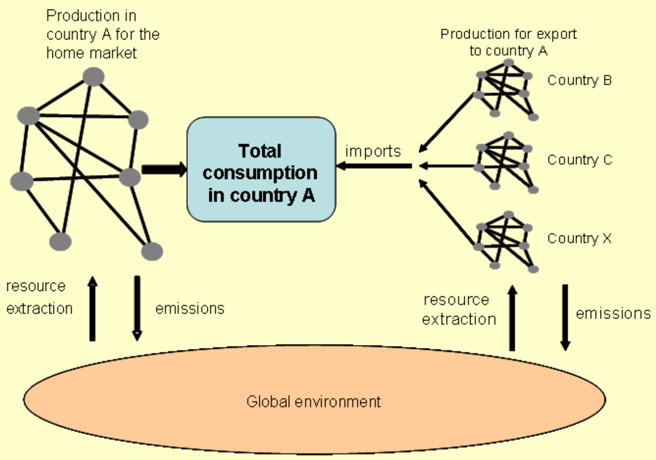
For an economy that trades with other countries there can be a large difference between the products that the country produces and the products which are finally consumed both by private households and the government. Similarly there can be significant differences between the environmental pressures associated with a country's total production and the pressures associated with the products it consumes (see Watson and Moll, 2008).



We term the first scenario the ***production perspective.*** This traditional 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) plus all direct emissions from households and government i.e. combustion of fuel for heating and private cars.

The alternative perspective for viewing nationally activated pressures is termed as the ***consumption perspective***. We define this as all environmental pressures caused directly or indirectly by national consumption. This only includes pressures from national production for the home market i.e. excludes pressures from production for the export market. It includes, however, pressures occurring in other countries to produce our imported goods. Finally, as with the production perspective it includes direct pressures arising in private households and government. Others have named this perspective a country's footprint.

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



Thus, while in the production perspective the individual production facility is in focus, under the consumption perspective it is the finally consumed product that is the focus (whose production cycle is illustrated by black flows between production branches in the diagram).

The *production perspective* can be investigated directly using NAMEAs in their basic form. NAMEAs provide a picture of where exactly in the national economy resources are *directly* used and air emissions and other wastes directly generated. For this perspective we only need the Environmental Accounts and gross output of economic sectors rather than the full scheme given in Figure 3. Total direct emissions and resource use attributable to a country can be obtained by summing contributions from each economic branch, and adding in direct pressures from households and government.

However, it should be noted that in this report for most of the analysis we have focussed on a special case of the production perspective which leaves out direct pressures from households and only includes direct pressures from economic sectors i.e. businesses and government services.

Using this kind of 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 NAMEA 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 NAMEAs by dividing the total pressures they are responsible for by their economic output.

Considerably more effort is required to shift to the *consumption perspective* which follows products consumed nationally (See Box 4). Complex matrix transformations developed by Leontief (1970) and others, termed environmentally extended input-output analyses (EE-IOA), are applied to the NAMEAs. Through the transformations, direct environmental pressures attributable to a given branch are re-allocated to the flows of goods and services it sells to other branches and eventually to the final consumer. 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 households, 30% of all its direct air emissions will be allocated to the final product of vehicles, 30% to food products and the remainder to electricity sold to households.

At the end of this process, the pressures allocated to a finally consumed product group are equivalent to the sum of all pressures accumulated along the full global production-cycles of those goods or in other words the indirect pressures ‘embodied’ in these products.

For the final use product group *food and beverages*, for example, it includes all pressures emitted during the production of food from the farm through to the supermarket shelf, including pressures activated by the production and application of fertilisers, by the production and combustion of fuels in agricultural machinery, by the production of electricity consumed in food processing plants etc.. To perform such calculations, one needs the full NAMEA data scheme as illustrated in Figure 3.

We calculate the total indirect pressures activated by consumption in a country by summing the embodied pressures of all nationally produced products and then subtracting the pressures embodied in products ending in the export market. We must then add in the pressures embodied in imported goods. This latter includes both final-use goods and inputs into national production chains e.g. imported fossil fuels, sub-components for machinery, pig-iron etc.

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

We may reach a point in the future where interlinked NAMEAs have been developed for all European countries and their key trade partners. For now, however, the EE-IOA method can only make rough estimates of pressures accumulated by imported goods. This is done by assuming that industries abroad generate the same waste emissions and use the same resources per unit output as the same industries in the home country (what is actually being measured here are *avoided national pressures*). Where goods are imported from developing and transition countries this assumption is likely to considerably underestimate their embodied pressures.

Finally, to create the true consumption perspective rather than just a product perspective we must add in the *direct* pressures from households released during the consumption of goods (i.e. emissions released while driving cars or burning gas or oil to heat houses).

These direct pressures released during consumption can also be allocated to various product groups to give a full picture of which groups are responsible for the most direct and indirect pressures during their production and subsequent consumption. However, this allocation cannot be carried out using EE-IOA but must use be estimated using other methods as described under section 4.4 of this report.

2.6 Data Used in this Report

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

The EEA and the ETC have aimed to collect the most up-to-date data available for this project.

As described earlier, the production perspective can draw on more simple NAMEAs than those given in Figure 3. As a result data availability for the production perspective is more comprehensive. The consumption perspective requires the full set of data given in Figure 3 including symmetrical economic input-output tables. 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 is usually compiled and provided by National Accounts units in national statistical institutions. Member States are obliged to provide Eurostat with economic data according to a reporting system under the European System of Accounts 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, must be reported yearly. The symmetric input/output tables required for the consumption perspective is required from Member States only once every 5 years.

The environmental data comes from a number of sources. Eurostat collects air emissions data in a form suitable for NAMEAs (so called air emission accounts or NAMEA-air) from all EU member states' national statistical institutions every two years. The most recent available data set used for analysing the production perspective in this report is based on the Eurostat survey conducted in 2006[15]. The data comprises 1995-2004 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. The aggregated

[15] A further survey was carried out in 2008 but the data is still being quality controlled by Eurostat.

pressures take account of the relative effect of the different emissions i.e. a kg of laughing gas (N_2O) has 310 times the climate change effect of a kg of CO_2. .

Table 2: Calculation of aggregated pressures from 8 emissions to air

Theme	***Substance***	***Weighting factors applied***	***Comments***
Climate Change (Global Warming)	CO_2	1	Aggregated greenhouse gas emissions, GHG, in CO_2-equivalents after 100 years
	N_2O	310	
	CH_4	21	
Acidification	SO_2	1.0 = 0.03125/0.03125	Aggregated acidification emissions in SO_2-equivalents (EEA 2002, p.83)
	NOx	0.7 = 0.02174/0.03125	
	NH_3	1.9 = 0.05882/0.03125	
Ground-level (tropospheric) Ozone Formation	NOx	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	

Data used for the production perspective

In Chapter 3 we look at aggregated production at the EU level. The industry breakdown for Eurostat's EU25 estimates is limited to 36 partially disaggregated economic branches. The chapter draws on a consistent economic-environmental data set from Eurostat. The datasets and coverage included in the analysis in Chapter 3 are given in Table 3.

Table 3: Data inputs for the production perspective analysis

Economic data	
Data type	Output, gross value added, broken down to 36 economic sectors
Country coverage	Aggregated EU-25
Data source	Eurostat 2006
Time series	1995-2004
Environmental Accounts – air emissions	
Environmental variables	Eight air emissions further aggregated to three pressures for 36 economic sectors: • *Emissions of GHGs (tonnes CO2-equiv)* • *Acidifying emissions (kg SO2-equiv)* • *Emissions of tropospheric ozone forming precursors (kg NMVOC-equiv)*
Country coverage	Aggregated EU-25
Time series	1995-2004
Data source	Eurostat NAMEA-air[16] 2006
Environmental Accounts – material flows	
Environmental variables	MFAs broken down into 36 economic sectors covering: • *Domestic Extraction Used – biomass* • *Domestic Extraction Used – minerals* • *Domestic Extraction Used – fossil fuels* • *Imports* • *Direct Material Input – DMI*
Country coverage	Aggregated EU-15
Time series	1995-2004
Data source	Eurostat MFA 2007 broken down by ETC/RWM

As an additional environmental extension for the production perspective, this report used economy-wide material flow accounts as provided by Eurostat (2007). This data set comprises only estimates for the EU15 as a whole and does not provide any industry

[16] downloadable from: http://epp.eurostat.ec.europa.eu/portal/page?_pageid=2873,63643317,2873_63643793&_dad=portal&_schema=PORTAL

breakdown. A breakdown was therefore carried out by hand by the ETC/RWM project team.

Data used for the consumption perspective

As noted earlier, EU member states are only obliged to provide Eurostat with the symmetric economic input/output tables required for the consumption perspective once every five years. Moreover, the data has a typical reporting lag of 2 to 3 years.

At the time of writing, the most recent reporting year with fairly good country coverage was 2000 (as reported to Eurostat in 2003). For this report, data for eight countries were collected as roughly representative of the EU economy: Denmark, Germany, Hungary, Italy, Netherlands, Spain, Sweden, and the United Kingdom. Data collected and analysed for the consumption perspective is described in Table 4. The analysis using these data sets is presented in Chapter 4.

Table 4: Data inputs for the consumption perspective analysis

Economic data	
Data type	Symmetric Input-Output tables (60 by 60 branches) for 8 countries comprising domestic production and imports
Country coverage	8 EU countries – DE, DK, ES, HU, IT, NE, SE, UK
Time series	1995 and 2000, except UK and ES 1995 only
Data source	Eurostat
Environmental Accounts – air emissions	
Environmental variables	Eight air emissions further aggregated to three pressures for 60, 31 and 17 economic sectors: • *Emissions of GHGs (tonnes CO2-equiv)* • *Acidifying emissions (kg SO2-equiv)* • *Emissions of tropospheric ozone forming precursors (kg NMVOC-equiv)*
Country coverage & Time series	As above
Data source	Obtained by ETC/RWM from national statistical authorities
Environmental Accounts – material flows	
Environmental variables	MFAs broken down into 60, 31 and 17 economic sectors covering: • *Domestic Extraction Used – biomass* • *Domestic Extraction Used – minerals* • *Domestic Extraction Used – fossil fuels* • *Imports* • *Direct Material Input – DMI*
Country coverage & Time series	As above
Data source	Eurostat MFA 2007 broken down by ETC/RWM

Symmetrical input/output tables have recently become available for a number of EU countries for 2005. However, the environmental accounts for 2005, collected by the 2008 survey, are unlikely to be released by Eurostat until at the earliest March 2009. It is the intention to update the findings under the consumption chapter of this report with 2005 data and publish as an EEA Report during summer 2009.

3 Environmental Hotspots in European Production

3.1 Introduction to the production perspective

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

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.

The 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 Watson and Moll, 2008). 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 greenhouse gases 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 NAMEAs, 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 in understanding how we can get closer to sustainable consumption and production.

Economic and environmental data used for this analysis are given in Table 3 in section 2.6. As described in the table, data has been used for the aggregated EU-25 economy, for the period 1995-2004.

3.2 Brief overview of European production patterns

European production output is dominated by services

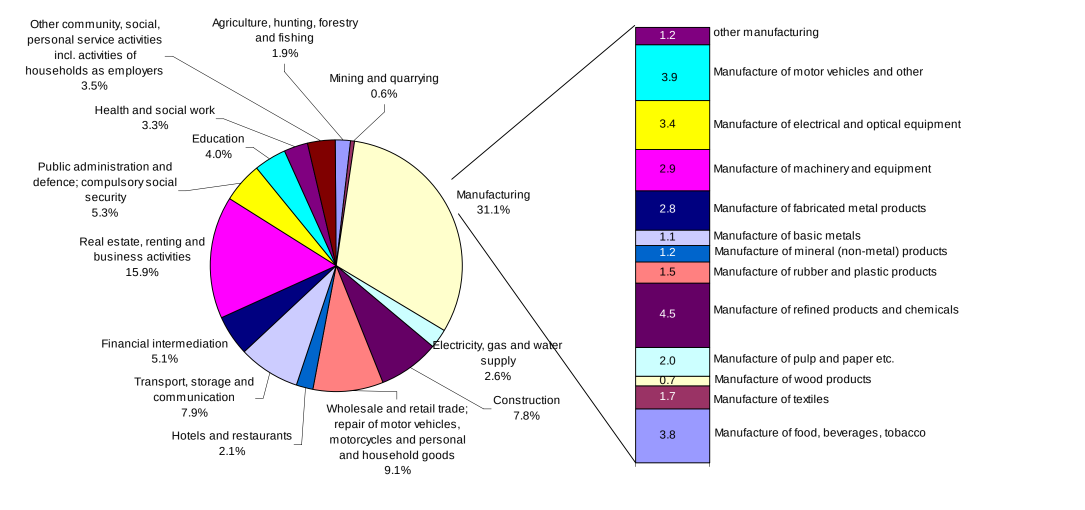
Before considering pressures it is worth taking a brief overview of how European production is broken down. A good means to describe the structure of the EU production system is to look at the composition of total production output broken down by economic sectors (see 4).

In recent decades the tertiary service sector has grown at the expense of agriculture and industrial production. More than half (ca. 56%) of EU's total production output is now generated by service industries. Market services (real estate, renting, retail and wholesale trade and transport services) account for ca. 40%, and non-market services (public administration, education, and health and social work) for the remaining 16%.

Manufacturing accounts for around 31% 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 contributes 8% to EU output while the supply of electricity, water and gas contributes 2.6%.

The primary sectors play only a minor role: agriculture, forestry and fishing with 1.9% and the mining sector with 0.6%.

