Resource productivity, environmental tax reform and sustainable growth in Europe

Decomposition Analysis of Greenhouse Gas Emissions and Energy and Material Inputs in Germany

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petrE (see http://www.petre.org.uk/papers.htm) is part of the Anglo-German Foundation research policy initiative: *Creating sustainable growth in Europe* (see http://www.agf.org.uk/currentprogramme/CreatingSustainableGrowthInEurope.php)

CONTENTS

1 INTRODUCTION

This paper is part of work package 1 A of the petrE project, which as a whole deals with the global dimensions of sustainable growth in Europe. The main goal of the petrE project is to generate new insights into the conditions of sustainable development and "how it might be promoted through public policy, by linking the concepts of resource productivity and environmental tax reform (ETR)". Based on this the project especially aims to provide policy recommendations for the design of ETRs, aiming to increase resource productivity and stimulate sustainable economic development in Europe.

Before starting the design of new policy instruments as well as the assessment of implemented measures knowledge about factors that drive the evolution of environmental/resource inputs is required. Therefore, the objective of work package 1A is to investigate if there is any relationship between trends in environmental/resource inputs, resource productivity, environmental quality, economic growth and competitiveness. Against this background this paper aims to identify patterns in the evolution of different environmental inputs in Germany. The other aspects of work package 1A are addressed in Wiebe (2007), Agnolucci (2007) and Agnolucci and Venn (2007). As growing environmental pressure and awareness lead to an increasing demand for environmentally-related data in politics, administration, economics and society, a number of approaches of economic environmental accounting have emerged. In order to provide an international framework for environmental and economic information an environmental satellite system (System for Integrated Environmental and Economic Accounting (SEEA)) to the System of National Accounts was established. The German environmental economic accounts are based on this framework, but they are laid out more comprehensive. Before answering the posed question this paper outlines which data are available in Germany and secondly illustrates the relation between economic datasets and environmental (material flow) datasets. Subsequently in order to sketch the scope of environmental datasets trends in German material inputs flows, energy input flows and overall greenhouse gas (GHG) emission are described. In section 3 the observed aggregated trends are decomposed both at a sectoral and at a macroeconomic level in order to identify specific patterns which in turn might provide for future policy design.

2 DATABASE

The interaction of the economy and the environment is depicted by the System of integrated Environmental and Economic Accounting (SEEA) which is a satellite system to the System of National Accounts (SNA) (UN 2003). Since environmental accounts are using concepts and classification consistent with those employed in National Accounts, data are fully compatible between SNA and SEEA. Similar to the SNA, a system of internationally agreed conceptions and classifications for environmental accounting was developed, mainly by the UN. Thus, SEEA endows the national databases with credibility as figures are derived from internationally recognised standards and it allows for cross-country comparisons. Both, the German and the British environmental accounts reflect these internationally agreed recommendations (Statistisches Bundesamt (Federal Statistical Office) 2006b, ONS 2004).

Thus, by describing the interaction between environment and economy in a way completely compatible with SNA description of economic activity, SEEA in connexion with SNA provides a reliable database for political discussion as well as for an analysis of the relation between international competitiveness and material flows.

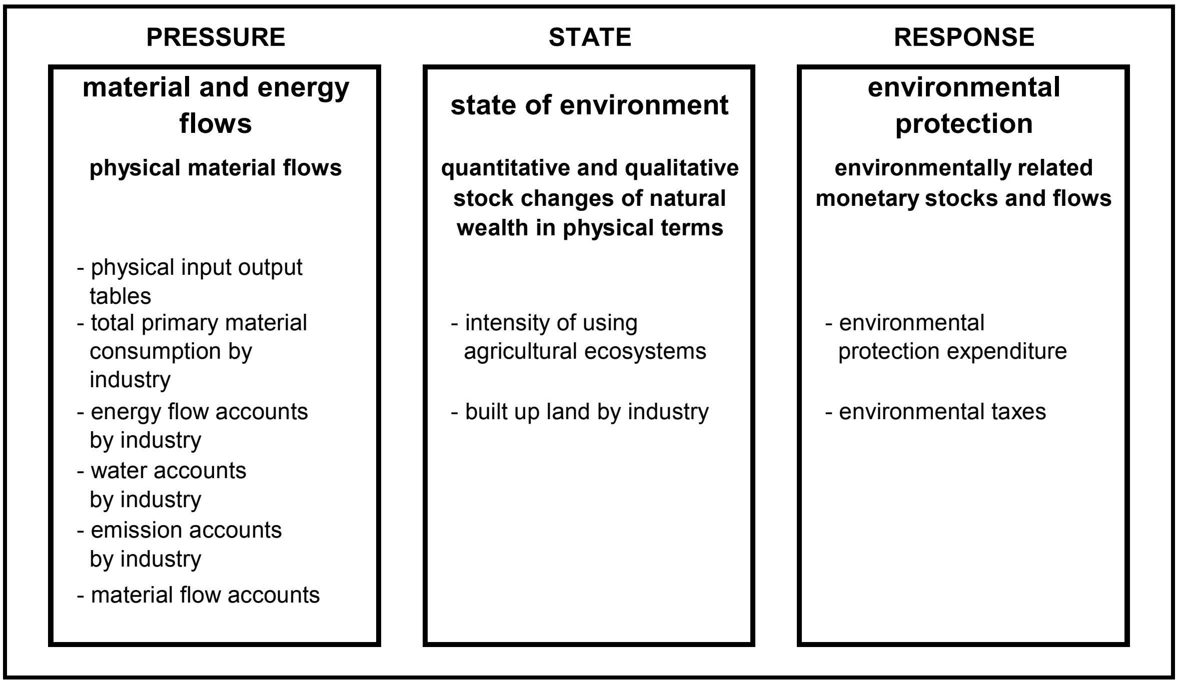
By describing the figures contained in the German SEEA, this and the following chapter give an overview of the general structure of SEEA and data usually included in SEEA. The German System of SEEA contains three modules, namely pressure, state and response. Each module describes one dimension of interaction between environment and economy. This structure is shown schematically in Figure 1.

Environmental impacts from material and energy flows are recorded in flow accounts (pressure module). These accounts present information about the total mass of natural resources and products used by the economy. In comparison SNA flow accounts present produced goods and services. Extending the SNA classifications by a classification of different types of material and energy, flow accounts that deal with flows between economy and environment could be created.

The module “state of environment” describes stocks. It contains for example information about how much land is in agricultural use at a certain point in time. As the use of nature usually goes along with negative impacts on environment and hence with a qualitative or quantitative degradation, SEEA datasets record the not produced component of an environmental asset. In contrast to this SNA records produced assets.

Hence, besides extending the SNA classifications by raw materials and pollutants as well as by environmental asset accounts, the main difference between SNA and SEEA is that SEEA is using physical units rather than monetary units. While economic flows and stocks can be valued through prices, monetary valuated environmental stocks and flows usually do not exist. Whereas the valuation of environmental stocks and flows faces a lot of problems such as cause-and-effect and aggregation problems. Therefore it is internationally agreed that the valuation of environmental flows and stocks should be left to researchers. Thus, the German accounts of environmental pressure and of environmental state are restricted to physical units.

Figure 1: Modules of the German System of SEEA – a schematical overview



Source: in style of Federal Statistical Office (2006b).

In contrast to this, "human response", the third module of the German SEEA, uses existing SNA figures – which are recorded in monetary units. This dataset comprises the environmentally-related parts of the SNA figures. For instance, the SNA records taxes paid by industry, upon this the SEEA register environmental-related parts of these tax expenditures. Beyond that, data on public and private investments and current expenditures for environmental protection are recorded in the datasets of this module.

The German SEEA does not contain any primary collected data but figures that are generated from existing official statistics. Besides that data from other institutions such as Federal Environmental Agency (Umweltbundesamt UBA) and German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung DIW) are used. As direct recording of environmental inputs and services is neither possible in monetary nor in physical units at the moment, these figures are generated indirectly by recording the absorption of pollutants and the used land, for instance (Federal Statistical Office 2006b). The volume changes of the following environmental inputs and services are recorded in German SEEA:

Environmental supply of raw materials

▪ energy	total primary energy supply
▪ raw materials	domestic extraction and consumption of abiotic material + imported abiotic goods
▪ water consumption	water consumption as water taken from nature

environment as sink for anthropogenic waste

▪ greenhouse gases	impacts of emissions
▪ air pollutants	impacts caused by emissions
▪ waste water	impacts of used water
▪ Waste	impacts caused by deposition

Structural usage of nature

▪ Land	land- use for built-up area

Economic input factors

▪ Labour	total hours worked
▪ Capital	capital utilisation as depreciation

Work package 1 of the petrE-project is designated to serve, at least to some extent, as a knowledge building tool for the other work packages of the petrE-project. As work packages three and five which deal with analyses of different policy instruments, put a special focus on energy and material inputs as well as on GHG emissions, historical trends in these figures are described in detail in the following sections. Subsequently, some of the underlying forces that contribute to these trends are identified by decomposition analyses (see section 3).

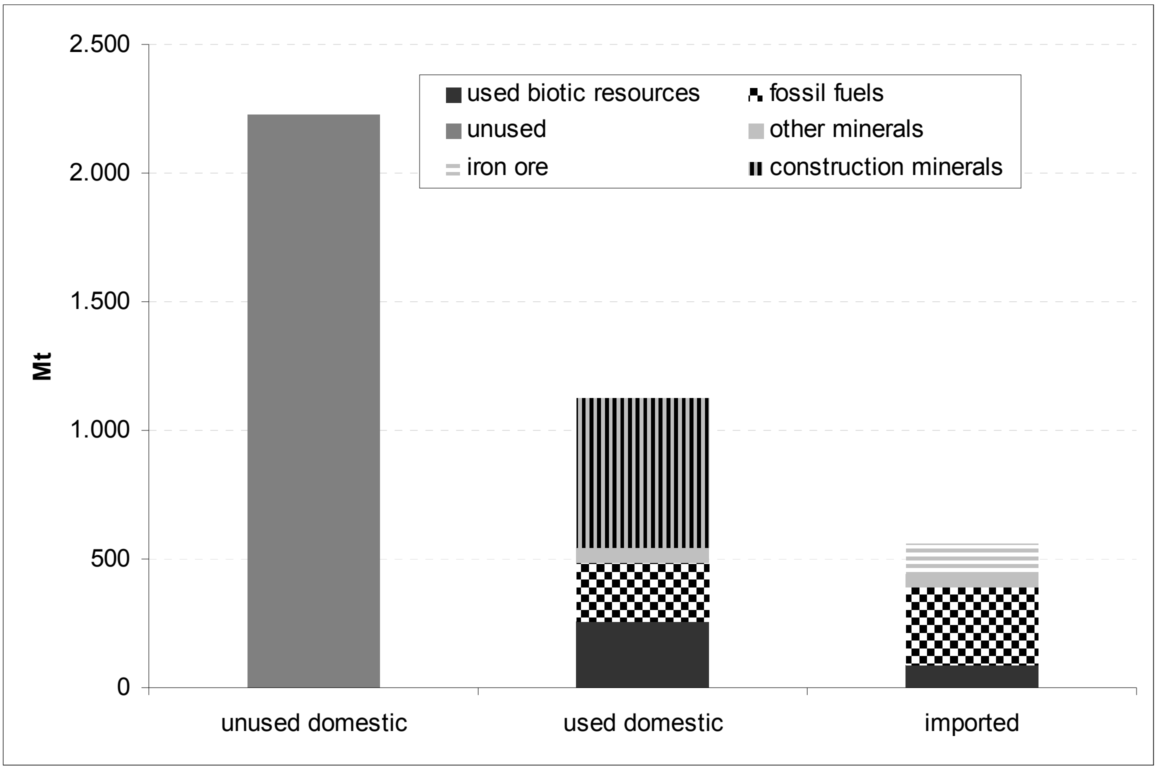
2.1 Material Flow Accounts

The dataset material flow aims to report the extent and the development of abiotic and biotic environmental inputs induced by economic activities. Data on the yields of agriculture, forestry, fishing, production and foreign trade comes from official statistics compiled by Federal Statistical Office (2006a). Supplementary information is taken from ministries, research institutions and industrial organisations. The dataset contains only direct material inputs, while indirect or hidden flows are not recorded. These flows comprise the quantity of raw material that is moved during the process of extraction, but not used in the production of goods and services. Indirect flows may result from domestic extraction or associated with extraction activities for exports in other countries.

Especially information on the amount of unused raw material extraction in other countries and therefore on indirect flows associated to raw material imports, semi-manufactured and final products is rare. Likewise, information on direct material requirements necessary to produce imported products is incomplete. Different approaches have been developed that allow for integrating indirect material flows into the datasets, and ensure thereby that all upstream requirements of primary material resources associated with imports and exports of goods and services are captured in material flow accounts as well. But up to now each of these approaches involves shortcomings respectively they have not been fully implemented due to data constraints. For instance, due to the required amount of data indirect material flows using life-cycle-analysis – an approach that calculates all material requirements along the whole life-cycle of a product – have only been calculated for a small number of products and in a few countries (Giljum et al. 2007). For similar reasons studies using environmental input-output-analysis to calculated indirect material flows focus on a single country by excluding trade flows between other countries and thereby material associated to these flows from the analysis. Or these studies assume that imported raw materials and goods are produced with domestic technology. The latter assumption might involve tremendous distortions if countries differ significantly in economic structure and technology.