Figure 4: Production output of the EU-25 by economic sector – 2004



Source: Eurostat NAMEA data set

3.3 Environmental pressures from European production

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

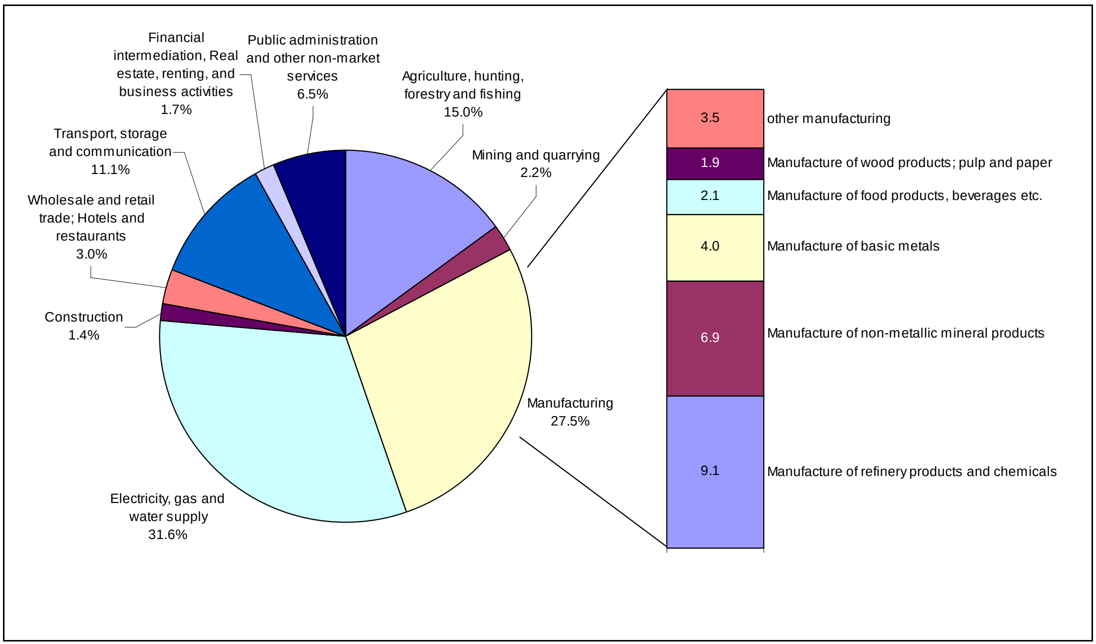
- *agriculture, hunting forestry and fisheries* (agriculture)*;*
- *electricity, gas and water supply* (electricity industry)*;*

- *manufacturing;* and
- *transport, storage and communication* (transport services)[17].

These four sectors together account for 75% of total greenhouse gas emissions from all EU production (see Figure 5) with the electricity industry (31.6%) and aggregated manufacturing industries (27.5%) 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 and chemicals (9.1% of total EU GHGs), manufacture of non-metallic mineral products such as cement (6.9%), and manufacture of basic metals including iron and steel production (4%).

Figure 5: Direct emissions of greenhouse gases by economic sector in the EU-25, 2004

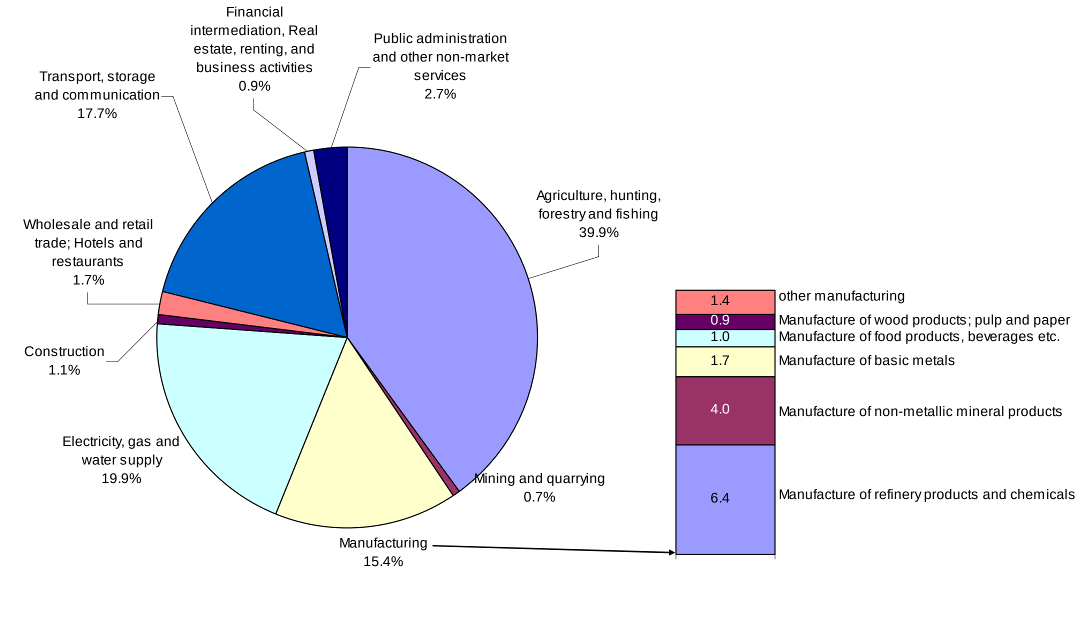


Source: Eurostat NAMEA data set

The same four key economic sectors account for some 93% of total acidifying emissions from all EU production (see Figure 6). Agriculture's contribution is mainly due to ammonia emissions (NH_3). The electricity industry's contribution mainly comprises SOx-emissions from fossil fuel combustion. Emissions of SOx and NOx 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 with some 15.4%. Within this broader sector the same 3 manufacturing industries dominate the emissions of acidifying gases: manufacture of refinery and chemical products (6.4%), mineral products including cement (4.0%), and basic metals (1.7%).

[17] 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. Greenhouse gas emissions directly arising from households' use of private cars are not considered here but discussed under the consumption perspective

Figure 6: Direct emissions of acidifying gases by domestic economic sectors for the EU-25, 2004

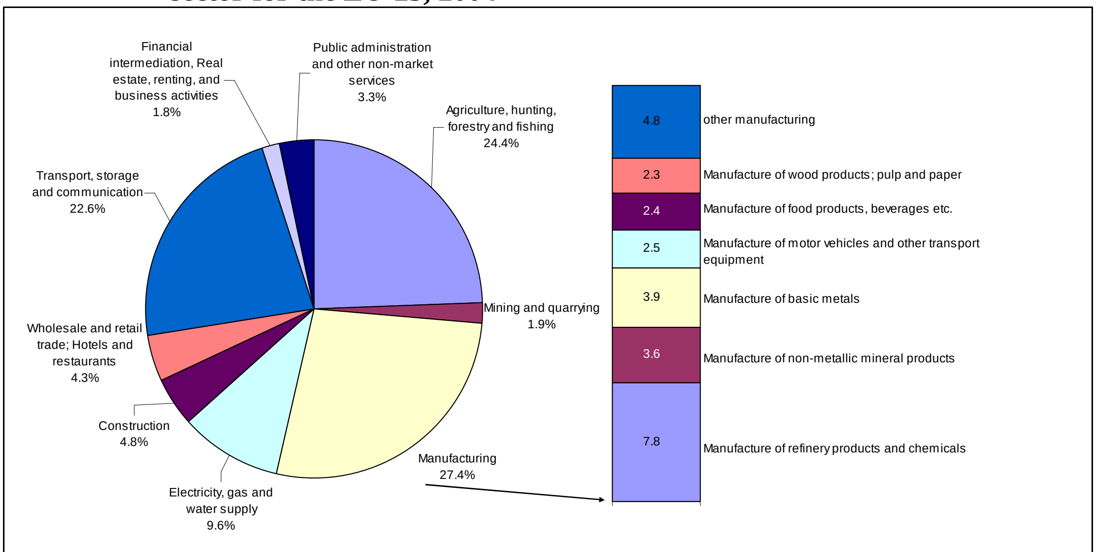


Source: Eurostat NAMEA data set

The four broad economic sectors also dominate emissions of ground ozone precursors, together accounting for 84% of emissions from all EU production (see Figure 7). 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 NOx-emissions; and for manufacturing it is NMVOCs. The construction industry and wholesale and retail services are also fairly important contributors.

Again the same three basic industries dominate emissions from the broad manufacturing sector but some other manufacturing industries are also important: the manufacture of motor vehicles, food products and wood products.

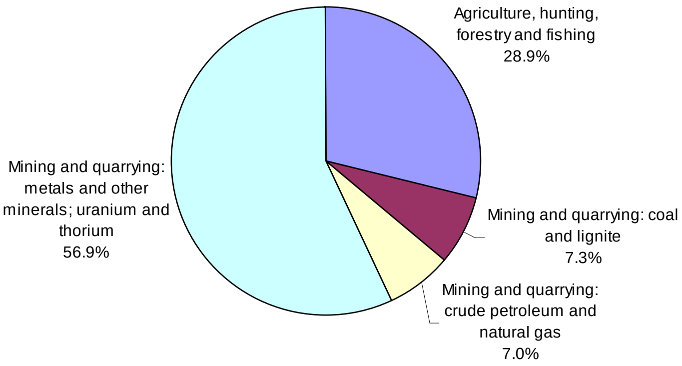
Figure 7: Direct emissions of ground-level ozone precursor gases by economic sector for the EU-25, 2004



Source: Eurostat NAMEA data set

Finally, Figure 8 shows the domestic extraction of virgin materials by domestic economic sectors for the EU-15. Only the agriculture and the mining sector 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.

Figure 8: Domestic Extraction Used (DEU) by economic sector, EU-15 2004



Source: Eurostat MFA data set

A handful of industries dominate pressures from European production

In conclusion, a limited number of economic sectors are responsible for the majority of production-related environmental pressures arising from the domestic production system *Agriculture* is a main contributor in all categories of environmental pressures analysed in this report. The *electricity industry* and *transport services* and *manufacturing* are main contributors of air emissions. 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, the *mining and quarrying* industries, unsurprisingly, dominate 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 lead to reductions in production-related environmental pressures and improvements in the eco-efficiencies of production as is shown in the following section.

3.4 Eco-efficiency of European production

One particular advantage of the Environmental Accounts data set employed in this study is that it allows an integrated analysis of the economic and environmental performance of economic sectors since the same classification system is used for both environmental and economic data.

Some of the economic sectors contributing most to environmental pressures are of comparatively low economic importance...

We begin by comparing production output (see Figure 4) of the main economic sectors with their contribution to direct environmental pressures (see Figure 5 to Figure 7). Such comparisons effectively identify the *pressure intensity* (pressure per unit economic output), or its inverse the *eco-efficiency*, of economic sectors.

A key finding is that some of the ‘hotspot’ economic sectors which dominate production-related environmental pressures in the EU, are of comparatively low economic importance.

Of the main sectors contributing most to air emission pressures, only the aggregated manufacturing branch contributes an equivalent proportion to gross value added (GVA) of the EU economy. For the other main polluters, the contribution to total EU gross value added is significantly lower than the contribution to total production-related environmental pressures. The electricity and agriculture sector, perform particularly badly accounting together for only 4% of gross value added but contributing 30% to 60% of total emissions of greenhouse gases, acidifying gases and ground-level ozone precursor gases.

...due to their high environmental intensities.

In other words the electricity and agricultural sectors and, to a lesser extent, transport services, have a high pressure-intensity compared to the average pressure intensity of the EU economy. In fact the first two industries have among the highest pressure-intensities of all economic sectors in the EU.

Service branches (with the exception of transport), on the other hand, show reasonably low GHG-emission-intensities. In other words, as services increase their share in the EU economy, GHG–emissions will tend to decrease.

The manufacturing sector, meanwhile, has a similar GHG-emission-intensity to the economy average. However, within manufacturing the manufacture of non-metallic mineral products (cement, class, ceramics etc.) has particularly high pressure-intensities for all three air-born pressure categories per unit output; the manufacture of basic metals has high intensities for both GHG emissions and acidifying gases while the manufacture of coke and refined petroleum products has a high GHG-emission-intensity (Table 5).

Table 5: Intensities of greenhouse gas emissions, acidifying emissions, and emissions of ground-level ozone precursors per unit output by selected economic sectors, EU-25 2004

	Greenhouse-gas-emission-intensity [kg CO2-equivalents/Euro]	Acidifying-emission-intensity [g SO2-equivalents/ Euro]	Intensity of emissions of ground-level ozone precursors [g NMVOC-equivalents/ Euro]
Total Industries	**0.21**	**1.17**	**1.16**
Agriculture, hunting, forestry and fishing	1.72	25.28	15.28
Mining and quarrying	0.83	1.56	4.00
Manufacturing	**0.19**	**0.59**	**1.04**
therein:			
Manufacture of refined petroleum products and chemicals and chemical products	0.43	1.66	2.02
Manufacture of other non-metallic mineral products	1.27	4.07	3.67
Manufacture of basic metals	0.76	1.85	4.09
Electricity, gas and water supply	2.67	9.25	4.41
Transport, storage and communication	0.30	2.66	3.36

Source: Eurostat NAMEA data set

3.5 Decoupling pressures from growth in output

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

Since society normally regards economic growth as a desirable feature of development, decoupling of environmental pressures from economic growth is a critical element of sustainable development strategies. This is also the case for *Sustainable Consumption & Production* (SCP).

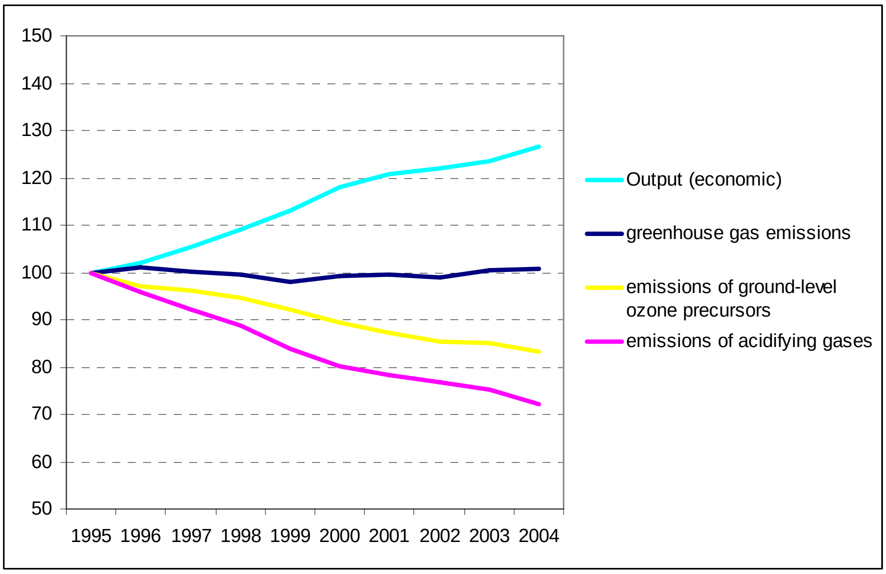
Absolute decoupling describes a situation where environmental pressures are stable or reducing, despite economic growth. Relative decoupling describes the case where environmental pressures are still growing but less rapidly than the economy. The rationale of SCP requires absolute rather than relative decoupling of these environmental pressures in the EU. Some key pressures such as greenhouse gas emissions must be reduced significantly in developed countries.

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

Decoupling in the whole economy

Between 1995 and 2004 the EU-25 realised a 27% growth in economic output. During this period, production-related emissions of acidifying gases and ground-level ozone precursors have been decoupled absolutely from economic output growth; i.e. decreased by 17% and 28% respectively (see Figure 9).

Figure 9: Economic output growth and direct environmental pressures, EU-25 – all economic sectors



Source: Eurostat NAMEA data set
Note: Economic output index measured on basis of PPP 2000 Euro

Emissions of GHGs as recorded using the NAMEA categorisation system remained nearly constant over the same period, hence decoupled only relatively from economic output growth across the EU-25.

The EE-IO method also allows decoupling to be broken down by various contributing factors. This can be a powerful tool in identifying the causes of decoupling, since some causes might have unwished for consequences, and can also give insights into which potential means for decoupling should be promoted in the future.

Using EE-IOA we can isolate two different causes of decoupling – *eco-efficiency improvements* and *changes in the structure* of the economy

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

- *Eco-efficiency effect* - improvements in eco-efficiency within individual economic sectors; and
- *Industry mix effect* - changes in the national production mix

The *eco-efficiency effect* occurs when individual economic branches get more eco-efficient over time through, for example, improvements in production processes, energy savings, substitution of 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-intensive branch expands its share in the economy, this will act against decoupling.

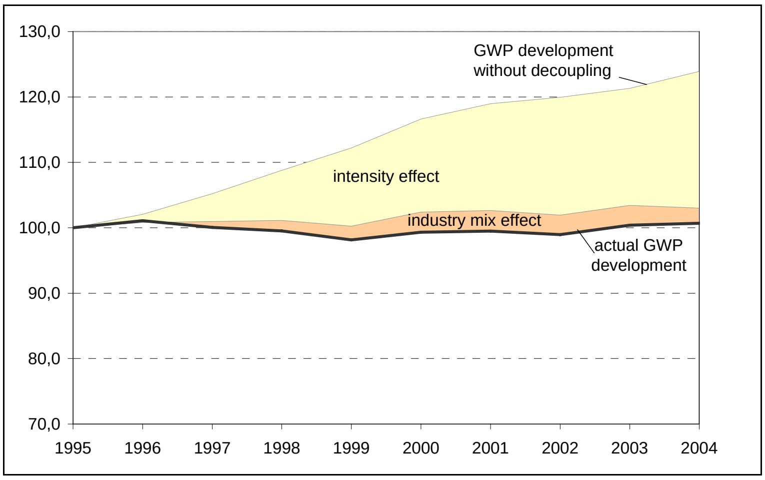
It is of key importance to note that *if* reductions in the share of heavy industries in the EU economy are a result of an 'outsourcing' of industrial production to countries outside the EU, rather than reflecting changes in consumption patterns, then the resulting decoupling effect is only regional.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

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

Figure 10 to 12 show how the two factors have contributed to decoupling in greenhouse gas emissions, acidifying emissions and ground ozone precursors between 1995 and 2004.

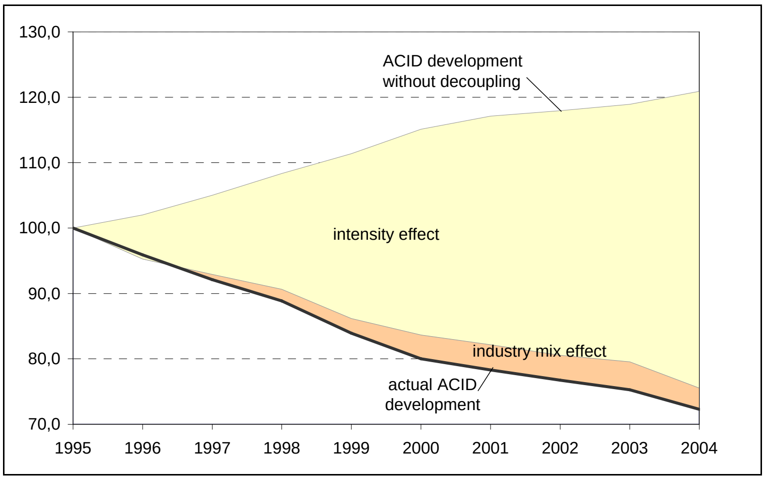
Decoupling in all three cases appears mainly to be a result of eco-efficiency improvements within branches. Changes in the structure of the economy i.e. industry mix has made a comparatively small contribution. However, this result may be influenced somewhat by the level of aggregation of the economy (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 10: Contribution of eco-efficiency and structural changes in the economy to decoupling in GHG emissions from production, EU-25



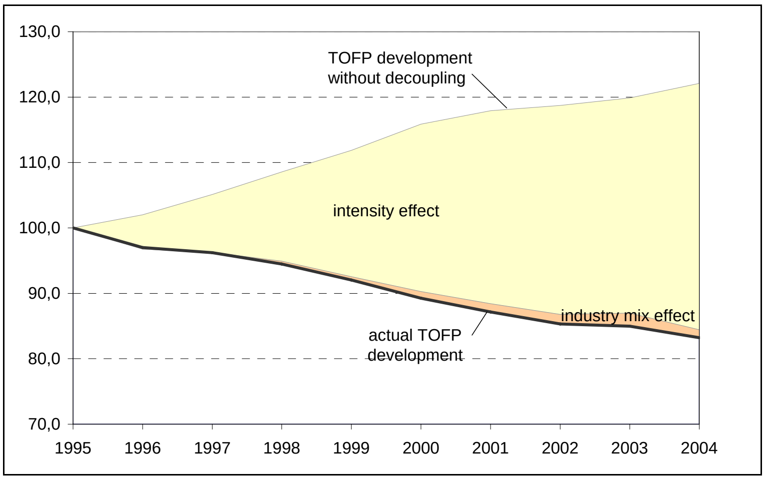
Source: Eurostat NAMEA data set

Figure 11: Contribution of eco-efficiency and structural changes in the economy to decoupling in acidifying emissions from production, EU-25



Source: Eurostat NAMEA data set

Figure 12: Contribution of eco-efficiency and structural changes in the economy to decoupling in ground ozone emissions from production, EU-25



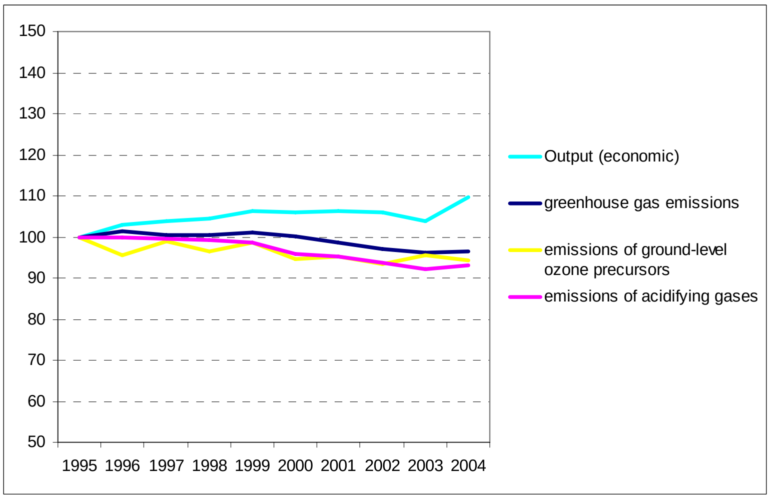
Source: Eurostat NAMEA data set

Decoupling in individual sectors

As shown above, decoupling of environmental pressures for the EU-25 as a whole has resulted mostly from eco-efficiency improvements in individual economic sectors. However, some sectors may have been more successful than others in improving eco-efficiency. Of particular interest are developments in the 'hotspot' sectors identified earlier.

Agriculture
The economic output of agriculture, measured in constant Euros, grew by 10% between 1995 and 2004. The three emission-related environmental pressures arising directly have been decoupled absolutely from growth in the sector decreasing by between 4 to 7% over the same period (Figure 13). Decoupling in acidifying emissions and ground-level ozone precursors have not been as rapid as in the economy as a whole (cf. Figure 9), while decoupling in GHG emissions has been more rapid.

Figure 13: Agriculture, hunting, forestry and fishing: decoupling of direct environmental pressures from growth in output, EU-25 1995-2004

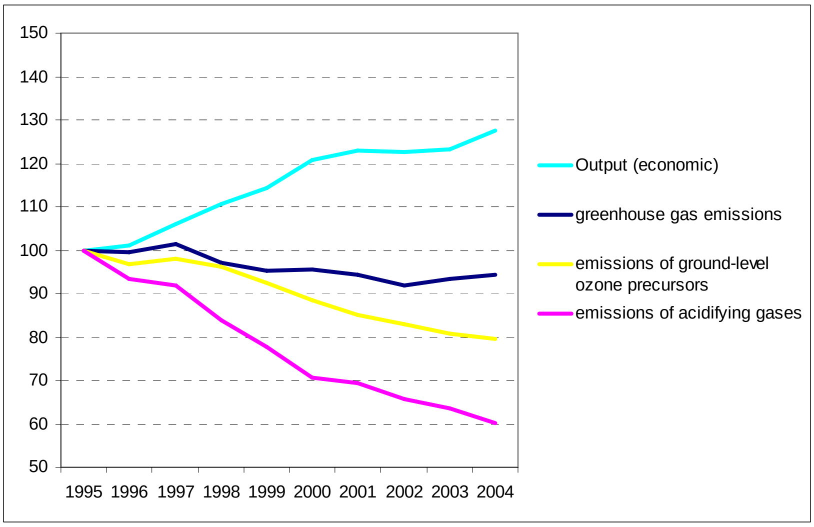


Source: Eurostat NAMEA data set
Note: Economic output index measured on basis of PPP 2000 Euro

Unlike other sectors, the agricultural contribution to acidification is mainly through ammonia-emissions rather than SOx- and NOx-emissions. Ammonia-emissions are linked to the size of animal livestock, 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 greenhouse gas emissions. Some of the decoupling achieved has been a result of reductions in cattle livestock during the analysis period (EEA 2008, p. 342).

Manufacturing
For the broad manufacturing sector (Figure 14) a stronger success story can be told in terms of absolute decoupling. The growth in output of almost 30 % between 1995 and 2004 –slightly greater than for the whole economy – was accompanied by a decrease in GHG emissions of 6%, a decrease in emissions of ground-level ozone precursors of 20% and a decrease of acidifying emissions of 40%. Those decoupling trends are more pronounced than for the economy as a whole. Since manufacturing represents 31% of the EU economy, decoupling within this sector has contributed significantly to decoupling in the EU economy as a whole.

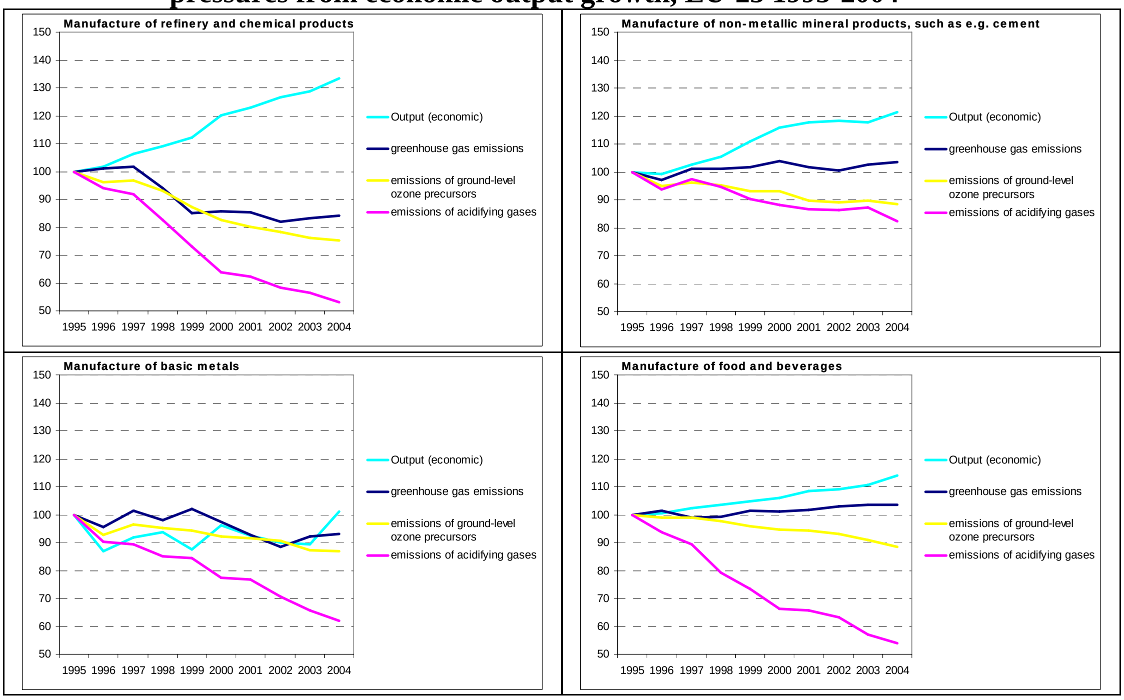
Figure 14: Manufacturing (broad): decoupling of direct environmental pressures from economic output growth, EU-25 1995-2004



Source: Eurostat NAMEA data set
Note: Economic output index measured on the basis of PPP 2000 Euro

Within the broad manufacturing sector, there are a number of single industries of high environmental relevance. Figure 15 shows decoupling graphs for the four most important manufacturing industries.