Thus, failing which reliable data recording, only direct material imports are included in the German material flow accounts. The dataset includes domestic material extraction by material, imported resources by material and material flows into industries.

Figure 2: Composition of material use, 2004



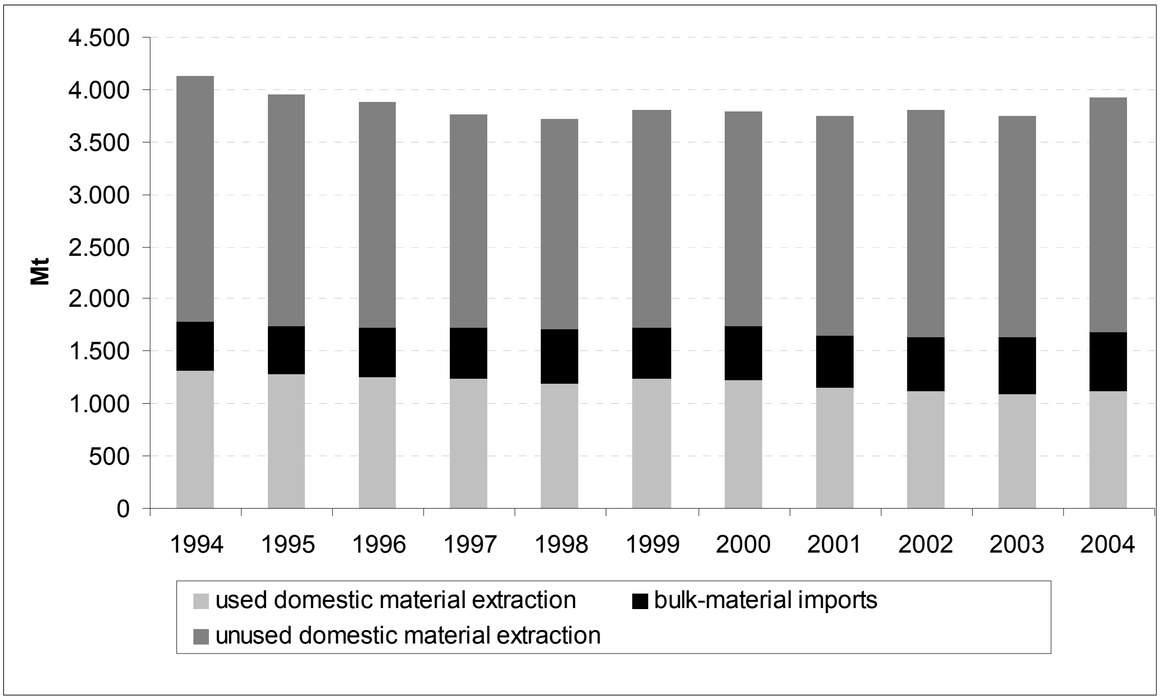
Source: Federal Statistical Office (2006c), table 1.5

In 2004, the German economy used 3.918 million tonnes (Mt) of primary material (excluding atmospheric gases). Of this total 3.356 Mt were extracted domestically (86 %), respectively 14 % were imported (562 Mt). 67 % (or 2.229 Mt) of material extracted domestically was left unused. These includes for instance wood harvesting losses such as timber felled, but left in the forests or overburden from mining and quarrying (Sheerin

2002). As material imports do not include these unused materials, the total material extracted on behalf of the German economy is therefore likely to be somewhat higher (see Figure 3). Used domestic extraction basically consisted of abiotic resources such as construction mineral (583 Mt), fossil fuels (277 Mt, whereof 182 Mt lignite) and biotic resources (261 Mt). Biotic materials include agricultural products, biomass used as livestock feeds and biomass from forestry, fishing and hunting. Whereas the production of meat; fish farms and animal products, such as eggs, milk are treated as part of the economic system, and thus it is not recorded as biotic raw material extraction. However, this differentiation is not applied to imported biotic products (Federal Statistical Office, UBA, Federal Institute for Geosciences and Natural Resources (BGR) 2007) (see Figure 2 and Figure 6). Thus, domestic biotic inputs are underestimated to some extent.

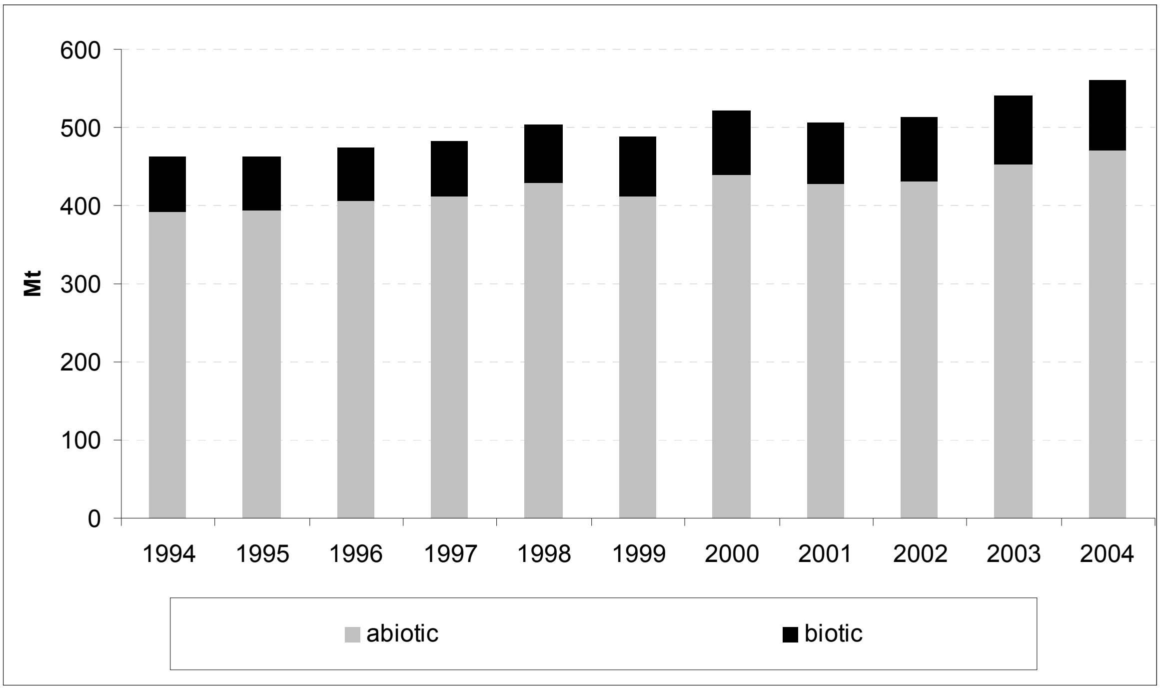
Imports were mainly composed of fossil fuels and products thereof (321 Mt), iron ore and products thereof (117 Mt), other mineral resources and products thereof (51 Mt) and biotic goods (90 Mt). Overall, fossil fuels accounted for 47 % of raw material use in 2004 (see Figure 2 and Figure 4).

Figure 3: Extracted material by origin, 1994-2004



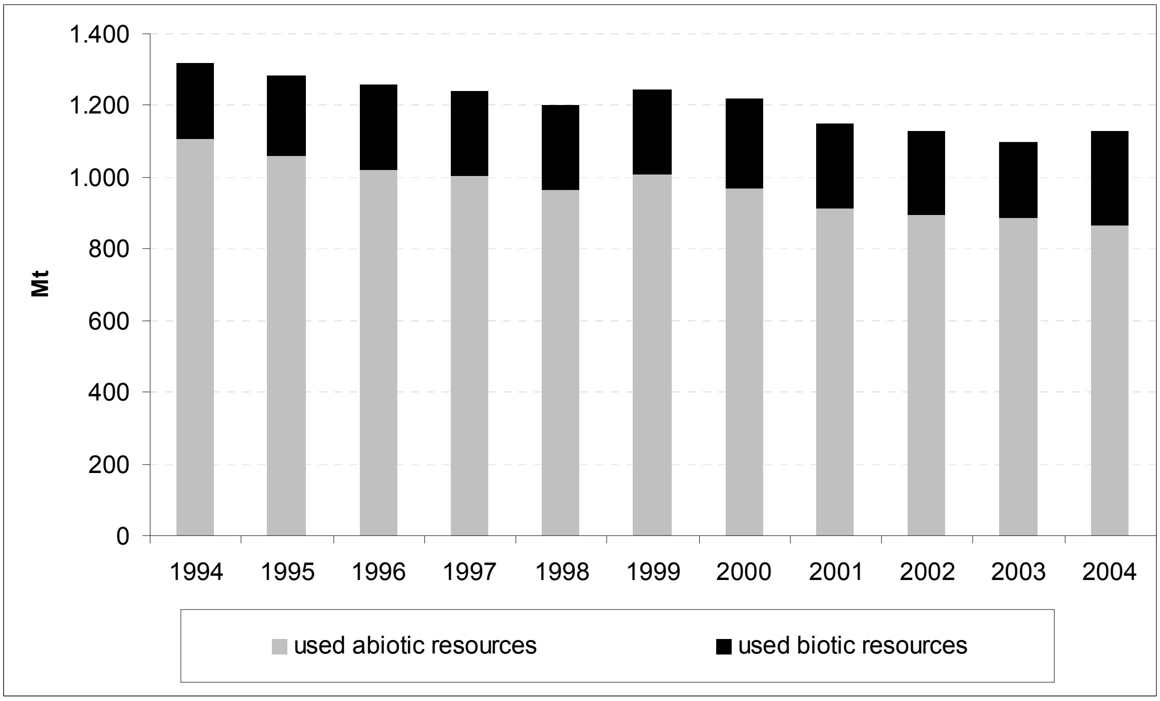
Source: Federal Statistical Office (2006c), table 1.5

Figure 4: Composition of imported material, 1994-2004



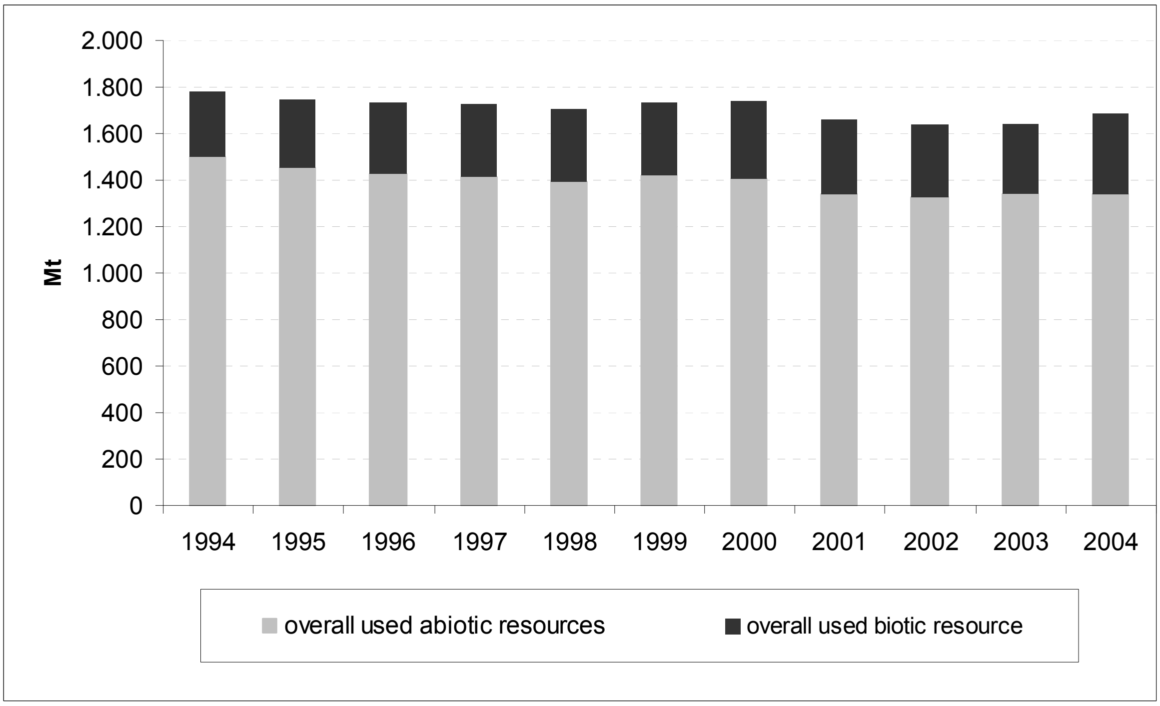
Source: Federal Statistical Office (2006c), table 1.5

Figure 5: Composition of domestically extracted material, 1994-2004



Source: Federal Statistical Office (2006c), table 1.5

Figure 6: Composition of used material, 1994-2004



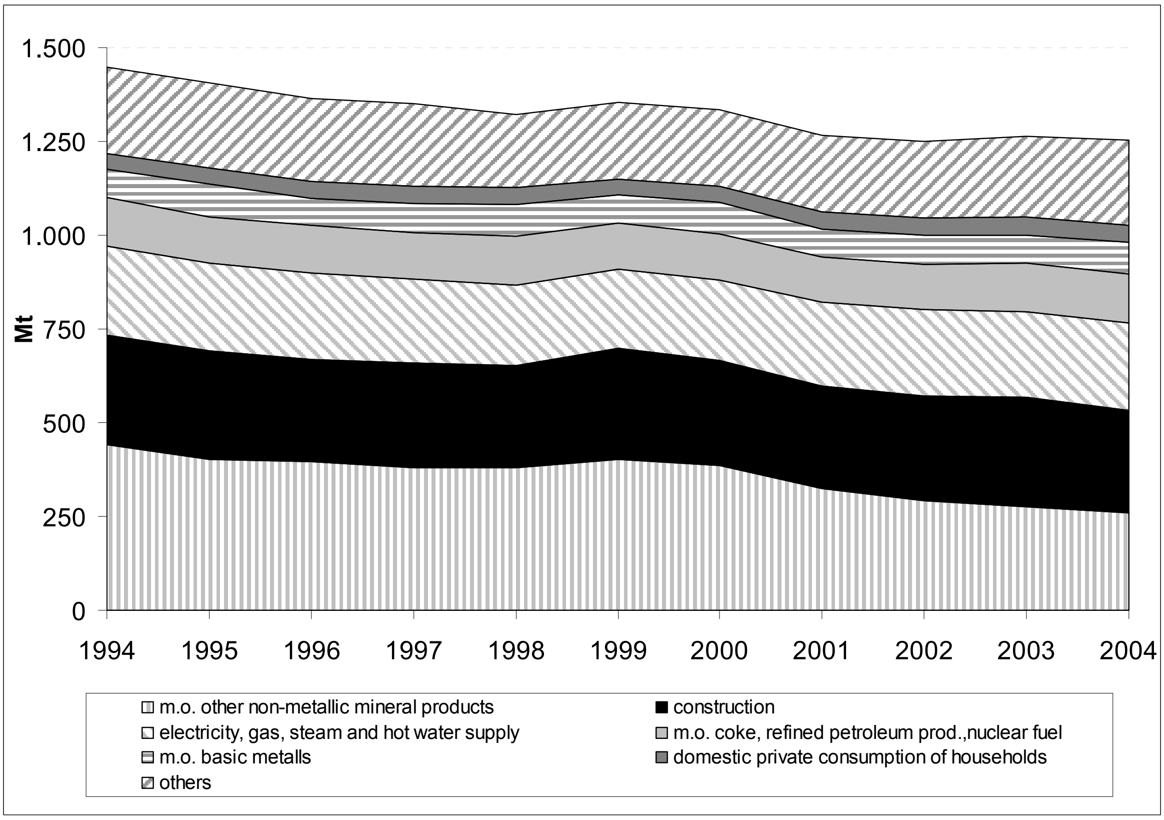
Source: Federal Statistical Office (2006c), table 1.5

Although the overall input of raw material (imports plus used and unused domestic extraction) recently rose, this was compensated by a significant decrease in the years leading up to 2001 (- 9.5 %) (see Figure 3). Thus, by 2004 a 5.2 % reduction compared to 1994 could be reached (- 215 Mt). However, the composition of overall raw material input changed in many respects. Between 1994 and 2004 abiotic raw material inputs dropped by 14 % whereas the input of biotic raw material went up by 22 . The latter involved a rise in both domestically extracted biotic raw materials (+ 23%) and imported biotic raw materials (+ 9 %). The decrease of abiotic raw materials inputs mainly referred to a significant decline in extraction and imports of construction materials (- 190 Mt), in line with the crisis in the construction sector. As this sector is speeding up recently, both extraction and imports of construction materials are likely to increase over the next years.

The decline of domestic extraction of fossil fuels (-51.4 Mt) was more than offset by the rise of fossil fuels imports (+ 66.1 Mt between 1994 and 2004). Hence, overall domestic reduction of raw material extractions has been partly substituted by an increase in imported raw materials. The impact of this development on the global material account cannot be identified at the moment as indirect material flows are not captured by the German SEEA.

Raw material flows into sectors evolved quite differently during the observation period. As no figures are recorded for biotic raw materials flowing into sectors, the following considers abiotic raw materials only.[1] As electricity, gas, steam and hot water supply, construction and manufacture of other non-metallic mineral products contribute to more than two thirds of abiotic raw material use, the evolution of these sectors has a strong impact on overall abiotic inputs (see Figure 1). Especially a 41 % reduction in “manufacture of other non-metallic mineral products” – which accounted for almost one third of used material in 1994 – caused a reduction at 11 % in overall abiotic material input in 2004 compared to 1994.

Figure 7: Composition of used material, 1994-2004



Source: Federal Statistical Office (2006c), table 4.4

2.2 ENERGY FLOW ACCOUNTS

Besides figures on total primary energy supply (TPES) available for 71 sectors corresponding to the IOT classification of the Federal Statistical Office, the dataset contains data on supply and use of energy, sectoral energy intensity and cumulated energy consumption. The latter includes direct and indirect energy consumption. Energy

[1] In line with its strategy of sustainability the German Government introduced a resource indicator. As this indicator referred to minerals and fossil fuels only, data on biotic raw materials have not been recorded yet.

consumption of imported (intermediate) goods is calculated under the assumption that foreign production processes and structures are equal to domestic ones.

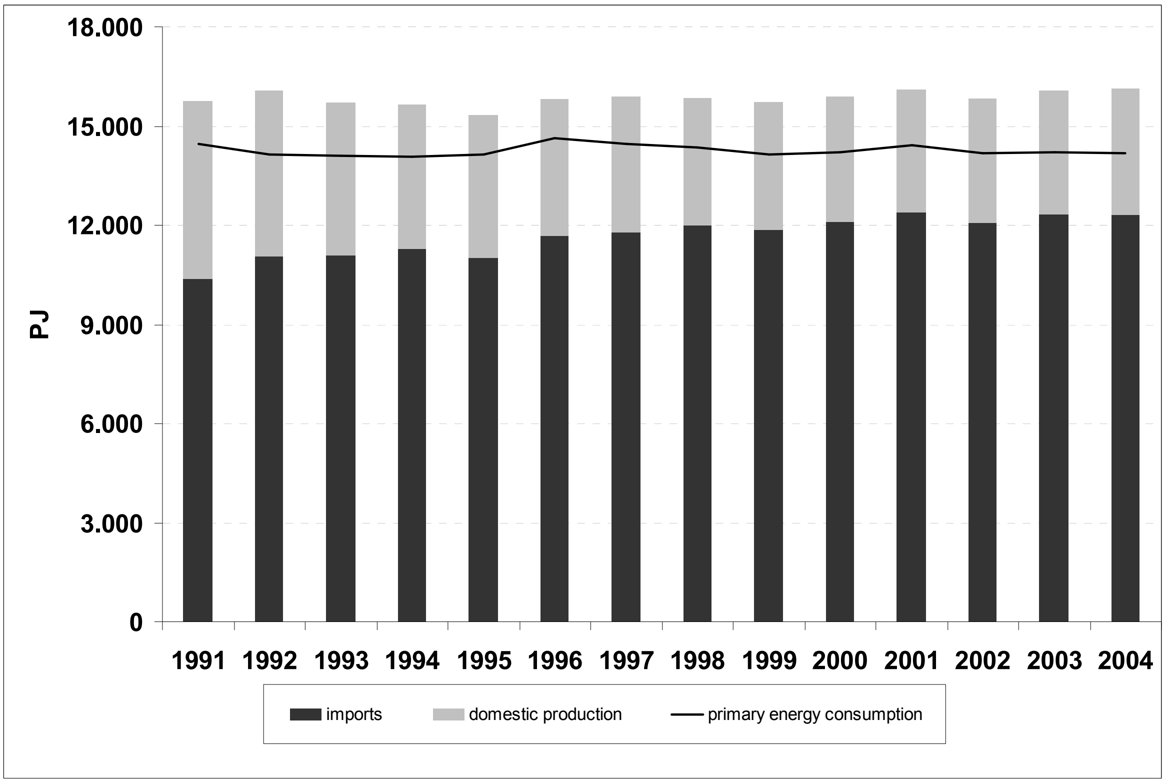
Data on energy consumption of households and industries are basically derived from energy balances provided by Arbeitsgemeinschaft Energiebilanzen (AGEB – working group on energy balances). Energy input data are available for the years 1991 and 2004. Data on “total energy supply” and on cumulated energy consumption are taken from input-output tables (IOT). Due to revisions of SNA, comprehensive IOT are merely available for 1995 and from 2000 onwards.

Between 1991 and 2004, primary energy consumption went up by 2.3 % (15,755 PJ to 16,124 PJ), while domestic energy carrier production decreased by 29 %. This results in a tightened energy dependency, as the share of imports in energy supply rose from 66 % to 76 % (see Figure 8). About 65 % of direct energy consumption was spent by industrial and commercial sectors between 1991 and 2004. Manufacture of chemicals and chemical products accounted for 12 % of total direct domestic consumption on average. Overall, direct energy consumption of manufacture of chemicals and chemical products increased by 2.7 % between 1991 and 2004. The shares of the other main contributors remained more or less constant, too. (manufacture of coke 2.5 %, manufacture of other non-metallic mineral products 2.8 %, manufacture of basic metals 7.1 %, trade and commerce sectors 5.3 %, post and telecommunications 7.2 %).

Primary energy consumption in manufacture of coke, refined petroleum products and nuclear fuel increased by 4.7 % (+ 358 PJ) between 1991 and 2004 whereas primary energy consumption of manufacture of other non-metallic mineral products and manufacture of basic metals decreased by 18 % (- 442 PJ) respectively by 7 % (- 989 PJ). Primary energy consumption of households (+2.7 %), trade and commerce (+ 0.6 %) and post and telecommunications (+ 15.8 %) increased in the same time period. Hence, the primary energy consumption of other industries decreased on average by 10.5 % between 1991 and 2004 (see Figure 9).

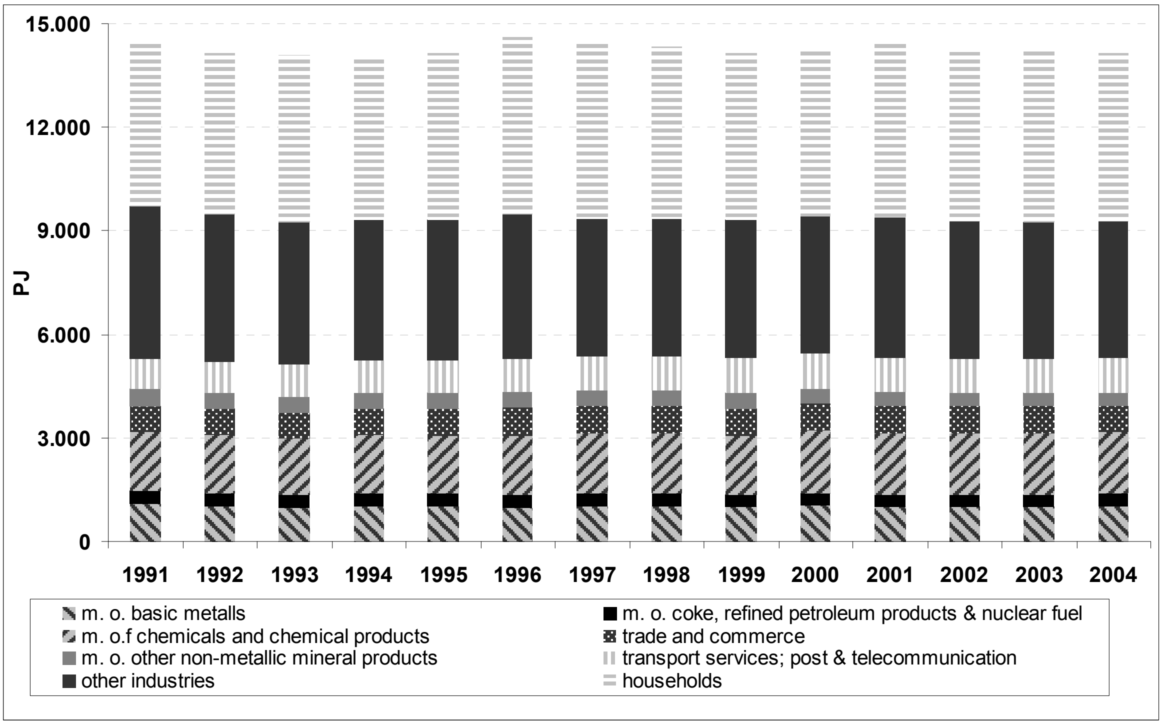
The great share of households and other industries in overall energy consumption suggests a policy strategy that not solely focuses on energy-intensive industries. As today, due the large proportion of energy costs of overall costs, these industries operate quite energy efficiently. Often the potential in existing technologies to reduce energy intensity further are nearly exploited in these industries. Therefore broader strategies such as building efficiency programmes should be included in the set of policy instruments. Even though the contribution of a single action (e.g. insulation of a detached house) is very small, the immense number of possible actions is promising.

Figure 8: Primary energy consumption by origin, 1991-2004



Source: Federal Statistical Office (2006c), tables 5.1.1, 5.2.2.1

Figure 9: Primary energy consumption by sector, 1991-2004



Source: Federal Statistical Office (2006c), tables 5.1.1, 5.2.2.1

2.3 Greenhouse Gas emissions

The Kyoto protocol specifies three greenhouse gases (GHG) and three groups of fluorinated GHG, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O, laughing gas), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6). In Germany these emissions primarily arise from fossil fuel combustion. Other important sources of GHG emissions are agriculture and the use of solvents.