Figure 15: Selected manufacturing industries: decoupling of environmental pressures from economic output growth, EU-25 1995-2004



Source: Eurostat NAMEA data set
Note: Economic output index measured on the basis of PPP 2000 Euro

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

The *manufacture of refinery and chemical products* has shown the strongest absolute decoupling in all three pressures. Due to its economic importance these eco-efficiency improvements have contributed significantly to the overall decoupling in manufacturing.

Comparatively little improvement in eco-efficiency was achieved in the manufacture of *non-metallic mineral products, including cement.* The *manufacture of basic metals* has fared even less well apart from a significant decoupling in acidifying gases.

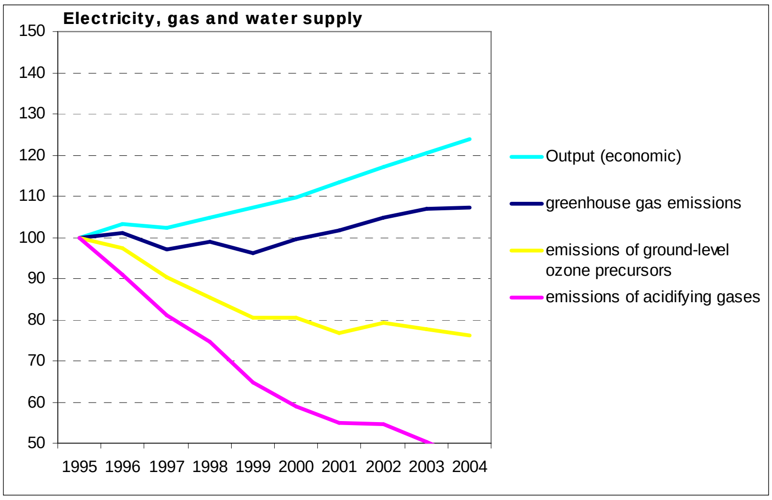
The two previous sectors are typical provider of basic materials. Technological means to improve the material and energy efficiency in respective production processes are physically limited. Once a high standard of material and energy efficiency is reached, environmental pressures will be closely linked with production volume growth.

GHG emissions from the *manufacture of food and beverages* grew despite only moderate growth in the sector's output. Emissions of acidifying gases were significantly reduced, however.

Electricity, gas and water supply
The electricity sector's economic output grew 25% over the period 1995-2004, similar to the growth in the whole economy (see Figure 16). Acidifying gases more than halved over this period mainly due to technological measures including flue gas desulphurisation and fuel switches in power plants (see e.g. EEA 2005, pp.93 ff.), while an increasing contribution from renewable production played a more minor role.

GHG emissions have only seen relatively decoupling from growth in output and, in particular, GHGs appear to have been recoupled to growth in output since the turn of the century. 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.

Figure 16: Electricity, gas and water supply: decoupling of environmental pressures from economic output growth, EU-25 1995-2004



Source: Eurostat NAMEA data set
Note: Economic output index measured on basis of PPP 2000 Euro

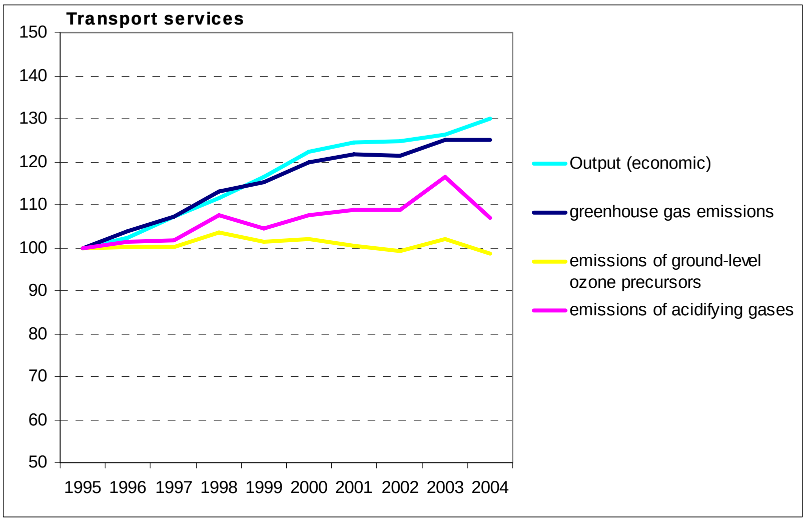
Transport services

Transport services have shown the poorest performance of the priority economic sectors in terms of improvements in eco-efficiencies (Figure 17). The sector has grown more rapidly than the economy as a whole at 30%, 1995-2004. Emissions of GHGs have hardly seen any decoupling, increasing by 25% over the same period. Only emissions of ground-level ozone precursors showed absolute decoupling.

....transport services have been least successful

The trends in GHGs, are particularly worrying since the sector is expanding its share of the EU-economy.

Figure 17: Transport services: decoupling of direct environmental pressures from economic output growth, EU-25 1995-2004



Source: Eurostat NAMEA data set

Note: Economic output index measured on basis of PPP 2000 Euro

3.6 Summary of hotspots in 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 50 to 80% of emission of greenhouse gases, acidifying gases, and ground-level ozone precursors from all European production,

Of the 4 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 of the EU25 economy but together emit 47% and 60% of greenhouse gas emissions and acidifying emissions respectively. Service industries, with the exception of transport, meanwhile, show low environmental-intensities. 56% of the EU's economic output is currently 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 tropospheric ozone precursors decreased by 17% and 28% respectively between 1995 and 2004 despite an economic growth of 27%. Production-related greenhouse gas emissions remained fairly stable during the same period.

For all three types of environmental pressure, decoupling appears mostly to have been achieved through improvements in eco-efficiency within 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. Analyses of more disaggregated economic sectors might show an increased importance of structural changes in observed decoupling.

Of the hotspot economic sectors only the manufacturing sector managed to reach an absolute decoupling in all three pressure categories. The transport services industry fared worst of all with greenhouse gas emissions increasing by 25% between 1995 and 2004, only slightly slower than growth in output.

Achieving an 80% 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.

However, 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% 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 intensity industries to low intensity 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 an 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 negative net effects (i.e. 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. This includes products produced in the home country for home consumption and products imported for consumption, but excludes production chains of exports.

The perspective, instead of focusing on direct pressures released by national entities, concentrates on global direct and indirect environmental pressures activated by the national consumption of goods and services. Due to international trade, total environmental pressures attributable to a country's consumption can be markedly different to those arising directly in its borders (Watson and Moll, 2008).

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 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 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 first real possibility for estimating pressures caused by national consumption

Using EE-IO 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. 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.

The EE-IO methods presented here offer the first real possibility for estimating the indirect pressures associated with national consumption and present a first step towards national monitoring of global pressures activated by national consumption. This is the first time that such methods have been used in a range of EU countries.

Economic and environmental data used for this analysis are given in Table 4 in Section 2.6. As described in Section 2.5 and 2.6, the consumption perspective requires complex national input-output tables. Due to the lack of these tables the analysis is limited to 8 EU countries for the years 1995 and 2000 (only 6 countries with both years).

4.2 Brief Overview of European consumption

Private household consumption represents about 60% of total national 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.

Most final products end up in households. Within the EU, *private* household consumption represents ~60% of total consumption. Government consumption and capital formation represent ~20% each.

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

Products can be broadly distinguished between material goods and services. 2/3 of total household consumption in the EU is made up of services while material goods account for the remaining third. Capital formation is dominated by consumption of material goods (85%) in the form of machinery and buildings, while government consumption is dominated by services.

We will now look at environmental pressures activated by consumption in the 8 EU countries 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

Figure 18 breaks down environmental pressures 'embodied' in total products consumed in the 8 EU countries, into 31 broad product groups. It indicates the accumulated environmental pressures arising along the global production chain of each product group. The four environmental pressures are *greenhouse gas emissions, acidifying emissions, emissions of ground ozone precursors* and *material extraction.*

It is clear that just a few product groups contribute significantly (30-40%) to all four environmental pressures. These are:

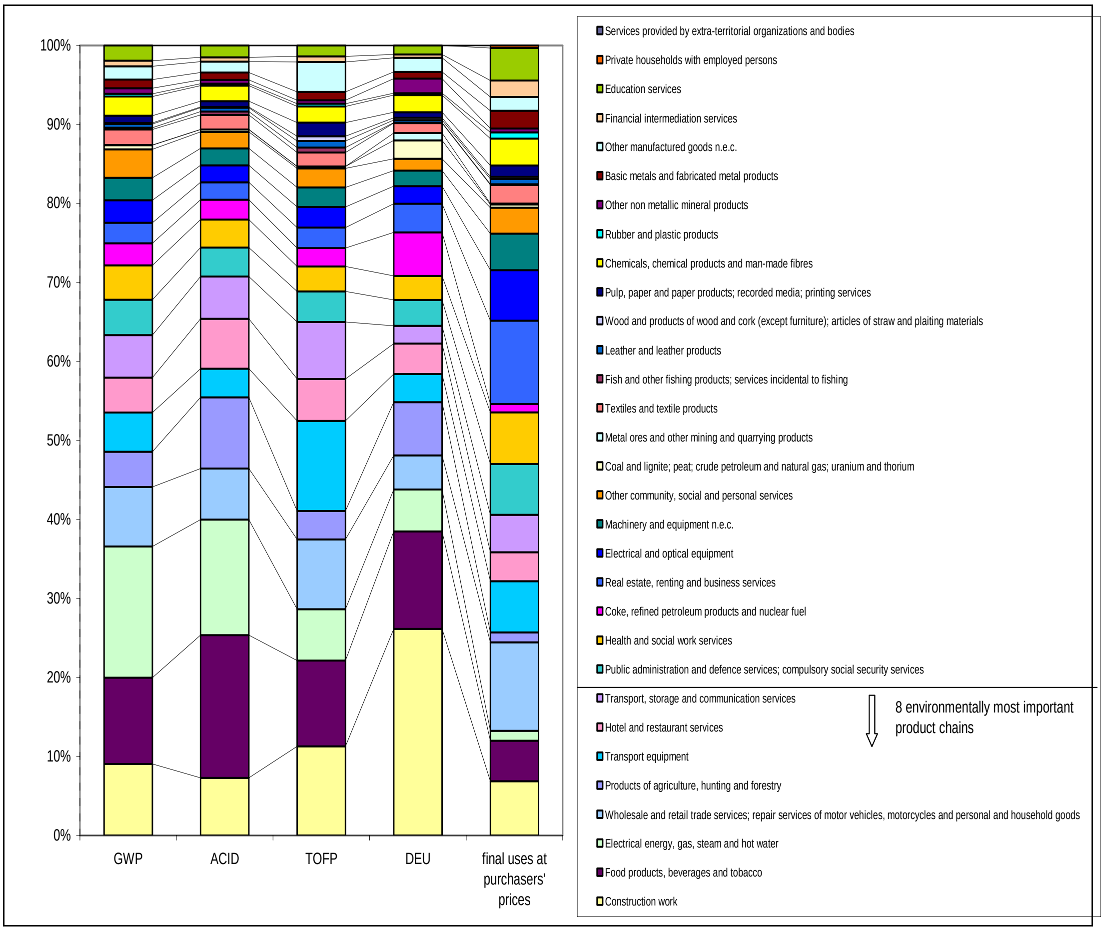
- *construction works* i.e. buildings and infrastructures
- *food products, beverages and alcohol*
- *electricity, gas, steam and hot water* the majority of which is electricity

Production chains for a further 5 products also accumulate significant environmental pressures:

- *Wholesale and retail services*
- *Products of agriculture, hunting and forestry*
- *Transport equipment*
- *Hotel and restaurant services*
- *Transport, storage and communication services*

These 8 key product groups together account for 60-70% of the key environmental pressures caused by consumption.

Figure 18: Purchasing value of consumed product groups and accumulated environmental pressures along their production chains; EU8 1995/2000



Source: ETC/RWM data set

The value of the same 8 product groups however, represents only about 40% of total national consumption i.e. they contribute significantly more to environmental pressures than they do to the economy. There are some particular product groups whose significant contribution to environmental pressures is not reflected in their share of consumption expenditure. Electricity is a prime example. At the other end of the scale certain products – particularly services – have a high economic value relative to their 'embodied' environmental pressures (e.g. health and social services).

Spending 100 Euros for such 'eco-efficient products' is environmentally favourable compared to spending the same amount on an 'eco-intensive' product. 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 Section 4.6 and 4.7.

4.4 Total pressures from 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 consumed products. To gain a picture of the total environmental pressures activated by consumption we need to add in the *direct* pressures released by households. It would also be useful to assign these pressures to the use of particular product groups.

The NAMEA tables used for this study provide data on direct emissions from households but do not allow these to be allocated to particular consumption areas[18]. Other studies have identified, however, how direct household emissions can be split between different consumption types i.e. private car use, heating, hot water, cooking etc.

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

Greenhouse gas emissions

The average greenhouse gas emissions associated with consumption in the 8 countries were around 11 tonnes per capita - approximately twice the global average, and roughly 4 times the estimated global per capita average which would keep global temperature rise to within the critical 2° C target set by the European Council.

Of this total more than 2 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%)[19]. The remaining 9 tonnes are embodied in finally consumed products according to the proportions given in the left hand bar of Figure 18 above. The most important product with respect to GHG emissions is electricity.

Emissions of acidifying substances

National consumption in the 8 EU countries globally causes around 60 kg of SO_2-equivalents per capita. 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 the second bar in Figure 18). The consumption of electricity in households can again be assigned by function as under GHGs above.

Emissions of ground ozone precursors

National consumption causes on average around 69 kg of emissions of ozone precursor substances per capita in the 8 countries. Private households *directly* emit 30% to the total again through combustion of fuel in cars (~2/3) and fuel for heating and hot water in houses (~1/3). The remaining 70% of ozone precursors activated by consumption are *indirect* embodied in final products as given in the third bar of Figure 19.