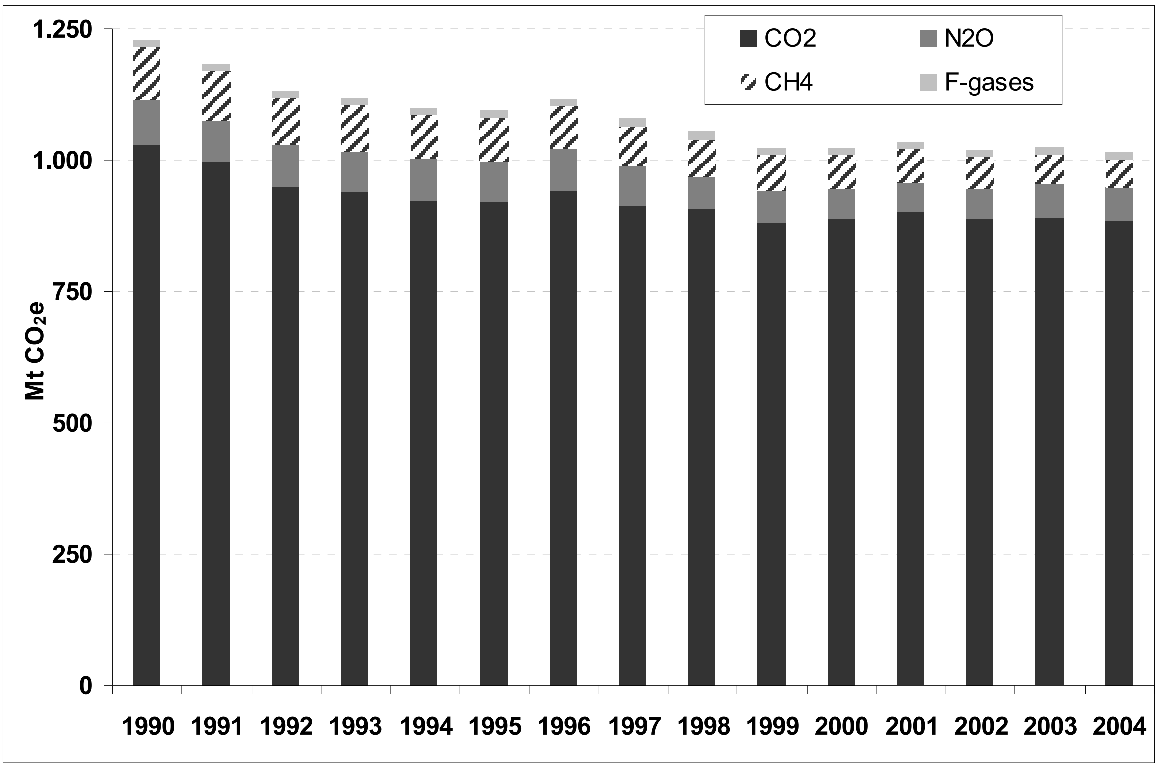
Data for GHG were converted into tonnes of CO_2-equivalent (t CO_2e) using global warming potential. Global warming potential is a method that compares the relative effects of different GHG emission by measuring the effectiveness in global warming of a GHG relative to CO_2 over a 100 year time horizon. Each of the six GHG has a different global warming potential. The dataset comprises the years 1990 to 2004.

Activity data for emission calculation are taken from AGEB (working group on energy balances, AGEB 1995) and IOT (provided by the federal statistical office itself). In addition to that, emission factors provided by UBA (Federal Environmental Agency) are used.

Figure 10 shows that CO_2 was the largest contributor to global warming between 1990 and 2004 with 85 % on average of the weighted cumulated emissions. In this time period, CO_2 shares increased steadily, while total weighted emissions had fallen by 19 % since 1990 comprehending a decline in all GHG but HFC (and thereby overall F-gases). Shut downs of emission intensive enterprises in East Germany caused in large part this trend.

In 2004 CO_2 emissions were 15.1 % (-144.38 Mt CO_2) below the level of 1990. In 1996 a small increase in CO_2 emissions was observed, due to a cold winter.

Figure 10: GHG emissions by gas, 1990-2004



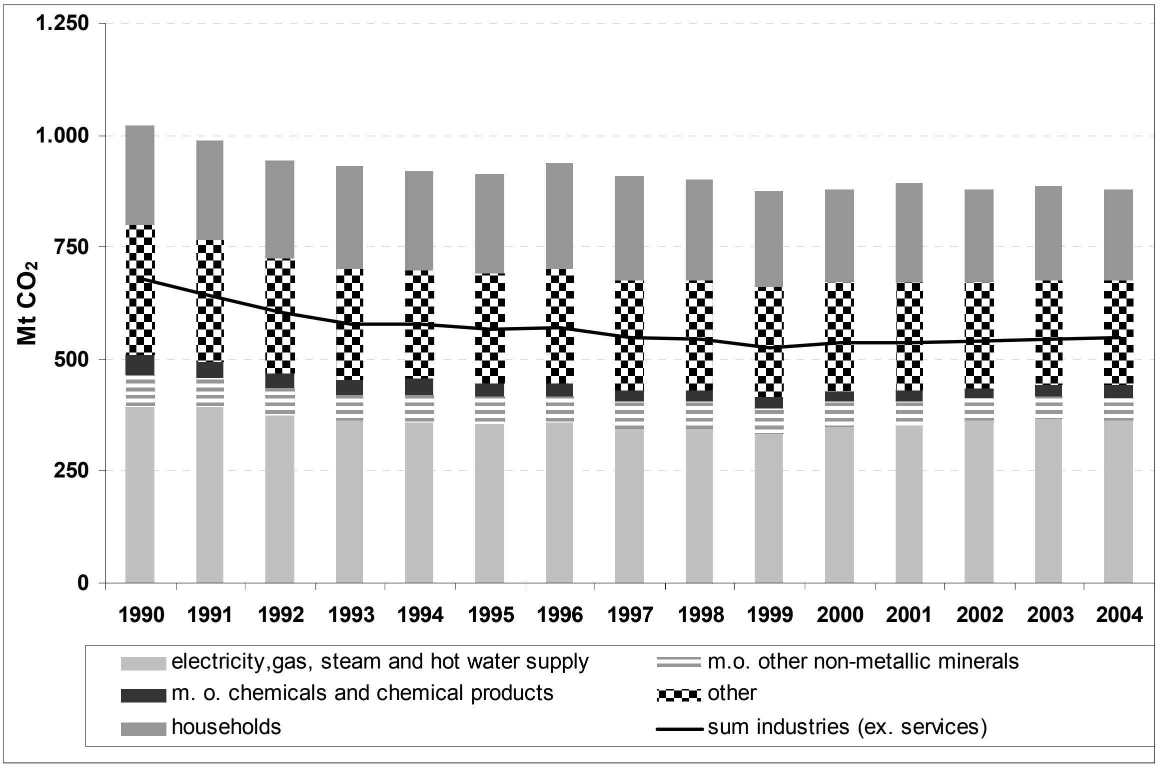
Source: Federal Statistical Office (2006c), tables 6.1.2, 6.2.2, 6.3.2, 6.4.2

CH_4 emissions were the second largest contributor to overall German GHG emissions in 1990 (8.1 %). CH_4 emissions dropped by 66.2 % (48.35 Mt CO_2e) during the observation period. Since 1996 however, N_2O emission has been the second largest contributor to global warming, as the reduction of N_2O emission has been relatively weaker, (-27.7 % compared to 1990). In 2004 N_2O emissions added up to 64.28 Mt CO_2e (CH_4: 51.44 Mt CO_2e). Emissions of F-gases increased by 17.4 % or 2.3 Mt CO_2e between 1990 and 2004. This trend was basically caused by strong increases in HFC (70.1 %; 4.4 Mt CO_2e) which offset the reduction in SF_6 (-6.6 %; -0.3 Mt CO_2e) and in PFC (-118.2 %; -1.9 Mt CO_2e).

So far, emissions differentiated by sectors have been calculated for CO_2, CH_4 and N_2O. The bulk of CO_2 is emitted by industrial sectors (2004: 62 %), households accounted for almost 23 %. The latter basically stemmed from heating and transport.

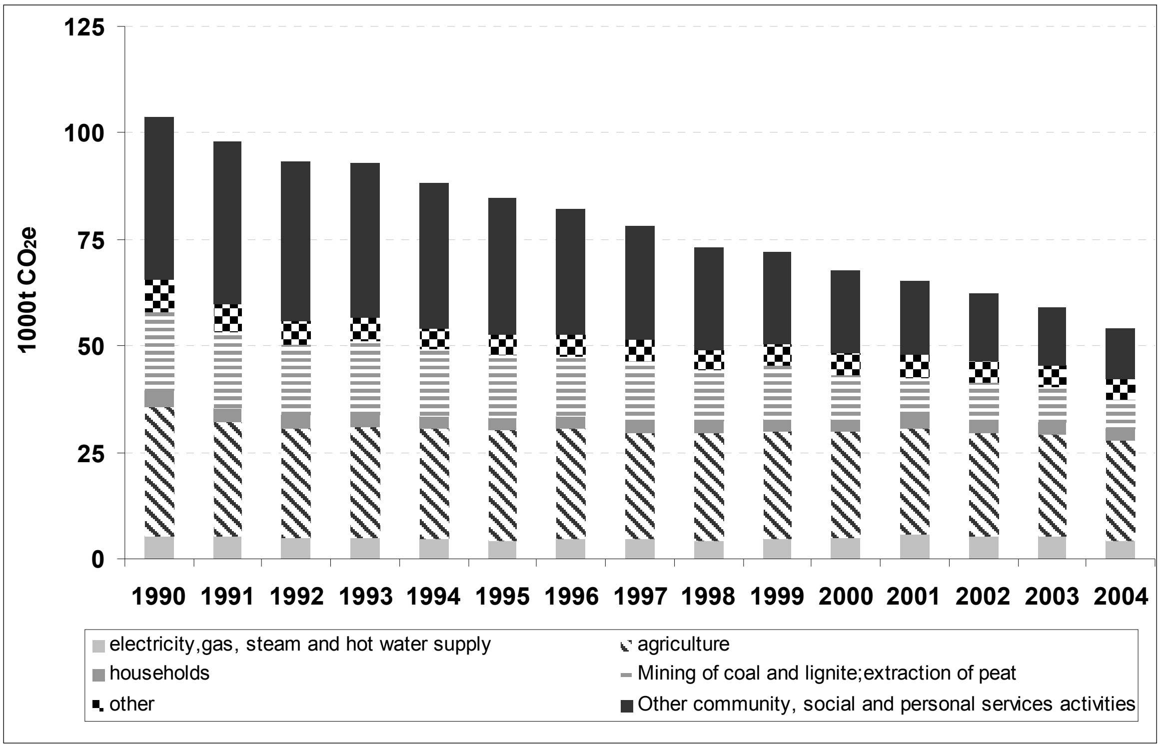
Electricity, gas, steam and hot water supply was responsible for 39 % of overall and 67% of industrial CO_2 emission in 2004 (see Figure 11). Since 1990 the emissions of this sector declined by 7.5 % (-30 Mt CO_2), mainly caused by fuel switches and improvements in production technologies. CO_2 emissions of other main industrial contributors such as manufacture of other non-metallic mineral products (7 % share in overall CO_2 emissions in 2004 – 23 Mt CO_2 compared to 1990) and manufacture of chemicals and chemical products (4.5 %, -15 Mt CO_2) also fell significantly. Furthermore a drop in CO_2 emissions of most sectors could be observed. In some service sectors such as sale, maintenance and repair of motor vehicles and motorcycles, retail sale of automotive fuel, air transport, transport support, post and telecommunications, financial intermediation, insurance and pension funding; activities auxiliary to financial intermediation, real estate, renting and business activities, education, health and social work and other community, social and personal service activities however CO_2 emissions went up, resulting in an overall increase in services sectors contribution to CO_2 emissions by 5.6 % between 1990 and 2004.