Material Use (domestic extraction used)

The average global material extraction activated by consumption in the 8 EU countries stands at 16.5 tonnes per capita[20], double the global average at 8.8 t per capita[21].

[18] It is possible to extend the NAMEA data framework to allow this kind of allocation of final consumption of products by certain consumption purposes or areas.

[19] derived from the Eurostat NAMEA data set

[20] Domestic Extraction Used (DEU)

Households do not extract any material goods directly. All material extraction activated by consumption is indirect, taking pace during the production of goods and services delivered to the consumer (see fourth column in Figure 18).

4.5 The Priority Consumption Areas

Both direct household pressures and indirect pressures embodied in products can be assigned to some broad areas of consumption.

The consumption areas *eating & drinking, housing & infrastructure* and *mobility* account for ~2/3 of key environmental pressures

For example both agricultural products and food products can be assigned to a broad functional consumption area of *Eating & Drinking*. In addition, a proportion (~30%)[22] of the pressures embodied in the consumption of electricity in households is used for the storage and preparation of food which again can be assigned to *Eating & Drinking*. Finally, a substantial part of the pressures 'embodied' in the restaurants and hotels services and retail services can also be assigned to this consumption area.

Similarly, direct pressures from households can be assigned to two broad areas – the transport of people (~40%) and the use of housing through heating (~60%).

The results of this loose allocation are presented in Figure 19. As can be seen a large part of environmental pressures from European consumption can be grouped into three broad consumption areas:

1. Eating & drinking
2. Housing & infrastructures
3. Mobility

Altogether, these three consumption areas account for around 60-70% for each of the key environmental pressures studied.

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[23] commissioned by the European Commission. EIPRO concluded that products from three areas of consumption – food and drink, private transportation, and housing – together are responsible for 70-80% of the various environmental impacts of private consumption.

The three consumption areas should be prioritised in SCP strategy and action at EU and national level. The identification of hotspots within the consumption and production systems activated by these consumption areas is considered in detail in Section 4.8.

First, however, it is worth using the EE-IO methodology to analyse *past* trends in pressures related to consumption and how these have been affected by the three main drivers: economic growth, changes in the efficiency of production along product chains and changes in the mix of goods actually being consumed. The eco-intensity of the production chain of products is a key factor in this analysis.

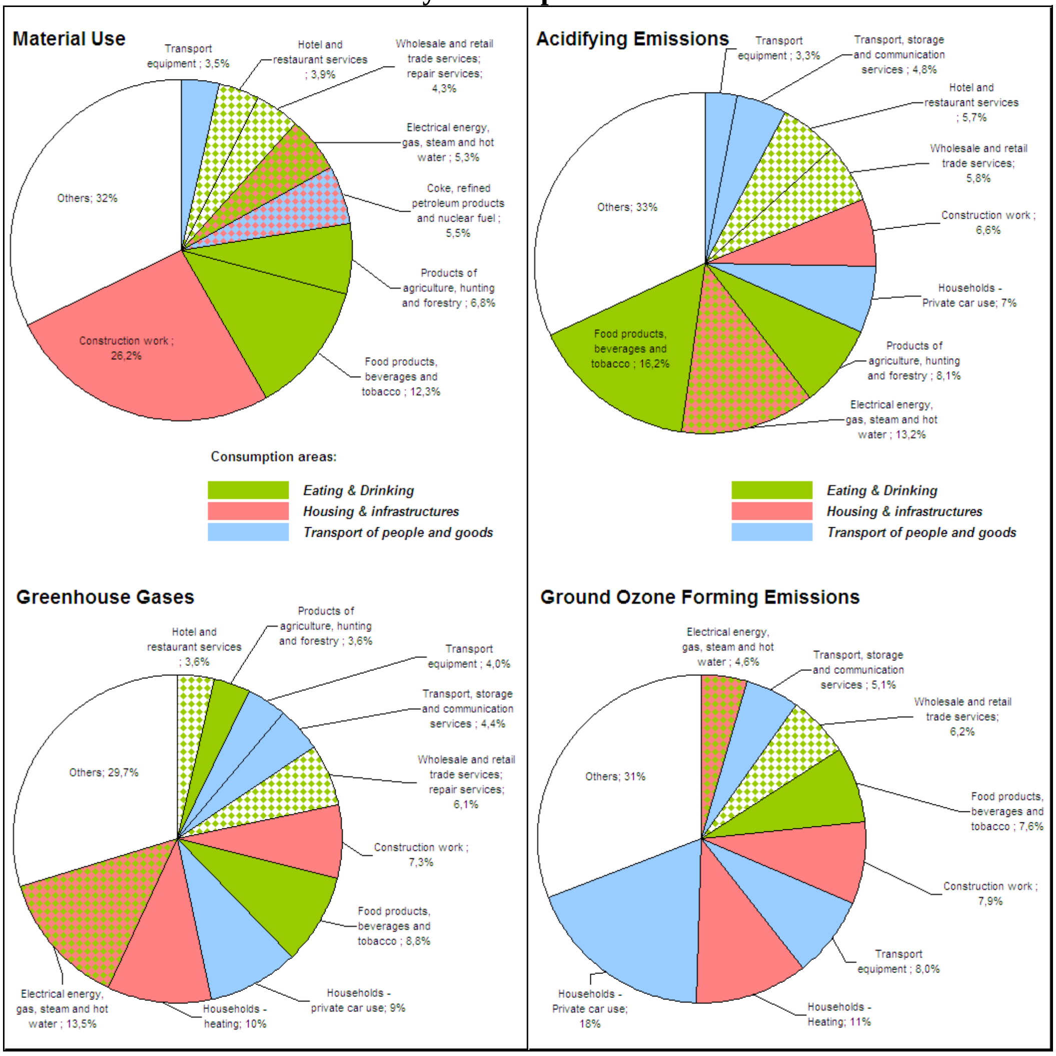
---

[21] #MOSUS data; see www.materialflows.net

[22] See for example VDEW (2006) and ODYSSEE household energy stats http://www.odyssee-indicators.org/reports/ee_households.php

[23] "Environmental Impacts of PROducts": http://susproc.jrc.es/pages/r4.htm ; see Tukker *et al*., 2006

Figure 19: Direct and indirect pressures from national consumption which can be attributed to three key consumption areas.



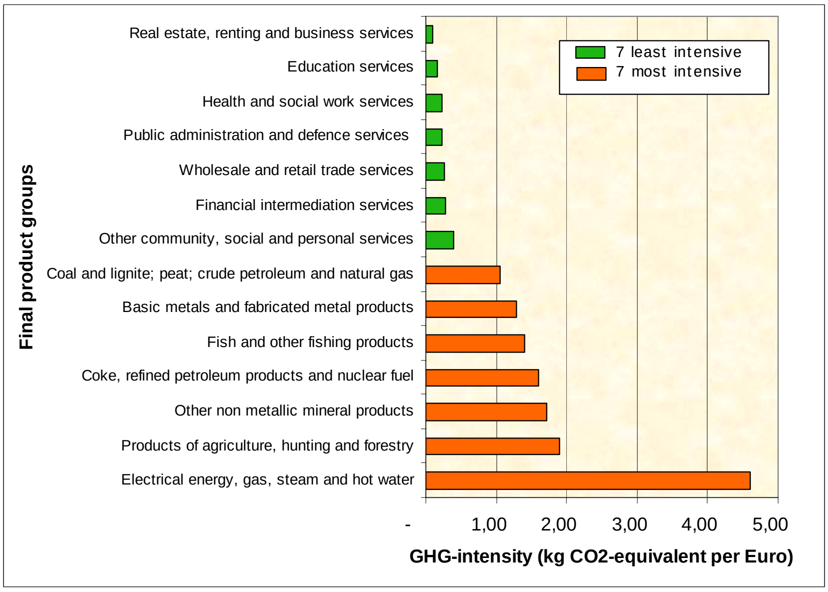
Checked areas show pressures which can be allocated to two of the consumption areas, or only partially to a single consumption area Source: ETC/RWM data set

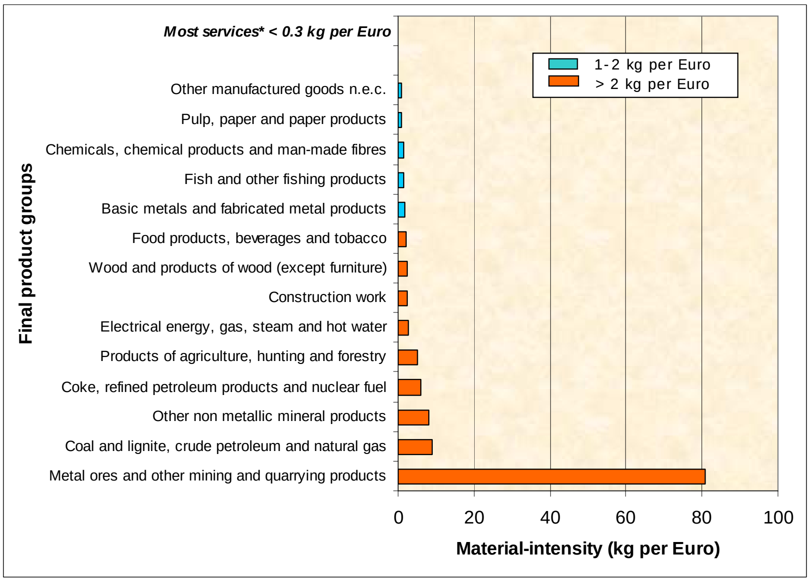
4.6 Eco-intensity of final consumption products

As shown by Figure 18 earlier, 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 eco-intensity (i.e. environmental pressure per Euro of consumption expenditure) of the production chains of the various products. The inverse of eco-intensity is called eco-efficiency.

Figure 20 compares the GHG emissions -intensity and the material-intensity of some broad product groups. Only the 7 most intensive and 7 least intensive (i.e. most efficient) are shown for GHG emissions. For GHGs the intensities range from less than 0.2 kg CO_2-eq. per Euro for services to 4.6 kg CO_2-eq./EUR for electricity.

Figure 20: Differences in GHG emissions-intensity and material-intensity along global production chains of final product groups (8 European countries)





*except transport and services and hotel and restaurant services
Source: ETC/RWM data set

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

The range of material-intensities is much greater, between less than 0.3 kg per Euro for most services to 80 kg per EUR for metal ores and other mining and quarrying products. In addition to other mining activities electricity, agricultural products and construction works also have relatively high material intensities.

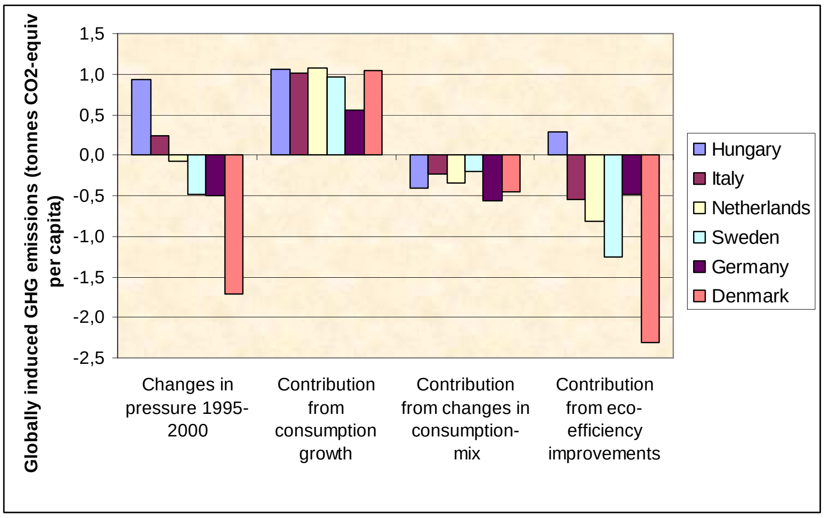
In both cases services, with the exception of transport services (mid-range for both GHGs and material use), have comparatively low intensities. Spending one Euro for services is significantly more environmentally friendly than spending one Euro on electricity, petroleum or cement. Therefore decoupling of environmental pressures from growth can in part be achieved by channelling increasing income towards services rather than material goods.

Though not shown here, a second finding from the EE-IOA analysis 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 8 countries due to the low use of fossil fuels in electricity production.

4.7 Decoupling trends in Consumption

In this section we examine developments in environmental pressures activated by national consumption over a five-year period in the six EU countries with available data. We examine the extent to which environmental pressures activated by national consumption have been decoupled from growth in consumption spending. An EE-IO method called *decomposition analysis* (see e.g. de Haan 2001, Dietzenbacher & Los 1998, Jensen & Olson 2003) is used to break down the decoupling trends into various contributing factors.

Figure 21: Changes in global greenhouse gas emissions per capita 1995-2000 activated by consumption in EU countries and main contributing factors



Source: ETC/RWM data set

The left-hand bars in Figure 21 show the development in GHGs per capita activated globally by consumption in the 6 countries from 1995 to 2000. The other three sets of bars show three contributing factors to these changes in absolute pressures.

The first contributing factor is the economic growth in consumption. By comparing growth in consumption to the overall change in pressures it can be seen that some decoupling has taken place in all six countries. However in Hungary and Italy only relative decoupling was achieved[24].

[24] Absolute decoupling is where environmental pressures are stable or falling despite economic growth. Relative decoupling is where environmental pressures are still growing but at a slower rate than the economy.

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

The two factors which have contributed to decoupling are shown in the final two sets of bars. 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 by the population and the state. As described in the last section when consumption expenditure shifts from pressure-intensive product clusters to less intensive clusters this has a positive decoupling effect.

The second factor contributing to decoupling is concerned with improvements *within* production chains i.e. improvements in efficiency 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.

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. European policy to date has focused almost exclusively on this second group of measures.

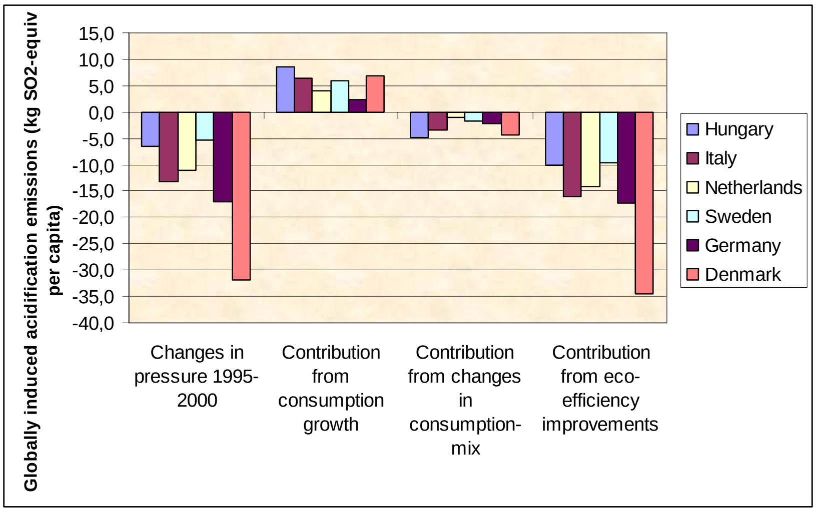
In Figure 21, it can be seen that with a single exception, both factors had positive decoupling effect on global GHG emissions caused by consumption in all six countries between 1995 and 2000. However, in all countries except Hungary and Germany improvements in eco-efficiency of production chains have had a stronger decoupling effect than changes in the mix of goods consumed.

In 4 out of 6 countries decoupling of air emissions from growth has mainly been a result of eco-efficiency improvements

For acidification emissions (Figure 22) and emissions of ground ozone precursors (Figure 23) all countries with available data show 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 each case. In other words, progress through improved production processes has been significantly greater than gains made through changing consumption patterns.

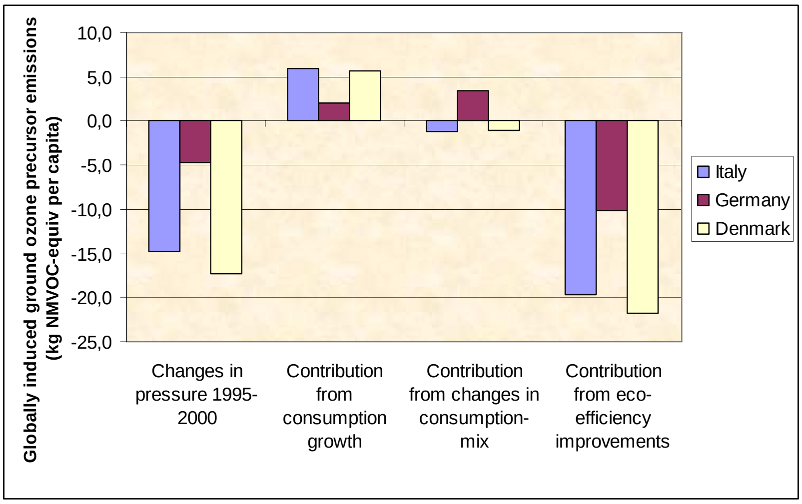
Changing consumption patterns in Germany actually acted in the opposite direction for ground ozone precursors between 1995 and 2000, with increased share of goods with high ‘embodied’ ozone precursor emissions. The cause of this unfavourable trend was a relative increase in purchases of cars and fossil fuels by Germans during that period.

Figure 22: Changes in global acidifying emissions per capita, 1995-2000, activated by consumption in EU countries and main contributing factors



Source: ETC/RWM data set

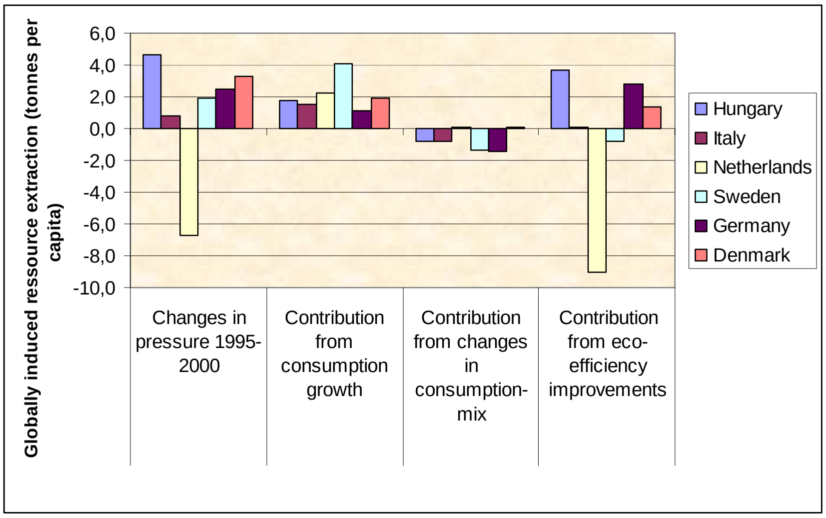
Figure 23: Changes in global emissions of ground ozone precursors per capita 1995-2000 activated by consumption and main contributing factors



Source: ETC/RWM data set

The picture was markedly different for global material extraction (Figure 24). Unlike the air emissions related pressures, global material extraction saw little decoupling from increases in consumption. Global material extraction activated by consumption in Hungary, Germany and Denmark actually increased more rapidly than growth in consumption. The main reason was a significant worsening of resource efficiency in production processes, more than offsetting the small gains made in more favourable consumption patterns.

Figure 24: Changes in resource extraction per capita 1995-2000 activated by consumption and main contributing factors



Source: ETC/RWM data set

EE-IOA based decomposition analysis has proved its ability to 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 compliment or conflict with one another in decoupling pressures from growth.

For air emissions and greenhouse gases 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[25].

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

The EU Commission has recently set a target for reducing GHG emissions by 80% by 2050 as the European contribution to keeping global temperature increases to 2^0C above pre-industrial levels (see also den Elzen and Meinshausen, 2005). This will require significantly more rapid decoupling than has been observed so far. 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 – a shift to less pressure-intensive goods and services.

The next section investigates the consumption/production systems serving housing, eating & drinking and mobility and identifies the key hotspots within them for future action through both technology improvements and changes in consumption patterns.

4.8 The Three Priority Areas – A More Detailed View

The three broad consumption areas of *Eating & Drinking*, *Housing & Infrastructures* and *Mobility* were identified earlier as contributing some 60-70% of environmental pressures

[25] 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-efficiency factor (Hass, 2008).

activated by consumption. Much of the focus of sustainable consumption and production will need to focus on how these three needs can be met more sustainably.

A first stage is to carry out a more thorough investigation of the complex consumption and production systems activated by these needs areas, and highlighting the hotspots or leverage points within these where most pressures arise. The next stage will be to identify potential actions for pulling these levers and prioritising these with regard to potential environmental gains but also public acceptability, and ease of carrying them out. The EE-IO method can contribute to the first stage but the second stage requires other tools including LCAs, cost-benefit analysis and policy effectiveness assessments.

We begin with the first stage, the contribution of EE-IO analysis to greater understanding of the consumption and production systems underlying the three priority areas.

Eating & Drinking

The consumption activity of *Eating & Drinking* includes the use of a number of products and services, all of which accumulate environmental pressures along their lifecycle. The most obvious of these are the purchase of food and beverages and agricultural products, including all environmental pressures accumulated during their production.

There are also a number of other products and services which are at least partially connected to eating & drinking. In some of these cases the NAMEA tables aren't able to accurately attribute pressures to eating & drinking, due to a lack of information in the tables over what function finally consumed products actually serve. Other studies are needed to supplement the NAMEA data.

For example, the preparation and storage of food and beverages in households consumes electricity (e.g. by cookers, ovens, fridges, freezers and dishwashers). However, in the NAMEA, household electricity consumption by these appliances is not distinguishable from electricity used for lighting, TV, home computers etc. The NAMEA therefore needs to be supplemented by detailed studies of electricity consumption in households, including bottom-up household survey data[26]. According to a German study (VDEW, 2006) approximately 20% of private household's electricity consumption can be assigned to the storage and preparation of food including process heat (e.g. cookers) and mechanical energy (including fridges and freezers). A proportion of direct pressures emitted in households through the burning of fossil fuels can also be attributed to eating & drinking i.e. the use of gas and oil cookers.

In addition to eating at home, many Europeans often choose to eat out in restaurants and fast food outlets. A proportion of the pressures attributed to the final use of the NAMEA category *hotel and restaurant services* can also be assigned to eating & drinking. Here we conservatively assume 50% but this figure needs to be backed up by further research.

Furthermore, as food and beverages are sold in supermarkets and shops, at least part of the pressures induced by the NAMEA category *wholesale and retail services* can be attributed to this consumption area. Again in the absence of detailed studies we conservatively assume a minimum of 20%, and again this needs to be investigated through non-EEIOA methods.

---

[26] See e.g. ODYSSEE-project website: => "Publications => "Sectoral profiles - Graphs of indicators by sector" => "Households" => "Household energy consumption in the EU-27" http://www.odyssee-indicators.org/reports/ee_households.php

The consumption area of eating & drinking accounts for 15-30% of key pressures caused by consumption.....

Table 6 summarises the final use of product groups clustered to the area of eating & drinking together with the pressures generated. According to the table some 15-30% of key pressures can be allocated to *Eating & Drinking*. Eating & drinking contributes approximately 2 tonnes CO_2-equivalents of greenhouse gases per capita.

....and as many GHG emissions as the EU aims to emit from all activities by 2050

This is equivalent to the quantity which Europeans will need to budget for *all* their activities in the long term if we are to meet the European Commission's 2050 target of an 80% reduction in GHGs (from ~10 tonnes/capita to ~2 tonnes/capita). Even if a proportion of GHG reductions in Europe are gained through investments in carbon offsetting projects in other regions it is clear that considerable savings will also be necessary in pressures activated by European's demand for eating & drinking.

Table 6: Direct and indirect (global) environmental pressures attributable to *Eating & Drinking*

Product name	Greenhouse gas emissions		Acidifying emissions		Ground ozone forming precursors		Material Use	
	tonnes CO2-equivalents per capita	as % of total from consumption of all products	kg SO2-equivalents per capita	as % of total from consumption of all products	kg NMVOC-equivalents per capita	as % of total from consumption of all products	tonnes per capita	as % of total from consumption of all products
Products of agriculture, hunting and forestry	0,4	3,6%	4,9	8,1%	1,8	2,5%	1,1	6,8%
Fish and other fishing products; services incidental to fishing	0,02	0,2%	0,2	0,4%	0,3	0,4%	0,0	0,1%
Food products, beverages and tobacco	1,0	8,8%	9,7	16,2%	5,3	7,6%	2,0	12,3%
Electrical energy, gas, steam and hot water (20%)	0,3	2,7%	1,6	2,6%	0,6	0,9%	0,2	1,1%
Wholesale and retail trade services; personal and household goods (20%)	0,1	1,2%	0,7	1,2%	0,9	1,2%	0,1	0,9%
Hotel and restaurant services (50%)	0,2	1,8%	1,7	2,8%	1,3	1,9%	0,3	1,9%
attributable to eating & drinking	**2,0**	**18%**	**18,8**	**31%**	**10,1**	**15%**	**3,8**	**23%**

Source: ETC/RWM data set

The table above can be used to identify the broad hotspots in pressures. The actual production of food and beverages (agricultural products, fish and food products) is the key cause of environmental pressures associated with eating & drinking (cf Table 6). In the case of greenhouse gas emissions it accounts for about 70% of the total life cycle pressures.

The agricultural stage dominates pressures released during the production of food products

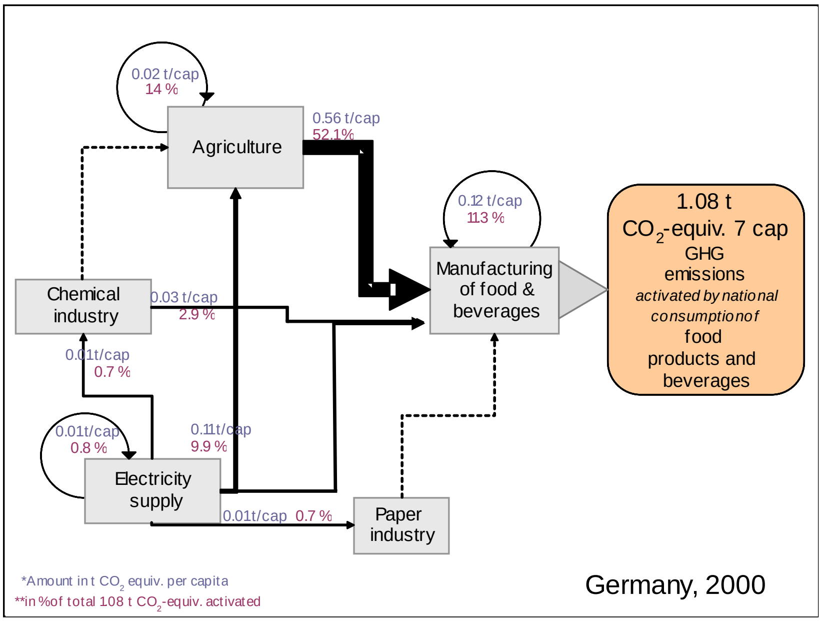
The EE-IO-data-tool can be further used to analyse the production chain (or production tree) of each of the product groups included in the table. Through these chain analyses the production stages generating the highest environmental pressures can be identified.

Figure 25 gives the results of this analysis for GHG emissions associated with food products in Germany. The food processing industry only directly contributes 11% of the total greenhouse gases generated by the final use of food products. Agricultural production dominates with over 50% of the total. A significant part (around 15%) of pressures is also induced by electricity, which is used as an intermediate good by several production stages (e.g. agriculture, food industry, paper industry and chemical industry) in the food process tree.