Figure 11: CO_2 emissions by sector, 1990-2004



Source: Federal Statistical Office (2006c), table 6.2.2

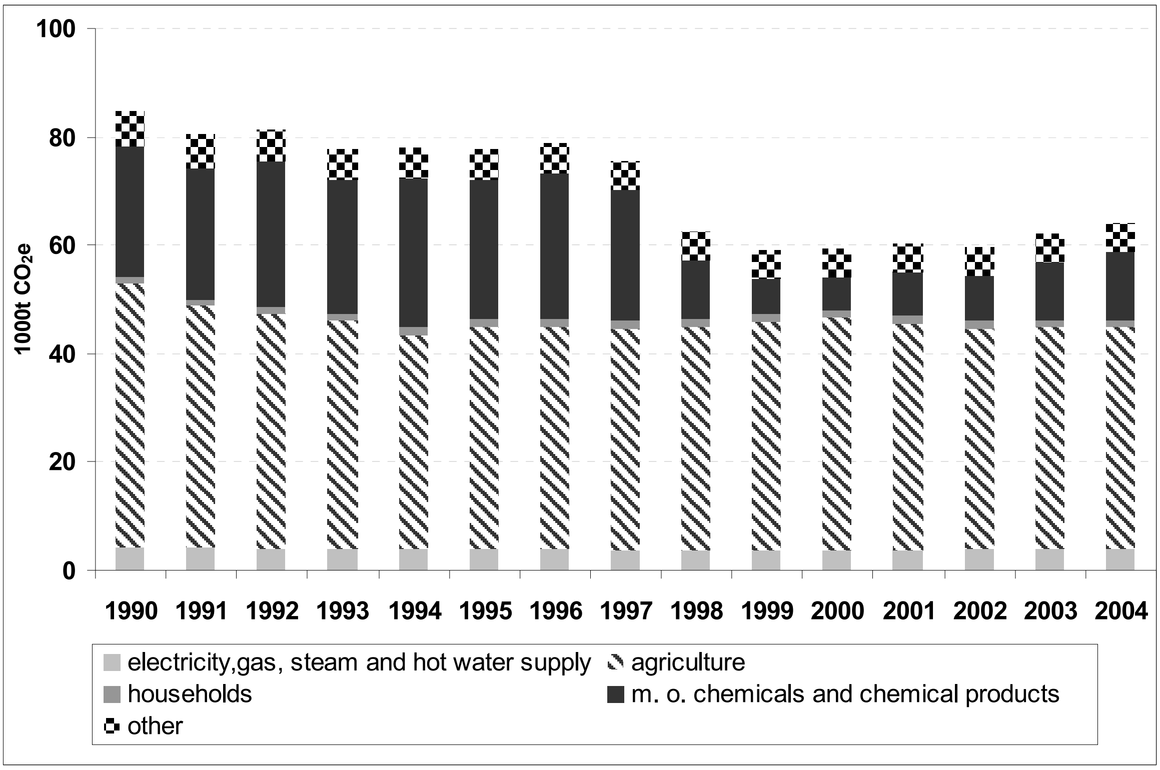
Figure 12: CH_4 emissions by sector, 1990-2004



Source: Federal Statistical Office (2006c), table 6.3.2

Agriculture was responsible for 45 % (23 Mt CO_2e) of overall CH_4 emissions in 2004. Between 1990 and 2004 its emissions decreased by 7 Mt CO_2e. In most other sectors CH_4 emissions also decreased or remained nearly unchanged (in absolute terms) between 1990 and 2004, resulting in an overall decline of 47 Mt CO_2e of all sectors not individually shown in Figure 12. The observed strong decline in total CH_4 emissions (-49 %) mainly stemmed from a 68 % reduction in other community, social and personal services (-26 Mt CO_2e). This can basically be attributed to strong reductions in "sewage and refuse disposal, sanitation and similar activities". Furthermore CH_4 emissions from mining of coal and lignite; extraction of peat declined by 11.508 t CO_2e. CH_4 emissions from household decreased only slightly by 1.169 t CO_2e.

Figure 13: **N_2O emissions by sector, 1990-2004**



Source: Federal Statistical Office (2006c), table 6.4.2

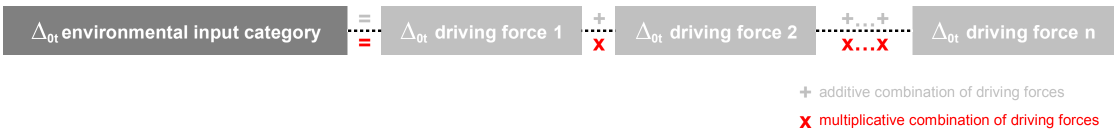
Agriculture accounted for the bulk of N_2O emissions between 1990 and 2004. For the years 1990 up to 1995 a steady decrease from 48.535 t CO_2 in 1990 to 41.013 t in 1995 could be observed. After a small increase in 1999 and 2000, N_2O emissions in agriculture returned to 1995-1998 levels. In all other sectors except for manufacture of chemicals and chemical products N_2O emissions remained nearly unchanged. The strong decline in manufacture of chemicals and chemical products in 1998 was basically responsible for the observed reduction of overall N_2O emissions. Since 2001 this sectors N_2O emissions increased again, and thereby overall N_2O emissions.

3 DECOMPOSITION ANALYSIS

3.1 METHOD

The design of new policy instruments as well as the assessment of implemented measures requires the knowledge of factors that influence the evolution of environmental input categories. In order to identify these driving forces, we decompose each category's development. This so called decomposition analysis is a mathematical instrument that allows for determining the contribution of changes in single driving forces (both decrease and increase) on changes in a dependent variable between two periods. In our case the dependent variable is environmental input category (see Figure 14). The change of each driving force describes its impact on the dependent variable's change while leaving all other independent variables unchanged (Schoer, Schweinert 2005). The following section provides interested readers with details about the used method. Those particularly interested in results rather than technical descriptions of the used methodology may wish to skip this section and turn directly to chapter 3.2.

Figure 14: concept of decomposition analysis



Decomposition analyses used in the field of EEA can be divided into two types – index decomposition analysis (IDA) and structural decomposition analysis (SDA). SDA is based on an input-output-model (IO-model) which includes information on intermediate deliveries. But in contrast to traditional IO-analysis SDA is less limited by the assumption of constant IO-coefficients: as SDA aims to identify, among other things, the impact of changing IO-coefficients on the dependent variable. Indirect effects, that emerge when direct demand changes in one sector affects the sector's inputs from other sectors, are capture in SDA by the Leontief inverse. In contrast to this IDA measures direct effects only, as it is based on sector level data (Wadeskog, Palm 2003). Dieckmann et al. (1999) grouped recently used approaches without distinguishing between the two different methodical concepts SDA and IDA, as follows:

- *combination of driving forces*: Changes in single driving forces can be linked additively or multiplicatively (see Figure 14). Furthermore changes in the dependent variable and its underlying forces can either be expressed in absolute or relative terms (Gerlinger 2004 or Rørmose, Olsen 2003).

- *time concept*: Even though the theoretical background of SDA and IDA is time continuous, decomposition studies often use a discrete time framework, applying both a year-by year analysis or the consideration of a start year and a target year only (Rørmose, Olsen 2003).
- *choice of index*: This choice is quite essential to decomposition analysis. Several options exist (for an overview see Dieckmann et al. 1999): Laspeyres (base year weights), Paasche (target year weights) and Marshall-Edgeworth (mean of base year and target year weights) indices can be applied in SDA as well as in IDA. In addition, research related to IDA has generated further indices such as conventional Divisia, refined Divisia and adaptive weighting Divisia index (Wadeskog, Palm 2003). Ang and Zhang (2003), for instance, provide further information about IDA methods.
- *Addressing the residual term*: Particularly in approaches using Laspeyres or Paasche indices a residual term occur. This term captures the so-called mixed effect that emerges from simultaneous changes in the considered driving forces.[1]. Rørmose and Olsen (2003) describe the occurrence of the residual in a quite catchy way. The occurrence of a residual term implies that the aggregate is not perfectly decomposed. In general there are two options to deal with the residual: If it is unwanted, the decomposition has either to be specified in a way that the residual is avoided by using other indices than the pure Laspeyres or Paasche index. Or the isolated effects (Seibel 2003) have to be considered only. If the residual is accepted, basically three different possibilities arose to address it (Seibel 2003): Firstly, if the residual is small, it can be neglected, thus leaving the decomposition incomplete. This implies that the isolated effects are considered only (see above). Secondly, explicit examination of the residual by analysing isolated and mixed effects. And finally, the residual can be distributed among the isolated effects.
- *Level of disaggregation*: Generally decomposition analyses can be conducted at a sectoral level or at the level of the national economy. In the latter case the decomposition analysis is either based on overall figures (one dimensional equation) or each driving force is broken down by sectors and subsequently the sectoral effects of each driving force are aggregated to the overall figure. The results in either case depend on the chosen level of sectoral breakdown, respectively (at the level of the national economy) on the level of the underlying sectoral breakdown. Rørmose and Olsen (2003) showed that the more disaggregated the driving forces are, the larger the effects identified by the decomposition analysis. This implies the more aggregated driving forces are, the more information is lost. Therefore, decomposition analysis should be done on a level as detailed as possible, subsequently results can be aggregated.

By combining these criteria differently, miscellaneous decomposition analyses for both types can be derived. Even though each of these approaches is consistent and equivalent according to statistical theory they may yield different results. Thus, a decomposition problem has no unique solution (Dieckmann et al. 1999).

Hence, it cannot be concluded which of the two concepts (and which combination of the mentioned criteria) is better. The proceeding rather depends on the data at hand and the objective of the analysis.

The focus of this chapter is to check whether the data at hand allows for identifying any specific patterns in the evolution of different sectoral environmental inputs. And if so, to analyse them. In general an IDA, which is less data intensive than SDA, might be sufficient to ascertain if any stereotypes exist. However, when analysing the identified patterns it is preferable to include as many details as possible about determinants behind the changes in environmental inputs over time. As SDA allows for including indirect effects without neglecting the direct effects, whereas IDA merely considers direct effects, the application of SDA for the study at hand is to be favoured. The application of SDA for analysing factors that determine changes in environmental inputs, is also recommended by several studies e.g. Seibel (2003); Rørmose, Olsen (2003); Wadeskog, Palm (2003).

However, currently IOT for Germany are merely available for the years 2000 to 2003. This time period is far too short to assess the influence of technological changes, economic growth and structural changes on environmental inputs, as their impacts usually emerge gradually. Therefore we apply an IDA first.

As done in most other decomposition studies we use a period-wise approach and analyse changes between two points in time (1995 and 2004). This type of analysis neglects the annual evolution of each component and thus implicitly assumes that both the base year and the comparison year are representative averages of the trend between the two years (Nanduri 1998). Furthermore we employ a method[1] with full decomposition and thus, without a residual term, because this better fits the idea of decomposing the evolution of an aggregate in its parts. This proceeding is chosen by several statistical offices (Seibel 2003, Wadeskog, Palm 2003, Rørmose, Olsen (2003).

Changes in environmental inputs can be decomposed on a total economic, sectoral, intra-sectoral and enterprise level. The German SEEA data allows for decomposition on the sectoral level. Using information on overall and sectoral gross value added (GVA) evolution at the same time, we explain changes in sectoral environmental inputs by the following equation:

$$EI_i = \frac{EI_i}{GVA_i} * \frac{GVA_i}{GVA} * GVA$$

EI_i: environmental input of sector i

GVA_i: economic activity (gross value added) of sector i at constant prices

[1] Seibel (2003) termed this method “extended method, simple factors”.

GVA: economic activity (gross value added) of the overall economy

Each term on the right-hand side represents one driving force. The first term describes the environmental-input intensity of a sector's GVA (intensity effect). An increase of the term indicates a raise of a sector's environmental input intensity and vice versa. The second term defines the share of sectoral GVA in overall GVA (structural effect). Structural changes of the economy cause changes in this term. The last term captures the economic growth effect of the overall economy (production effect).

As the subsequent analyses show the use of GVA might cause problems if GVA and production diverge, for example substandard price development in air transport resulted in a strong increase in the sector's energy intensity. Using the production value instead of GVA would avoid this problem. But as GVA data are provided by SEEA in the same industry classification, we use these activity data, since they are consistently available for the whole observation period.

3.2 Decomposition of Sectoral Trends

As can be seen from the description of the database in section 2 the input of all examined environmental input categories diminished between 1994 and 2004, although trends in single sectors deviated from macroeconomic trends. The following decomposition analyses on a sector level aim to identify whether the observed developments follow any specific patterns. Furthermore the impact of trends in single sectors on macroeconomic numbers should be explored.

As percentages tend to conceal the impact of components on the macroeconomic numbers, volume changes and shares in overall environmental input are shown on a sector level, too (see Table 2, Table 4 and Table 6). However, it is worth noting that the following decomposition analyses consider only structural changes between sectors, while intra-sectoral structural changes that in turn influence the environmental input intensity and the sectoral performance are neglected.

The growth in overall GVA (+ 16.7 % on average between 1994 and 2004) had an input augmenting impact on environmental consumption of all sectors (see third column Table 1, Table 3 and Table 5). Whilst at the same time the economic importance of primary sectors in terms of contribution to GVA diminished (exception: fishing and Extraction of crude oil and petroleum). In 2004 primary sectors accounted for 1.3 % of overall GVA.

Similar trends could be observed for most industrial sectors. For instance, in line with changes in international labour division the share of domestic textile production and electronics as well as the weight of other labour intensive sectors and/or sectors producing low-grade goods decreased. The construction sector's crisis which followed the overheating tendency in the course of German reunification, which resulted in a steadily decrease in construction sector's GVA from 1995 onwards is captured in the dataset as well.

By contrast, the contribution to overall GVA of export-orientated, high-order industrial sectors such as automotive engineering, engineering and chemicals increased. But, these could not offset the diminishing role of other secondary industries, thus the contribution of secondary sectors to GVA steadily decreased from 31 % (1994) to 26.8 % in 2004. This development indicates a shift towards a more and more service orientated economy as in return the contribution of trade and service sectors to GVA increased during the observation period. This trend was further strengthened by raising national and international outsourcing of business services. In 2004, tertiary sectors accounted for 71.9% of overall GVA.

However, the declining contribution of post and telecommunications and electricity, gas, steam and hot water supply (secondary sector) might stem from changes in competition policy, while the decrease in land transport is caused by changes in data collection. For example, up to 1998 Bundesbahn/Deutsche Bahn AG as a whole was recorded under “land transport”. In 1999 the enterprise was divided in a number of companies, which are partly recorded under “transport support” according to their main activity (see second column Table 1, Table 3 and Table 5).

To analyse changes in energy inputs we used consumption of primary energy (CPE), as sectoral energy use data provided by SEEA are not free of double counting. Between 1994 and 2004 energy intensity decreased in most sectors. In primary sectors and “secondary sectors with decreasing economic importance”, decreases in both components normally offset the energy-input-augmenting effect of overall economic growth. The figures for tobacco products and textiles might assume that the remaining production could only be maintained with increasing energy input. Similarly, despite the crisis of the construction sector, which induced strong reductions in the sector’s primary energy consumption as well as in manufacture of other non-metallic mineral products, both sectors’ energy intensity increased.