Material use (domestic extraction used – DEU) can also be analysed along the production chain of food products. In total about 3 t of material extraction is accumulated along the product chain for food and beverages. The majority (59%) stems from the extraction of biomass from the agriculture sector which is then delivered to the food industry. A further 15% results from the delivery of mining and quarrying products to the agricultural sector.

In conclusion, the environmental pressures of the consumption area *eating & drinking* are mainly related to the agricultural production stage. Second most important is the use of electricity by agriculture, industries and households in conjunction with eating & drinking. Contrary to public perception, packaging and transport does not seem to play a significant role (see Fritsche *et al*., 2007; Weidema *et al* 2008).

Figure 25: Chain analysis: Indirect contributions of different process stages to GWP activated by national consumption of food products, Germany 2000[27]



Source: ETC/RWM data set [Table 12]

Housing & Infrastructures

Like eating & drinking the consumption activity area *use of Housing & Infrastructures* includes a number of different product and services all of which have embodied environmental pressures. Before housing and infrastructures can be used they must first be constructed and thereafter there physical structure maintained. The direct and indirect pressures related to the national consumption of construction works therefore lie wholly within this broad consumption activity.

In this report the actual use stage of *Housing & Infrastructures* is taken only to include the use of buildings[28]. The main pressures associated with the use phase of buildings are direct and indirect pressures associated with the use of lighting, space heating and hot water in private households and government buildings.

The *direct* pressures arise from the combustion of fossil fuels for space heating and hot water supply. The NAMEA-tool records two categories of direct pressures from households one for fossil fuels consumed by private transport and one for fossil fuels consumed for ‘heating and others’. It is conservatively assumed that 90% of the GHGs from the second category are emitted in connection with heating and hot water in

---

[27] This flow chart is an extract of a 60 by 60 matrix table. It only contains the main hotspots along the process chain of food products.

[28] To avoid overlap with the *Transport of persons and goods* consumption area the use stage of transport infrastructure, for example, is not included.

housing. Similarly use of fossil fuels in public buildings is grouped within various government services along with other fossil fuels used by those services. As a conservative estimate it is assumed that 10% of the direct and indirect environmental pressures associated with public services are for heating/cooling of public buildings. Again such assumptions need to be tested through bottom-up studies based on surveys or other methods.

Indirect pressures associated with the use phase of buildings are mainly caused by the use of electricity in households and government buildings for lighting, heating and cooling and hot water. Of the final electricity use by households and governments some 30% is assumed to be used for these functions. Finally indirect pressures related to the real estate and renting services are also assigned to the consumption area of housing and infrastructure.

The consumption area of housing & infrastructure accounts for 15-30% of key pressures caused by consumption…

Table 7 summarises the final used product groups which are associated with the area of *Housing & Infrastructures* together with the pressures generated along their production chains, plus the direct pressures from private households for heating their homes. According to the table around 15-30% of key pressures activated by national consumption can be associated with the use of *Housing & Infrastructure*s.

The area of *Housing & Infrastructures* contributes approximately 2.5 tonnes CO_2-equivalents of greenhouse gases per capita. This is greater than the quantity which Europeans will need to budget for *all* their activities in the long term if we are to meet the European Commission's 2050 target of an 80% reduction in GHGs (i.e. a reduction from ~10 tonnes/capita to ~2 tonnes/capita).

….and more GHG emissions than the EU aims to emit from all its activities by 2050

Table 7 reveals that two main hot spots dominate environmental pressures: heating in households and the demand for new construction work.

Table 7: Direct and indirect (global) environmental pressures attributable to *Housing & Infrastructures*

Product name	Greenhouse gas emissions		Acidifying emissions		Ground ozone forming precursors		Material Use	
	tonnes CO2-equivalents per capita	*as % of total from consumption of all products*	*kg SO2-equivalents per capita*	*as % of total from consumption of all products*	*kg NMVOC-equivalents per capita*	*as % of total from consumption of all products*	*tonnes per capita*	*as % of total from consumption of all products*
Electrical energy, gas, steam and hot water (30%)	0,4	4,0%	2,4	4,0%	1,0	1,4%	0,3	1,6%
Construction work	0,8	7,3%	3,9	6,6%	5,5	7,9%	4,3	26,2%
Real estate, renting and business services	0,2	2,1%	1,2	2,0%	1,3	1,8%	0,6	3,6%
Priv.Housh. Heating + others (90%)	1,0	9,2%	1,8	3,0%	7,1	10,2%	-	0,0%
attributable to housing & infrastructure	**2,5**	**23%**	**9,3**	**16%**	**14,7**	**21%**	**5,2**	**31%**

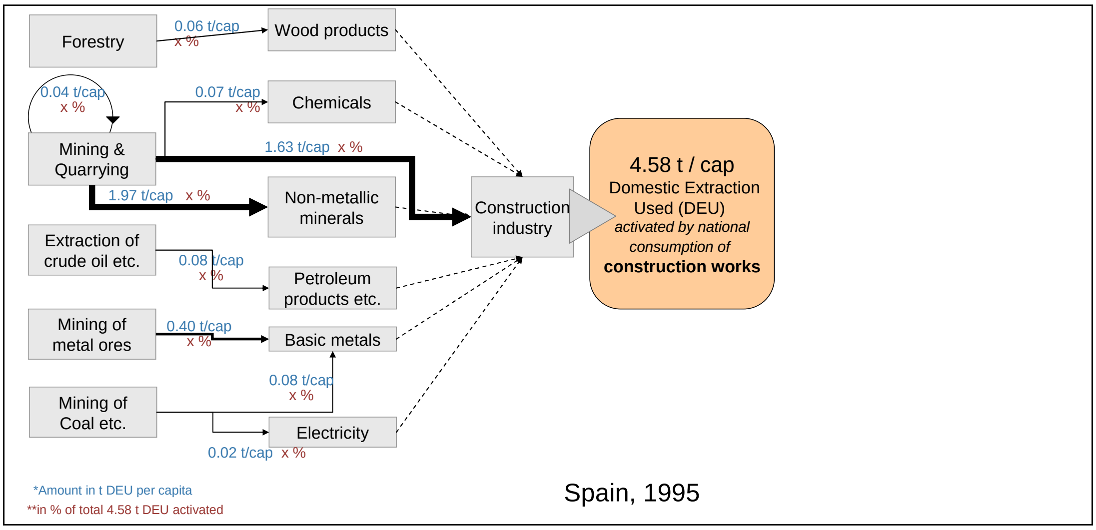
Source: ETC/RWM data set

In case of GHG emissions the maintenance/running of buildings is more dominant than the actual construction of new works. Direct GHG emissions by private households associated with heating and hot water comprises 40% of the total GHG emissions from this consumption area (1 t out of 2.5 t CO_2-equivalents per capita) while indirect emissions through the final use of electricity for lighting, heating and hot water account for a further 16% (0.4 t CO_2-equivalents per capita). Although the use stage of buildings dominates life-cycle emissions of GHGs, the construction stage of buildings and other infrastructures is an important contributor: accounting for 30% (0.8 t CO_2-equivalents per capita) of total GHG emissions associated with housing & infrastructures.

In the case of material use the construction stage is responsible for around 50% of material extraction associated with the use of housing & infrastructures. This includes both construction of new buildings and infrastructures and the repair of the existing stock. Construction of buildings and infrastructures therefore presents a suitable subject for further more detailed study

The EE-IOA method was used to analyse the production chain of construction works in order to identify hotspots. Figure 26 shows the results for *construction works* in Spain in 1995.

Figure 26: Chain analysis: Indirect contributions of different process stages to material use (DEU) induced by the final consumption of construction works, Spain 1995[29]



Source: ETC/RWM data set [Table 12]

The majority of the induced material extraction occurred in the mining and quarrying sector (sand and gravel, natural stone etc.). This is mainly used for the production of cement, glass, bricks, tiles and other construction products accounting for almost 2 t DEU per capita, and with direct deliveries to the construction sector amounting to 1.6 t/cap. The final use of construction works further induces significant extractions in the metal ores mining sector (0.4 t/cap) used for the production of steel, aluminium and copper components for buildings (steel, aluminium, copper etc.).

In the case of GHGs, chain analysis reveals that nearly a quarter of emissions associated with the final use of construction works stem from the non-metallic minerals industry (production of cement, glass, tiles, bricks etc.). A further quarter stems from the electricity consumed by several intermediate industries, most importantly by the non-metallic mineral industry but also by the basic metals industry. The construction industry itself contributes around 10% of GHG emissions directly, while the basic metal industry (steel, aluminium, copper etc.) contributes an equivalent amount. The minerals mining industry (sand, gravel, clay etc.) accounts for around 7% of GHG

In conclusion, the GHG pressures of the consumption area *housing & infrastructures* are mainly related to the heating of buildings and provision of hot water. Second most important is the construction of new works. For material use, the hotspot lies in the final

[29] This flow chart is an extract of a 60 by 60 matrix table. It only contains the main hotspots along the process chain of construction works.

use of construction works, mainly in the mining and quarrying sector, producing the raw materials for construction components and construction works.

Mobility

Environmental pressures arising along a number of final product chains can be assigned to this broad consumption area. These include the provision of transport services purchased by households (railways, metro, buses, airlines, taxis and ferry and cruise services) a good part of the extraction and delivery of petroleum products to private households (fuel for private cars) and the transport equipment purchased by households (i.e. cars, trailers etc.). Over above these indirect production chain pressures are the *direct* pressures arising from households concerned with the *use* of private cars (i.e. exhaust emissions).

One could also include the construction and maintenance of transport infrastructure to this area, but this has already been dealt with under the area of housing & infrastructures in the previous section. Most freight transport is excluded here since the only freight services typically purchased directly by households are postal services and house moving services. The majority of freight services are included in the chains of other purchased goods.

The consumption area of mobility accounts for 15-30% of key pressures caused by consumption

Table 8 summarises the pressures generated directly and indirectly by the final use of these product groups and the direct pressures by private households attributed to the area of *Mobility*. Based on this characterisation one may allocate around 15-30% of total European consumption-activated pressures to *Mobility*.

Table 8: Direct and indirect (global) environmental pressures attributable to *Mobility*

	Greenhouse gas emissions		Acidifying emissions		Ground ozone forming precursors		Material Use	
product name	*tonnes CO2-equivalents per capita*	*as % of total from consumption of all products*	*kg SO2-equivalents per capita*	*as % of total from consumption of all products*	*kg NMVOC-equivalents per capita*	*as % of total from consumption of all products*	*tonnes per capita*	*as % of total from consumption of all products*
Coke, refined petroleum products and nuclear fuel (20%)	0,3	2,3%	1,4	2,3%	1,1	1,6%	0,9	5,5%
Transport equipment	0,4	4,0%	2,0	3,3%	5,5	8,0%	0,6	3,5%
Transport, storage and communication services	0,5	4,4%	2,9	4,8%	3,5	5,1%	0,4	2,2%
Priv.Housh. - Tranport	1,0	8,7%	3,9	6,6%	12,8	18,5%	-	0,0%
attributable to Mobility	**1,9**	**18%**	**9,1**	**15%**	**22,1**	**32%**	**1,1**	**7%**

Source: ETC/RWM data set

In the case of greenhouse gas emissions, the highest environmental pressures are associated with transport activities of private households. The use of private cars accounts for about 1 t CO_2-equivalents per capita to which can be added part (assumed 20% but needs to be established by other studies) of the GHG emissions associated with the extraction and delivery of petroleum products to households (0.1 t CO_2-equivalents per capita). The final use of transport services (mostly passenger transport) by households and governments is associated with a further 0.5 t CO_2-equivalents per capita. Finally 0.4 t CO_2-equivalents per capita is associated with the purchase of transport vehicles.

Altogether approximately 1.9 t CO_2-equivalents per capita may be attributed to the area *Mobility*. As with food, this is close to the target which European citizens will need to aim for in the future for *all* their activities by 2050.

Only 10% of the total GHG emissions activated by mobility are caused by the construction of vehicles

The environmental pressures related to transport services are dominated by pressures released directly by the service sectors themselves although supply of electricity represents approx. 10% of pressures mainly used for the operation of railways. A production chain analysis makes more sense for product chains with many important contributing links. In the case of *Mobility,* that is the purchase of transport vehicles. Only 10% of GHG emissions associated with the final consumption of vehicles actually occurs in vehicle assembly factories. The majority (60-70%) are indirectly induced in the electricity sector and basic metals industry.

In conclusion, the environmental pressures of the consumption area *Mobility* are mainly related to the running of private cars though the purchase of passenger transport services and the purchase of cars also induce significant pressures. In the latter case most of the pressures are emitted during the production of electricity and steel.

4.9 Identifying key actions within the consumption hotspots

The previous section examined the production and consumption systems associated with the consumption areas of *eating & drinking, housing & infrastructures* and *mobility* to identify the links in these systems which are responsible for the majority of environmental pressures. These are the hot spots within the systems activated by these consumption areas.

The next stage is to identify what actions can be taken to reduce the pressures at those hotspots. This is not as straightforward as it sounds.

The most obvious solution would be to aim actions directly at the hotspots themselves. For example, where a hotspot lies on part of a production chain it may be that pressures can be reduced directly through developing improved technology for that part of the production process. However, the consumption/production system is dynamic and it may be that greater environmental benefits could be gained through actions in a different part of the system from that where the most pressures are directly released. For example, more environmental gains within the C/P system serving *mobility* could potentially be achieved by reducing drivers generating transport demand, or by shifting demand from private cars to collective transport than by technological improvements in cars to directly reduce pressures.

Within each C/P system there will be many potential actions which can reduce pressures, and policy could be aimed at some or all of these on a broad front. Good governance also requires effective use of public resources to give maximum benefit i.e. policy should ideally be weighted towards those groups of actions which give greatest environmental and socio-economic returns. This is the subject of policy effectiveness studies and cost-benefit analysis which is beyond the scope of this report. However, a key element of this work is identifying the potential reductions in pressures that could be gained from various different actions within a C/P system. This element of work cannot be accomplished through the use of EE-IOA methods alone but requires a combination of additional approaches, e.g. life-cycle analyses, studies of available technology etc.

Part of this work has been begun by the JRC/IPTS Environmental Improvements of Products (IMPro) programme[30]. While two of the three current final reports focus mostly on potential technical improvements to cars and housing infrastructure respectively, the third report on meat and dairy products also includes changes in behaviour i.e. improved meal planning to avoid food waste. It stops short of considering changes in diets.

Future studies are needed comparing the potential gain from behavioural change and technological improvements in each of the 3 consumption areas

It concludes, however, that since only 20% improvements in impacts can be gained through technical improvements more focus should be placed on the potentially larger gains that could be made through changing diets i.e. a reduced meat and dairy intake or shifting from high pressure intensive beef to less pressure intensive chicken and pork (Weidema *et al* 2008).

Studies are required in the future on the potential gains from *changes in behaviour* within each of the three key consumption areas to supplement the reports coming out of the IMPro programme on potential gains from *technological improvements*.

4.10 Summary of hotspots in European consumption patterns

The report identified 8 product groups in the 8 EU countries, which indirectly account for 60-70% of the key environmental pressures caused by consumption. A number of these also were among the most eco-intensive final products. In addition, private households induce approximately 20% of environmental pressures directly – mainly associated with the use of fuels for private car driving and heating.

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[31] which will need to be confirmed by future studies using bottom-up[32] methods. Based on these assumptions the demand for three functional demand areas of *Eating & Drinking, Housing & Infrastructures,* and *Mobility* is found to cause around 60-70% of environmental pressures activated by national consumption in the 8 countries. This echoes findings from other European studies including the European Commission funded EIPro study (Tucker *et al* 2006).

Each of these three demand areas on their own lead to global emissions of 1.9-2.5 tonnes of CO2-equivalents per capita in the 8 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 European Commission's 2050 target of an 80% reduction in GHGs.

The EE-IOA methods were used to further analyse the hotspots in the production chains activated by these three consumption areas. In the consumption area of *Eating & Drinking* the agricultural production stage has been identified as the point in the lifecycle where most pressures are released. For *Housing & Infrastructure key* hotspots are related

[30] http://susproc.jrc.ec.europa.eu/activities/IPP/impro.html

[31] 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.

[32] NAMEA based analyses are often described as being 'top-down'; taking a starting point in national level accounts. 'Bottom-up' analyses are those taking a starting point in individual households or industries and then scaling up.

to heating and hot water use in buildings. In the case of *Mobility* it is private car use by households which activates the most environmental pressures.

For investigating the consumption and production systems in more detail and identifying and comparing actions to reduce environmental pressures, other tools are needed to supplement the EE-IOA methods. These include life-cycle analysis, detailed knowledge of production processes and consumption behaviour analysis. Means for instigating necessary change at the identified leverage points can be roughly divided into *behavioural* and *technological measures*.

It is suggested that focusing policy on production processes to reduce environmental pressures directly at source may not always have greatest potential for reducing pressures within the system. Actions focused on changing behaviour, and thus altering the drivers of production, could give equal or greater benefits than known potential process and technological improvements.

Decoupling 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* and *behavioural* based action and policy will be necessary.

5 A Tool for SCP – Strengths, Weaknesses and Future Development

As outlined in the introduction, this report has aimed to:

1. *introduce the tool of environmentally extended input-output analysis (EE-IOA) and examine its potential for answering key SCP policy questions*
2. *make a first use of it in identifying 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*

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.

The method when applied to *national accounting matrices including environmental accounts* (NAMEA) can be used to give an overview not only over 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 most effect.

The NAMEAs in their direct form can be used to identify 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 NAMEA tables 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 NAMEAs. 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 policy makers, identifying not only the hotspots in production processes but identifying what consumption patterns drive these national production processes *and* production processes abroad. EE-IOA analysis 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-IO analysis of NAMEA tables are summarised in Table 9 below. A number of these analyses were demonstrated in a European context in Chapters 3 and 4 of this report.

Table 9: SCP questions that can be answered using EE-IO analysis and NAMEA tables (*those in italics have been analysed for the EU or EU Member States in Chapters 3 and 4*)

(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

Source: The table has been derived from Table 14 given in Eurostat (2009)

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 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.

Further developments in data

The EE-IO analysis of NAMEA tables has proved a potentially powerful tool for SCP analysis. However, some weaknesses in the underlying data currently act as barriers to the method achieving its full potential. These include the following:

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

1. ***Outdated data*** – national and EU NAMEA tables 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 to Eurostat by countries every 2 years with a 3 year time delay. However, the reporting obligations for the symmetric input/output tables required to build the consumption perspective are only once every 5 years with time lags of at least 3 years. The most up to date symmetrical input-output data is typically 3 to 8 years old and sometimes longer (13 years in the UK). 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 the US and Japan. 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 NAMEA tables include no data on where imports are sourced nor 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[33] 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, toxic emissions to water and soil etc.

Some of these 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)** are likely to be changed to require more regular or timely reporting by national statistics offices of symmetric

[33] Brazil, Russia, India, China

input/output tables in the near future. In the shorter term, Eurostat could consider filling gaps and time lags through use of ‘now-casting’ methodologies using the officially submitted 5-yearly tables as the starting point or to use annually reported supply and use tables to derive symmetric input-output tables.

The resolution of input-output tables **(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 national statistical institutes which sometimes have more detailed industry breakdowns.

Better estimations of pressures embodied in imports **(issue 3)** are likely to be possible once the JRC-funded EXIOPOL initiative is completed in 2010[34]. The EXIOPOL consortium is building up an environmentally extended multi-regional environmentally extended input-output system representing 95% of the global economy. This model uses data on where imported goods originate, and is developing more accurate 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).** It should be noted, however, that the data year will be 2000 and there are currently no plans to regularly update the model as new data arises.

With respect to environmental scope **(issue 5)** Eurostat plan to include energy use, waste generation and treatment, and material flows in the future, which will improve the scope of potential analysis using EE-IOA. The goal of the EXIOPOL project also includes introducing land use, energy commodities and water consumption into the regional model. The usefulness of the method would be further strengthened by extending country coverage to the full EU27.

Supplementing ‘top-down’ with ‘bottom-up’ analysis

While the EE-IOA of NAMEA tables can address many SCP-relevant questions (See table 8) it was found that for deeper analysis of consumption and production systems other supplementary information and methods are needed.

For example, 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 or similar ‘bottom-up’[35] methods must be used.

In Chapter 4 a few such studies were used to assign direct household pressures to the three functional areas of *Eating & Drinking, Mobility* and *Housing & Infrastructures.* A more comprehensive review of bottom-up studies is needed in the future to check these assumptions

[34] http://www.feem-project.net/exiopol/index.php

[35] NAMEA based analyses are often described as being ‘top-down’; taking a starting point in national level accounts. ‘Bottom-up’ analyses are those taking a starting point in individual households or industries and then scaling up.

EE-IOA can guide policy towards the broad hot-spots in consumption and production patterns –

identifying potential actions requires supplementary methods

Similarly, while the ‘top-down’ EE-IOA method can identify hotspots in consumption and production patterns, they will need to be combined with ‘bottom-up’ tools to investigate these in more detail and to pinpoint and rank specific actions for reducing environmental pressures. These tools might include life-cycle analysis, detailed knowledge of production processes and consumption behaviour analysis.

Studies are needed using such methods to identify the most effective production and consumption based policy measures in all three key consumption areas. The Joint Research Centre and the Institute for Prospective Technological Studies have already made studies on the technological potential for improvements in these three consumption areas through the Environmental Improvement of Products (IMPro) programme[36]. These studies need to be supplemented by studies on the gains that can be made through behavioural change.

[36] http://susproc.jrc.ec.europa.eu/activities/IPP/impro.html

References

Den Elsen, M.G.J. and M. Meinshausen (2005) *Meeting the EU 2ºC climate target: global and regional emission implications*. Report of the Netherlands Environmental Assessment Agency (MNP) Report 728001031/2005. http://www.rivm.nl/bibliotheek/rapporten/728001031.pdf

De Haan, M. (2001): *A Structural Decomposition Analysis of Pollution in the Netherlands*. Economic Systems research, Vol. 13, No. 2.

De Haan, M. and S. J. Keuning (1996): *Taking the Environment into Account: The NAMEA Approach*. Review of Income and Wealth, Series 42, Number 2, 131-148.

Dietzenbacher, E. & B. Los (1998): *Structural Decomposition Techniques: Sense and Sensitivity*. Economic Systems Research, 10, pp. 307-323.

EEA (2002): Environmental signals 2002. Environmental assessment report no 5, Copenhagen

EEA (2005): The European environment - State and outlook 2005. Copenhagen

EEA (2007a): *Annual European Community LRTAP Convention Emission Inventory report 1990–2005. Submission to EMEP through the Executive Secretary of the UNECE*. EEA Technical report No 14/2007, EEA, Copenhagen.

EEA (2008): *Annual European Community greenhouse gas inventory 1990–2006 and inventory report 2008 - Submission to the UNFCCC Secretariat*. Technical report No 6/2008 (Version 27 May 2008); Copenhagen

Eurostat (2001): *Economy-wide material flow accounts and derived indicators. A methodological guide*. Luxembourg: European Commission

Eurostat (2007): Economy-wide Material Flow Accounts Resource Productivity – EU15 1990-2004. (prepared by Helga Weisz, Willi Haas, Nina Eisenmenger, Fridolin Krausmann, Anke Schaffartzik; Institute for Social Ecology, Faculty for Interdisciplinary Studies (IFF))

Eurostat (2009, forthcoming): *Manual for Air Emissions Accounts*. Luxembourg

Fritsche, U. R. and U. Eberle, (2007): *Treibhausgasemissionen durch Erzeugung und Verarbeitung von Lebensmitteln*. Arbeitspapier Öko-Institut, Darmstadt. http://www.oeko.de/oekodoc/328/2007-011-de.pdf

Hass, J. (2008) *Decomposition Analysis Sensitivity Analysis* Internal Eurostat document produced in association with Statistics Norway. Document NAMEA/TF/05 (2008). Luxembourg.

IPCC (2007): *Climate Change 2007: Mitigation*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Jensen, P.R. and T. Olsen (2003): *Analysis of Changes in Air Emissions in Denmark 1980–2001: Time series • Bridge tables • Decomposition analysis*. (Eurostat Grant agreement nr. 200141200007) Statistics Denmark, Copenhagen

Leontief, W. (1970) *Environmental repercussions and the economic structure: an input–output approach*, Review of Economics and Statistics, 52, pp. 262–271.

Keuning, S. J. and A. E. Steenge (1999): Introduction to the special issue on 'Environmental extensions of national accounts: the NAMEA framework.' Structural Change and Economic Dynamics, 10, 1-13.

Keuning, S. J. and M. de Haan (1998): *Netherlands: What's in a NAMEA? Recent results*. In K. Uno and P. Bartelmus (eds), Environmental Accounting in Theory and Practice. Kluwer Academic Publishers, Great Britain, 143-156.

Moll, S., J. Cabesa and E. Mollgaards (2007): *NAMEA Activities at Eurostat – More Than 10 Years of Experience*. In: Proceedings of the 3rd international conference "Environmental Accounting – Sustainable Development Indicators" 23-25 May 2007, Prague, Czech Republic. J.E. Purkyně University in Ústi nad Labem. ISBN 978-80-7044-883-0, pp.245-257

Miller, R.E. and P.D. Blair, (1985): *Input-Output Analysis: Foundations and Extensions*. Prentice-Hall Inc., Englewood Cliffs, New Jersey

Moll, S., M Vrgoc, D. Watson, A. Femia and O. Gravgård Pedersen (2007): *Environmental Input-Output Analyses based on NAMEA data – A comparative European study on environmental pressures arising from consumption and production patterns*. ETC/RWM working paper 2007/2, European Topic Centre on Resource and Waste Management, Copenhagen http://waste.eionet.europa.eu/publications/WP2-2007

Moll, S. and J. Acosta (2006): *Environmental Implications of Resource Use – NAMEA based Environmental Input-Output Analyses for Germany*. Journal of Industrial Ecology Jul 2006, Vol. 10, No. 3: 9-24

Ten Raa, T. (2005): *The Economics of Input-Output Analysis*. Cambridge University Press, Cambridge

Tukker A, G, Huppes J, Guinée R Heijungs, A de Koning, L van Oers, S Suh, T Geerken, M van Holderbeke, B Jansen and P Nielsen. (2006). *Environmental impacts of products (EIPRO). Analysis of the life cycle environmental impacts related to the total final consumption of the EU-25.* Sevilla: Institute for Prospective Technological Studies. (EUR 22284 EN). http://ec.europa.eu/environment/ipp/pdf/eipro_report.pdf

Verband der Elektrizitätswirtschaft e.V. (VDEW) (2006): *Endenergieverbrauch in Deutschland 2004*, Teil A: VDEW Projektgruppe „Nutzenergiebilanzen", 2006

Watson D. & S. Moll (2008) *Environmental benefits and disadvantages of economic specialisation within global markets, and implications for SCP monitoring*, *Conference* proceeding Sessions 1 and 2 pp 375-394, 2nd Conference of the Sustainable Consumption Research Exchange Network (*SCORE!)* 10-11th March; Brussels, Belgium (2008) http://www.score-network.org/files//24116_CF2_session_1-2.pdf

Weisz, H., F. Krausmann, N. Eisenmenger, C. Amann, and K. Hubacek,. (2005): *Development of material use in the EU-15: 1970-2001. Material composition, cross-country comparison, and material flow indicators*. Manuscript developed for Eurostat, Vienna: IFF

Weidema B.P., M. Wesnaes, J. Hermansen, T. Kristense and N. Halberg. (2008). *Environmental Improvement Potentials of Meat and Dairy Products*. Report to the European Commission Joint Research Council and Institute for Prospective Technological Studies. Report EUR 23491 EN – 2008 http://ftp.jrc.es/EURdoc/JRC46650.pdf

WWF; Zoological Society of London; Global Footprint Network (2006): Living Planet Report 2006. WWF, Zurich.