In secondary sectors with increasing economic performance basically improvements in energy productivity are observed, but normally these could not offset the input-augmenting effects of the sector’s and the overall economic development, whereas in manufacture of coke, refined petroleum products and nuclear fuel energy input remained nearly unchanged. This sector comprises two sub-sectors namely manufacture of coke and manufacture of refined petroleum products. Strong decreases in energy inputs of manufacture of coke (-63,812 TJ, -107 %) between 1994 and 2004 were nearly out weighted by increases in energy inputs of manufacture of petroleum products (+63,771 TJ, +20 %). The latter might be induced by increased traffic volume and good economic performance of chemical and pharmaceutical industry. The observed decline in energy intensity was basically caused by growing global demand for petroleum products inducing a raise in GVA (+ 295 %), which in turn had a favourable impact on the sector’s energy intensity component regardless whether or not real improvements in energy productivity are achieved.

Water transport shows similar figures, but in contrast strong reductions of energy input in physical terms could be observed (-58,862 TJ) (see Table 2). Besides autonomous technical improvements, higher energy prices might have induced this development, resulting, for example, in larger ships.

Table 1: Decomposition of consumption of primary energy, 1994-2004

production sectors	energy intensity component	sectoral performance	economic development	CPE
	percentage changes			
Agriculture, Hunting	-19,7	-11,0	15,9	-14,8
Forestry	-25,5	-31,8	13,3	-44,0
Fishing	-60,5	12,5	14,7	-33,2
Mining of coal & lignite				
Extraction of crude petroleum & gas	-35,5	8,7	16,4	-10,5
Mining of metal ores*				
Other mining & quarrying	-7,6	-45,5	13,9	-39,2
M. o. food products & beverages	-12,6	-8,7	16,7	-4,6
M. o. tobacco products	21,1	-46,4	16,7	-8,6
M. o. textiles	26,4	-53,6	16,7	-10,6
M. o. wearing apparel	16,8	-61,4	15,1	-29,5
Tanning & dressing of leather	-17,0	-35,6	13,8	-38,8
M. o. wood & products of wood & cork	-4,9	-30,7	15,5	-20,2
M. o. paper & paper products	2,3	-8,9	18,0	11,4
Publishing, printing & reproduction of recorded media	-6,7	-16,3	16,5	-6,4
M. o. coke, refined petroleum products & nuclear fuel	-179,3	156,8	22,5	0,0
M. o. chemicals & chemical products	-14,5	2,1	17,5	5,1
M. o. rubber & plastic products	-16,4	-0,2	17,1	0,6
M. o. other non-metallic mineral products	6,6	-43,6	15,5	-21,6
M. o. basic metalls	-9,4	-6,1	17,2	1,8
M. o. fabricated metal products	-17,1	-4,4	16,7	-4,8
M. o. machinery & equip.	-36,3	7,1	16,1	-13,1
M. o. office, accounting & computing machinery	-26,9	-25,7	13,8	-38,8
M. o. electrical, machinery & apparatus	-39,4	-17,2	13,5	-43,1
M. o. radio, television & communication equip.	-50,9	-2,2	14,0	-39,0
M. o. medical, precision & optical instruments	-55,0	12,8	15,2	-27,0
M. o. motor vehicles, (semi-) trailers	-41,3	40,4	18,9	18,0
M. o. other transport equip.	-8,7	25,7	20,0	37,0
M. o. furniture; manufacturing	-11,4	-23,8	15,5	-19,8
Recycling	-88,7	61,8	17,8	-9,1
Electricity, gas, steam & hot water supply	1,2	-16,5	17,2	1,9
Collection, purification & distribution of water	-30,3	14,4	17,3	1,3
Construction	5,3	-46,9	15,1	-26,5
Sale, maintenance & repair of motor vehicles	-10,5	26,2	19,9	35,6
Wholesale trade & commission trade	-15,9	-10,7	16,2	-10,3
Retail trade	-25,6	2,9	16,6	-6,1
Hotels & restaurants	-22,4	13,5	17,9	9,0
L& transport; transport via pipelines	-2,1	-17,6	16,8	-2,9
Water transport	-113,7	43,7	14,3	-55,7
Air transport	40,9	-19,2	20,6	42,3
Tranport support	-46,4	53,1	19,7	26,4
Post & telecommunications	6,8	-20,5	17,4	3,8
Financial intermediation, insurance & pension funding	-19,4	-3,8	16,5	-6,6
Real estate, renting & business activities	-6,0	16,5	19,4	29,9
Public administration & defence; compulsory social securit	-28,1	-11,0	15,1	-24,0
Education	-7,9	3,8	18,2	14,1
Health & social work	-7,2	18,0	19,5	30,2
Other community, social & personal service activities	8,3	5,6	19,7	33,6

Source: Federal Statistical Office (2006c), tables 2.3, 5.3.4.1

**: 2004 figures are not available.*

Complete denominations of production sectors are shown in Annex A.

Although energy intensity is very low in most tertiary sectors, except for the transport sectors, tertiary sectors accounted for one third of overall energy inputs in 2004, due to their large production volumes (see Table 2). As stated above most tertiary sectors experienced an increase in economic importance, which was accompanied by both improvements in energy productivity and increases in overall energy inputs. In two thirds of these sectors (tertiary with increasing economic importance) improvements in energy productivity could not offset input-augmenting effects of overall and sectoral economic development.

Except for transport sectors energy productivity improvements of tertiary sectors were relatively low compared to capital goods industries. While the latter face strong international competition, service sectors which usually experience little international competition might lack these cost-induced incentives to improve energy productivity.

Even though, the figures do not show it, air transport experienced a similar development as most tertiary sectors and improved its energy productivity: Although air transport's GVA (in constant prices) was of similar size in 1994 and 2004, between 1994 and 2000 it increased significantly by 33 %. This gain in economic importance was accompanied by small improvements in energy productivity. Despite further increasing air traffic and thereby increasing energy input (2004: + 116,633 TJ compared to 1994), substandard price development due to increased competition induced a fall in air transport's GVA, which basically caused the overall increase of energy intensity as well as the loss in economic importance between 1994 and 2004.

Further strong increases in energy input could be observed in health and social work, other community, social and personal service activities, manufacture of chemicals and chemical products and real estate, renting and business activities (see Table 2). These increases in primary energy consumption were normally owed to an augmentation of the sector's macroeconomic importance as energy intensity in most of these sectors decreased.

Overall CPE decreased slightly. This might basically stem from the observed overall tendency to reduce energy intensity and the diminishing energy inputs of manufacturing industries in line with their losses in overall economic importance, but as shown in Table 2, the overall evolution of CPE is in large part driven by specific trends of a few sectors.

As additional strong improvements in energy intensity of water transport seem doubtful and as reduction potentials in mining of coal and lignite; extraction of peat is limited as well, only small future contributions to reduction could be expected from these sectors. Furthermore, about one third of the observed energy input reduction was based on construction and manufacture of other non-metallic mineral products owing to the crisis in construction. The speeding up of the construction sector however might reverse the overall trend easily.

At first glance it seems promising to concentrate on policy measures in sectors which dominate the overall consumption. However, due the large share of energy cost in overall cost, these sectors use energy relative efficiently. Thus, further reductions of energy consumption in these sectors are normally connected with relatively higher mitigation cost. The development of new technologies and materials is regularly required to obtain further improvements in energy efficiency. In general, R&D activities in these sectors are costly. Furthermore many of the energy intensive sectors dominating the overall energy consumption of industries, are closely connected with the remaining sectors, thus cost increases in these energy intensive sectors might have stronger effects on competitiveness than other measurements with negative mitigation costs or relatively short amortisation periods.

Table 2: CPE by sector, 2004

production sectors	CPE 2004	share in CPE 2004	change 1994 to 2004
	TJ	percentage changes	TJ
Agriculture, Hunting	129.059	1,26	-22.466
Forestry	2.134	0,02	-1.676
Fishing	933	0,01	-465
Mining of coal & lignite	42.863	0,42	-57.348
Extraction of crude petroleum & gas	19.789	0,19	-2.324
Mining of metal ores	126	0,00	-335
Other mining & quarrying	20.236	0,20	-13.028
M. o. food products & beverages	238.002	2,32	-11.397
M. o. tobacco products	3.941	0,04	-370
M. o. textiles	42.048	0,41	-4.975
M. o. wearing apparel	5.135	0,05	-2.147
Tanning & dressing of leather	2.588	0,03	-1.639
M. o. wood & products of wood & cork	36.265	0,35	-9.155
M. o. paper & paper products	186.027	1,81	19.085
Publishing, printing & reproduction of recorded media	54.626	0,53	-3.751
M. o. coke, refined petroleum products & nuclear fuel	393.019	3,83	-10
M. o. chemicals & chemical products	1.415.179	13,81	68.941
M. o. rubber & plastic products	88.333	0,86	489
M. o. other non-metallic mineral products	282.831	2,76	-77.694
M. o. basic metalls	723.463	7,06	12.610
M. o. fabricated metal products	108.346	1,06	-5.406
M. o. machinery & equip.	95.914	0,94	-14.451
M. o. office, accounting & computing machinery	6.070	0,06	-3.856
M. o. electrical, machinery & apparatus	39.355	0,38	-29.816
M. o. radio, television & communication equip.	17.462	0,17	-11.185
M. o. medical, precision & optical instruments	20.366	0,20	-7.534
M. o. motor vehicles, (semi-) trailers	124.102	1,21	18.956
M. o. other transport equip.	21.312	0,21	5.758
M. o. furniture; manufacturing	27.304	0,27	-6.729
Recycling	7.490	0,07	-752
Electricity, gas, steam & hot water supply	3.447.034	33,63	63.902
Collection, purification & distribution of water	14.979	0,15	194
Construction	234.446	2,29	-84.489
Sale, maintenance & repair of motor vehicles	64.280	0,63	16.879
Wholesale trade & commission trade	113.060	1,10	-13.006
Retail trade	213.628	2,08	-13.862
Hotels & restaurants	93.235	0,91	7.690
L& transport; transport via pipelines	250.102	2,44	-7.392
Water transport	46.842	0,46	-58.862
Air transport	392.614	3,83	116.633
Tranport support	134.691	1,31	28.116
Post & telecommunications	40.589	0,40	1.476
Financial intermediation, insurance & pension funding	67.225	0,66	-4.752
Real estate, renting & business activities	254.761	2,49	58.679
Public administration & defence; compulsory social securi	201.156	1,96	-63.509
Education	148.660	1,45	18.355
Health & social work	172.310	1,68	40.016
Other community, social & personal service activities	206.476	2,01	51.975
overall	**10.250.404**	**100,00**	**-4.627**

Source: Federal Statistical Office (2006c), table 5.3.4.1

Table 3: Decomposition of GHG emissions, 1994-2004

production sectors	emission intensity component	sectoral performance	economic development	overal THG
	percentage changes			
Agriculture, Hunting	-10,4	-11,5	16,6	-5,3
Forestry	-18,3	-33,4	13,9	-37,7
Fishing	-40,3	14,0	16,5	-9,9
Mining of coal & lignite*				
Extraction of crude petroleum & gas	-12,5	9,7	18,3	15,6
Mining of metal ores*				
Other mining & quarrying	4,9	-49,1	14,9	-29,4
M. o. food products & beverages	-13,3	-8,7	16,6	-5,3
M. o. tobacco products	0,1	-41,3	15,0	-26,2
M. o. textiles	2,5	-47,0	14,8	-29,6
M. o. wearing apparel	-6,9	-53,0	13,3	-46,6
Tanning & dressing of leather	-43,0	-29,7	11,8	-60,9
M. o. wood & products of wood & cork	-27,0	-26,8	13,7	-40,2
M. o. paper & paper products	2,5	-8,9	18,0	11,6
Publishing, printing & reproduction of recorded media	-14,6	-15,6	15,9	-14,3
M. o. coke, refined petroleum products & nuclear fuel	-183,2	154,7	22,1	-6,4
M. o. chemicals & chemical products	-46,2	1,8	14,8	-29,7
M. o. rubber & plastic products	-39,9	-0,2	15,1	-25,0
M. o. other non-metallic mineral products	3,6	-42,9	15,2	-24,1
M. o. basic metalls	-9,1	-6,1	17,2	2,1
M. o. fabricated metal products	-22,6	-4,2	16,2	-10,6
M. o. machinery & equip.	-49,5	6,6	15,0	-27,9
M. o. office, accounting & computing machinery	-45,0	-22,7	12,3	-55,4
M. o. electrical, machinery & apparatus	-64,7	-14,3	11,4	-67,6
M. o. radio, television & communication equip.	-78,8	-1,8	11,6	-69,0
M. o. medical, precision & optical instruments	-75,2	11,4	13,4	-50,4
M. o. motor vehicles, (semi-) trailers	-64,7	36,1	16,8	-11,8
M. o. other transport equip.	-18,5	24,6	19,2	25,2
M. o. furniture; manufacturing	-31,0	-21,2	13,9	-38,3
Recycling	-90,3	61,4	17,7	-11,3
Electricity, gas, steam & hot water supply	0,7	-16,5	17,2	1,4
Collection, purification & distribution of water	-56,0	12,5	15,1	-28,4
Construction	22,1	-51,5	16,4	-13,0
Sale, maintenance & repair of motor vehicles	-14,8	25,7	19,6	30,4
Wholesale trade & commission trade	-20,3	-10,4	15,9	-14,9
Retail trade	-20,9	3,0	17,0	-0,9
Hotels & restaurants	-33,4	12,8	16,9	-3,6
L& transport; transport via pipelines	-23,1	-15,7	15,1	-23,7
Water transport	-115,2	43,3	14,2	-57,7
Air transport	31,3	-18,4	19,8	32,7
Tranport support	-47,8	52,7	19,6	24,5
Post & telecommunications	1,7	-20,0	17,0	-1,2
Financial intermediation, insurance & pension funding	-24,2	-3,7	16,1	-11,7
Real estate, renting & business activities	-2,9	16,7	19,7	33,5
Public administration & defence; compulsory social security	-40,4	-10,2	14,1	-36,6
Education	4,5	4,0	19,2	27,7
Health & social work	-14,1	17,4	18,9	22,2
Other community, social & personal service activities	-57,2	4,0	14,1	-39,1

Source: Federal Statistical Office (2006c), tables 2.3, 6.1.2

° Figures are not corrected for temperature effects, as real GHG emissions are the objective of this decomposition.

**: 2004 figures are not available.*

Trends in emission intensity equalled those in energy intensity as the bulk of German GHG emissions are CO_2 emissions stemming from fuel combustion (see Figure 10). Emission intensity increased basically in the same sectors as energy intensity did. The strong reductions in overall emissions and emission intensity in other community, social and personal service activities, a sector with one of the strongest increases in energy input and energy intensity, arose from strong reductions in CH_4 emissions of sewage and refuse disposal, sanitation and similar activities (-22 Mt CO_2e).

In contrast to energy input which might suggest a loose connexion between increasing economic performance and increases in energy input, no clear relationship could be observed in terms of GHG emissions. Rather strong decreases in emission intensity could be observed in most sectors which regularly offset the input-augmenting effects of sectoral and overall economic growth. This might be due to the overlapping of two effects – increasing energy prices and the threat of increased focus on GHG emissions since the ratification of the Kyoto-protocol (see Table 3).

Except for electricity, gas, steam and hot water supply and air transport all big polluters (with a share above 2 % in overall GHG emissions in 1994) decreased their GHG emissions between 1994 and 2004. Emission increases in electricity, gas, steam and hot water supply basically stemmed from fuel switches in electricity generation. Energy input in electricity generation decreased by 10.9 % (-426 TJ) between 1994 and 2004 (see Table 2), but due to increased use of lignite emissions rose by 4.1 Mt CO_2e. The strong reduction in manufacture of non-metallic mineral products was primarily based on the loss in economic importance owing to the crisis of the construction sector.

Although only 12 % of agriculture, hunting and related activities' GHG emissions were CO_2 emissions in 2004, the reductions of the second largest polluter basically arose from reductions in CO_2 emissions, while N_2O emissions increased by 1,560 Mt CO_2e to 40,904 Mt CO_2e in 2004. The reduction in mining of coal and lignite; extraction of peat depended on the same trends as describe above for energy input.

Similarly to energy input, GHG emission reductions on the macroeconomic level are basically based on evolutions in a few sectors, in this case these were the big polluters such as agriculture, hunting, and related activities, manufacture of other non-metallic mineral products, manufacture of chemicals and chemical products and other community social and personal service activities, which account for more than 60 % of the observed reductions (see Table 4). Except for manufacture of non-metallic minerals these reductions might be a bit more permanent than the observed reductions in energy input.

Table 4: GHG emissions by sector, 2004

production sectors	overall THG 2004	share in THG 2004	change 1994 to 2004
	1000 t CO_2e	percentage changes	1000 t CO_2e
Agriculture, Hunting	72.953	9,26	-4.099
Forestry	13	0,00	-8
Fishing	219	0,03	-24
Mining of coal & lignite			
Extraction of crude petroleum & gas	2.066	0,26	278
Mining of metal ores	3	0,00	-19
Other mining & quarrying	9.849	1,25	-4.092
M. o. food products & beverages	11.857	1,51	-665
M. o. tobacco products	194	0,02	-69
M. o. textiles	1.379	0,18	-581
M. o. wearing apparel	128	0,02	-112
Tanning & dressing of leather	56	0,01	-87
M. o. wood & products of wood & cork	1.280	0,16	-860
M. o. paper & paper products	9.226	1,17	962
Publishing, printing & reproduction of recorded media	2.334	0,30	-389
M. o. coke, refined petroleum products & nuclear fuel	17.047	2,16	-1.159
M. o. chemicals & chemical products	43.956	5,58	-18.527
M. o. rubber & plastic products	1.975	0,25	-657
M. o. other non-metallic mineral products	46.525	5,91	-14.757
M. o. basic metalls	10.920	1,39	223
M. o. fabricated metal products	4.316	0,55	-514
M. o. machinery & equip.	3.591	0,46	-1.391
M. o. office, accounting & computing machinery	206	0,03	-256
M. o. electrical, machinery & apparatus	1.083	0,14	-2.262
M. o. radio, television & communication equip.	441	0,06	-981
M. o. medical, precision & optical instruments	673	0,09	-684
M. o. motor vehicles, (semi-) trailers	3.787	0,48	-505
M. o. other transport equip.	759	0,10	153
M. o. furniture; manufacturing	1.058	0,13	-656
Recycling	497	0,06	-63
Electricity, gas, steam & hot water supply	374.192	47,50	5.096
Collection, purification & distribution of water	68	0,01	-27
Construction	9.607	1,22	-1.433
Sale, maintenance & repair of motor vehicles	2.215	0,28	516
Wholesale trade & commission trade	6.574	0,83	-1.148
Retail trade	10.650	1,35	-95
Hotels & restaurants	2.895	0,37	-109
L& transport; transport via pipelines	12.670	1,61	-3.932
Water transport	994	0,13	-1.357
Air transport	22.387	2,84	5.516
Tranport support	13.758	1,75	2.710
Post & telecommunications	1.603	0,20	-20
Financial intermediation, insurance & pension funding	2.675	0,34	-354
Real estate, renting & business activities	16.064	2,04	4.029
Public administration & defence; compulsory social security	7.970	1,01	-4.597
Education	8.250	1,05	1.791
Health & social work	9.188	1,17	1.672
Other community, social & personal service activities	29.009	3,68	-18.598
overall	**787.825**	**100,00**	**-69.315**

Source: Federal Statistical Office (2006c), tables 2.3, 6.1.2

Table 5: Decomposition of abiotic material input, 1994-2004

production sectors	material intensity	sectoral performance	economic development	overall abiotic material input
	percentage changes			
Agriculture, Hunting	-37,0	-9,9	14,4	-32,5
Forestry	1,2	-37,5	15,5	-20,8
Fishing	-38,7	14,1	16,6	-8,0
Mining of coal & lignite*				
Extraction of crude petroleum & gas	-34,7	8,7	16,4	-9,5
Mining of metal ores*				
Other mining & quarrying	-1,9	-47,1	14,3	-34,7
M. o. food products & beverages	40,7	-11,1	21,1	50,7
M. o. tobacco products	70,6	-58,3	20,6	32,9
M. o. textiles	42,4	-58,1	17,9	2,2
M. o. wearing apparel	16,9	-61,4	15,1	-29,4
Tanning & dressing of leather	14,9	-42,9	16,4	-11,7
M. o. wood & products of wood & cork	-19,8	-28,1	14,3	-33,7
M. o. paper & paper products	127,1	-14,3	28,4	141,2
Publishing, printing & reproduction of recorded media	4,1	-17,2	17,4	4,3
M. o. coke, refined petroleum products & nuclear fuel	-178,1	157,5	22,6	1,9
M. o. chemicals & chemical products	-2,7	2,2	18,5	18,0
M. o. rubber & plastic products	7,7	-0,2	19,2	26,6
M. o. other non-metallic mineral products	-16,4	-38,0	13,7	-40,7
M. o. basic metalls	-0,4	-6,3	18,0	11,2
M. o. fabricated metal products	6,9	-4,9	18,7	20,7
M. o. machinery & equip.	3,9	8,6	19,6	32,1
M. o. office, accounting & computing machinery	3,2	-30,7	16,2	-11,3
M. o. electrical, machinery & apparatus	15,7	-23,5	18,0	10,2
M. o. radio, television & communication equip.	6,7	-2,9	18,9	22,6
M. o. medical, precision & optical instruments	-15,6	15,8	18,6	18,8
M. o. motor vehicles, (semi-) trailers	18,5	51,4	24,3	94,2
M. o. other transport equip.	-19,6	24,5	19,1	23,9
M. o. furniture; manufacturing	-13,2	-23,6	15,3	-21,5
Recycling	-76,6	65,3	18,9	7,6
Electricity, gas, steam & hot water supply	-3,6	-16,1	16,8	-2,9
Collection, purification & distribution of water	26,8	18,5	22,3	67,6
Construction	29,6	-53,5	17,0	-6,9
Sale, maintenance & repair of motor vehicles	-8,1	26,5	20,1	38,5
Wholesale trade & commission trade	17,2	-12,6	19,0	23,6
Retail trade	8,9	3,4	19,6	31,9
Hotels & restaurants	-26,8	13,2	17,5	3,9
L& transport; transport via pipelines	-31,8	-14,9	14,4	-32,3
Water transport	-64,0	56,3	18,9	11,2
Air transport	3,0	-16,1	17,4	4,4
Tranport support	6,6	65,3	24,5	96,4
Post & telecommunications	44,6	-24,3	20,5	40,8
Financial intermediation, insurance & pension funding	7,1	-4,3	18,8	21,6
Real estate, renting & business activities	42,3	20,0	23,6	85,9
Public administration & defence; compulsory social security	-28,8	-11,0	15,0	-24,8
Education	7,1	4,0	19,5	30,6
Health & social work	3,3	18,8	20,4	42,5
Other community, social & personal service activities	-36,3	4,5	15,9	-15,8

Source: Federal Statistical Office (2006c), tables 2.3, 4.4
**: 2004 figures are not available.*

Material input rose in nearly all sectors with increased economic importance, but without further in-depth analysis, no specific pattern could be identified, as in almost half of these sectors material intensity increased as well. Furthermore material intensity increased in two thirds of sectors with diminishing economic performance, which lead to material input augmentation in half of these sectors (see Table 5). However, in most of the considered sectors volume changes in material input were relatively small (see Table 6).

Almost 75 % of material input was used by manufacture of coke, refined petroleum and nuclear fuels, manufacture of non-metallic minerals, electricity, gas, steam and hot water supply and construction in 2004 (see Table 6). Likewise the change of material inputs at the macro levels was determined by specific sectoral evolution. Associated to the crisis of the construction sector, decreased demand for manufactured other non-metallic mineral products accounted for 90 % of the observed reduction in material input.

Table 6: Abiotic material input by sector, 2004

production sectors	overall abiotic material input 2004	share in overall abiotic material input 2004	change 1994 to 2004
	1000 tons	percentage changes	1000 tons
Agriculture, Hunting	7.701	0,64	-3.707
Forestry	1.699	0,14	-447
Fishing	178	0,01	-16
Mining of coal & lignite	12.861	1,07	-17.617
Extraction of crude petroleum & gas	470	0,04	-49
Mining of metal ores	0	0,00	-17
Other mining & quarrying	2.452	0,20	-1.303
M. o. food products & beverages	22.192	1,84	7.464
M. o. tobacco products	96	0,01	24
M. o. textiles	2.058	0,17	44
M. o. wearing apparel	198	0,02	-82
Tanning & dressing of leather	192	0,02	-25
M. o. wood & products of wood & cork	621	0,05	-315
M. o. paper & paper products	7.225	0,60	4.230
Publishing, printing & reproduction of recorded media	988	0,08	41
M. o. coke, refined petroleum products & nuclear fuel	133.063	11,03	2.474
M. o. chemicals & chemical products	37.781	3,13	5.762
M. o. rubber & plastic products	8.517	0,71	1.791
M. o. other non-metallic mineral products	261.273	21,66	-179.119
M. o. basic metalls	81.908	6,79	8.261
M. o. fabricated metal products	12.433	1,03	2.131
M. o. machinery & equip.	9.520	0,79	2.311
M. o. office, accounting & computing machinery	197	0,02	-25
M. o. electrical, machinery & apparatus	3.481	0,29	323
M. o. radio, television & communication equip.	1.318	0,11	243
M. o. medical, precision & optical instruments	959	0,08	152
M. o. motor vehicles, (semi-) trailers	14.570	1,21	7.069
M. o. other transport equip.	1.441	0,12	278
M. o. furniture; manufacturing	1.140	0,09	-313
Recycling	108	0,01	8
Electricity, gas, steam & hot water supply	230.983	19,15	-6.985
Collection, purification & distribution of water	212	0,02	85
Construction	272.364	22,58	-20.256
Sale, maintenance & repair of motor vehicles	907	0,08	252
Wholesale trade & commission trade	1.088	0,09	208
Retail trade	2.243	0,19	542
Hotels & restaurants	2.536	0,21	96
L& transport; transport via pipelines	2.243	0,19	-1.071
Water transport	563	0,05	57
Air transport	8.000	0,66	335
Tranport support	762	0,06	374
Post & telecommunications	276	0,02	80
Financial intermediation, insurance & pension funding	615	0,05	109
Real estate, renting & business activities	134	0,01	62
Public administration & defence; compulsory social security	36.113	2,99	-11.897
Education	2.197	0,18	515
Health & social work	3.039	0,25	906
Other community, social & personal service activities	15.162	1,26	-2.855
overall	**1.206.079**	**100**	**-243.211**

Source: Federal Statistical Office (2006c), table 4.4

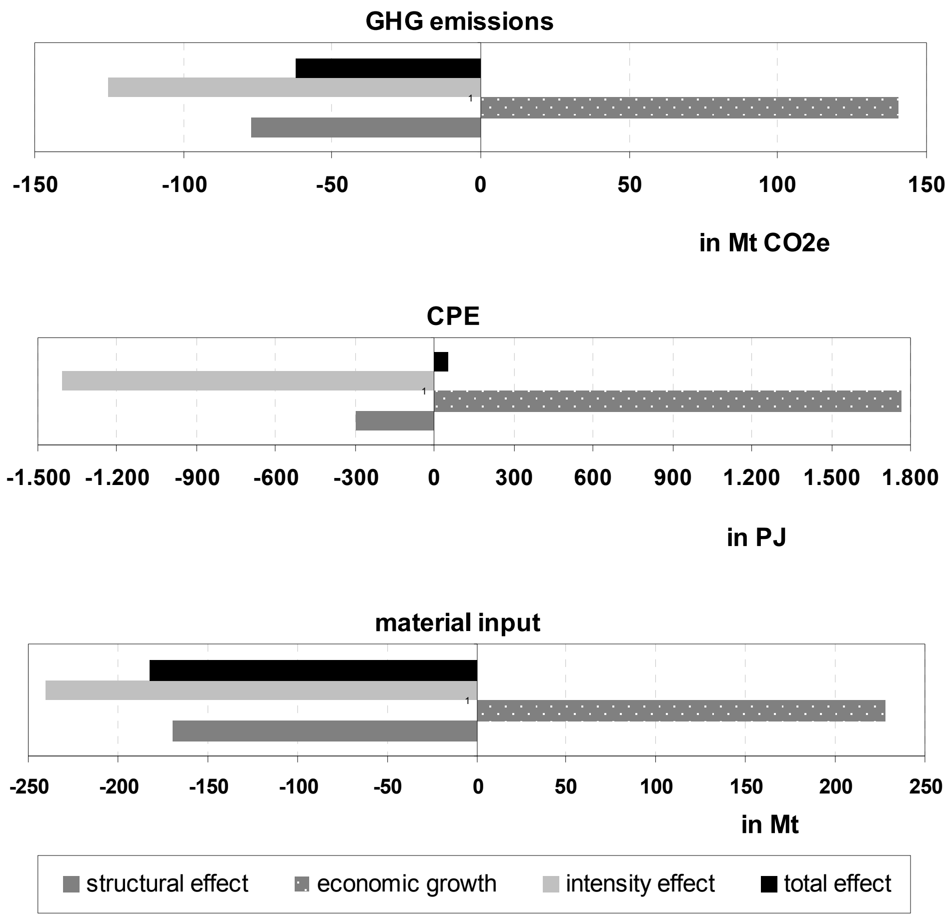
3.3 Decomposition of Aggregated Trends

Even though no specific patterns in the evolution of environmental inputs were detected by the preceding decomposition analyses, at least a tendency to reduce energy and emission intensity and tertiarisation was identified. This raises the question how the observed structural change affects macroeconomic figures.

In the following we therefore decompose the changes of the environmental input categories at the macroeconomic level. For this purpose we use the formula introduced in chapter 3.1. Instead of looking separately at sectoral figures (chapter 3.2), we summed them up (Seibel 2003).

Again, the growth in overall GVA had an augmenting effect on the usage of the three considered categories, whilst structural changes and productivity improvements had a reducing impact.

Figure 15: Decomposition on a macroeconomic level



Source: Federal Statistical Office (2006c), tables 2.3, 4.4, 5.3.1.1, 6.1.2

Figures do not include mining of coal, lignite and metal ores.

Although the basic overall structures resemble each other, the structural effect in CPE turns out to be less important. This might rely on increasing energy prices and taxes respectively expected rises in energy price – due to exhaustibility of fossil fuels, increasing energy demand of emerging markets and unstable situations in some of the mayor oil and gas production countries – which induces not only an energy efficient development of tertiary sectors right from the beginning but also improvements of energy productivity in all other sectors. However, to prove this statement information on sectoral developments of energy price and information about the underlying forces of these price changes are necessary.

For material input and GHG-emissions such incentives are less clear. Therefore improvements of environmental productivity seem to be less demanding and thus, structural effect gains weight. To what extent these structural changes rely on relocation is investigated in Wiebe (forthcoming). That study also tries to incorporate the impact of international competition on sectoral usage of the three considered environmental input categories. However, it is noteworthy, that the observed aggregated effects are primarily determined by trends in a few underlying sectors, as the analyses in chapter 3.2 showed.

4 Conclusion

The considerations of chapter 2 yield a reduction of environmental input in all three categories. As the subsequent decomposition of these changes into a structural, intensity and macroeconomic growth effect showed, the observed trends were not based on any specific identifiable patterns. Even though tendencies towards higher energy and emission productivity were located at a sectoral level, the strong diverging evolution of sectors impeded the derivation of any patterns. Furthermore the dominance of a few sectors, especially their contribution to the aggregate structural components, partly distorted aggregated numbers. The dominance of the specific trends in a few sectors impedes the interpretation of aggregate figures with respect to sustainability, as moderate changes in these sectors could reverse macroeconomic trends easily. For example the recently observed speeding up of the construction sector as well as the recovery of the German economy have the potential to overcompensate the achieved reduction in energy input (see Table 2).

Comparable studies for other countries, e. g. Sweden and Denmark, have not identified any specific patterns either, nevertheless they often concluded that overall trends are determined by the development of a few sectors. For example a decomposition of Swedish CO_2 emissions showed that trends in overall CO_2 emissions are dominated by the development of CO_2 emissions of transportation. The importance of transportation for trends in overall CO_2 emissions was also identified in other countries e. g in the UK (Wadeskog and Palm 2003), but cannot be observed in Germany. A decomposition analysis of Danish air emissions between 1980 and 2001 identified a domination of electricity, gas, steam and hot water supply. Similar to Germany changes in overall energy intensity and thereby overall emissions intensity had a favourable impact on Danish CO_2 emissions.

In order to still identify potential patterns, the inclusion of further parameters into the analyses is necessary. As the evolution of energy intensity and emission intensity showed, energy prices and environmental regulations might have some impact on sectoral energy input and emissions. Therefore energy prices and environmental regulations – as far as they are quantifiable in monetary terms (such as energy taxes) – ought to be considered, too. While in the absence of material-input related environmental regulations less than half of these sectors improved material productivity. Also trends in air transport, which is neither included in emission trading nor is its kerosene consumption taxed point at a productivity improving impact of increasing energy prices and taxes. Besides identifying any specific patterns the impact of these parameters could be assessed. In turn this might provide for future policy design not only in terms of material input but also to react and adapt to environmental pressure of overall economic recovery and especially of the resource intensive construction sector.

However the incorporation of energy prices is difficult, as the SEEA dataset only provides aggregated energy and material inputs per sector. Corresponding aggregated energy and material prices do not exist. The calculation of these prices would cause problems as well, as sectoral inputs by material are neither released to the public nor are associated sectoral input prices.

Considering sustainable development questions about impacts of structural changes, environmental regulations and changes in energy prices on competitiveness arise. Are there any, and if so what does this mean for the competitiveness of the total economy. Further research on this topic e.g. by analysing the relationship between trade shares and environmental inputs is necessary to answer these questions.

The preceding paper as well as most other studies in this field focus merely on a single country while leaving the impact on global resource input open. In order to sort this out, the inclusion of all, direct and indirect, resource requirements need to be explicitly included into the analysis. Up to now, indirect environmental usage abroad was either not considered in official datasets or research studies or recorded under the assumption that foreign production processes and structures are equal to domestic ones. Work package 5 of this project addresses exactly this problem.

5 Annex A

Figure 16: Denomination of production sectors

Agriculture, Hunting	Agriculture, Hunting and related activities
Forestry	Forestry, logging and related service activites
Fishing	Fishing, operation of fish hatcheries and fish farms;service activities incidental to fishing
Mining of coal & lignite	Mining of coal and lignite;extraction of peat*
Extraction of crude petroleum & gas	Extraction of crude petroleum and gas;service activities incidental to oil and gas extraction
Mining of metal ores	Mining of metal ores (including uranium and thorium ores)
Other mining & quarrying	Other mining and quarrying
M. o. food products & beverages	Manufacture of food products and beverages
M. o. tobacco products	Manufacture of tobacco products
M. o. textiles	Manufacture of textiles
M. o. wearing apparel	Manufacture of wearing apparel;dressing and dyeing of fur
Tanning & dressing of leather	Tanning and dressing of leather
M. o. wood;wood & cork products	Manufacture of wood and products of wood and cork (except furniture)
M. o. paper & paper products	Manufacture of paper and paper products
Publishing, printing & reproduction of recorded media	Publishing, printing and reproduction of recorded media
M. o. coke, refined petroleum products & nuclear fuel	Manufacture of coke, refined petroleum products and nuclear fuel
M. o. chemicals & chemical products	Manufacture of chemicals and chemical products
M. o. rubber & plastic products	Manufacture of rubber and plastic products
M. o. other non-metallic mineral products	Manufacture of other non-metallic mineral products
M. o. basic metalls	Manufacture of basic metalls
M. o. fabricated metal products	Manufacture of fabricated metal products, except machinery and equipment
M. o. machinery & equipment	Manufacture of machinery and equipment n.e.c.
M. o. office, accounting & computing machinery	Manufacture of office, accounting and computing machinery
M. o. electrical, machinery & apparatus.	Manufacture of electrical, machinery and apparatus n.e.c.
M. o. radio, television & communication equip.	Manufacture of radio, television and communication equipment and apparatus
M. o. medical, precision, optical instruments	Manufacture of medical, precision and optical instruments, watches and clocks
M. o. motor vehicles, (semi-) trailers	Manufacture of motor vehicles, trailers and semi-trailers
M. o. other transport equip.	Manufacture of other transport equipment
M. o. furniture; manufacturing	Manufacture of furniture; manufacturing n.e.c.
Recycling	Recycling
Electricity, gas, steam & hot water supply	Electricity, gas, steam and hot water supply
Collection, purification & distribution of water	Collection, purification and distribution of water
Construction	Construction
Sale, repair of motor vehicles	Sale, maintenance and repair of motor vehicles and motorcycles;retail sale of automotive fuel
Wholesale trade & commission trade	Wholesale trade and commission trade, except of motor vehicles and motorcycles
Retail trade	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods
Hotels & restaurants	Hotels and restaurants
Land transport; transport via pipelines	Land transport; transport via pipelines
Water transport	Water transport
Air transport	Air transport
Tranport support	Tranport support
Post & telecommunications	Post and telecommunications
Financial intermediation, insurance & pension funding	Financial intermediation, insurance and pension funding; activities auxilary to financial intermediation
Real estate, renting & business activities	Real estate, renting and business activities
Public administration & defence; compulsory social security	Public administration and defence; compulsory social security
Education	Education
Health & social work	Health and social work
Other community, social & personal service activities	Other community, social and personal service activities

REFERENCES

AGEB (1995): Preface to the Energy Balances for the Federal Republic of Germany, http://www.ag-energiebilanzen.de/daten/vorengl.pdf.

Ang, B.W., Zhang F.Q., Choi K.H. (1998): Factorizing changes in energy and environmental indicators through decomposition, in: Energy, Volume 23 Issue 6, pp.489–495.

Ang, B. W., Zhang, F. Q. (2000): A survey of index decomposition analysis in energy and environmental studies, in: Energy, Volume 25 Issue 12, pp. 1149-1176.

Agnolucci, P, Venn, A. (2007*):* Industrial Energy Intensities in the UK: Is there a deterministic or stochastic difference among sectors, London.

Agnolucci, P. (2007): The Energy Demand in the British and German Industrial Sectors: Heterogeneity and Common Factors, London.

Dieckmann, J. et al. (1999): Energie-Effizienz-Indikatoren – Statistische Grundlagen, theoretische Fundierung und Orientierungsbasis für die politische Praxis, Heidelberg.

Gerlinger, K. (2004): Muster globaler anthropogener CO_2-Emissionen: Sozio-ökonomische Determinanten und ihre Wirkung, Potsdam.

Giljum S. et al. (2007): Quantifying indirect material flows of traded products with a multi-regional environmental input-output model – A methodological concept paper, Vienna, Osnabrück.

German Federal Statistical Office (2006a): Use of the Environment and the Economy – Explanation of the tables on Environmental-Economic Accounting 2006, Wiesbaden.

German Federal Statistical Office (2006b): Umweltnutzung und Wirtschaft – Bericht zu den umweltökonomischen Gesamtrechnungen, Wiesbaden.

German Federal Statistical Office (2006c): Tables on Environmental-Economic Accounting 2006, http://www.destatis.de/allg/e/veroe/tables_eea2006.htm, Wiesbaden.

German Federal Statistical Office, UBA, BGR (2007): Environmental data for Germany; Practicing Sustainability – Protecting Natural Resources and the Environment, 2007 edition, Berlin-Brandenburg.

Hoffren, J. et al. (2000): Statistical Decomposition Modelling on the Basis of Material Flow Accounting. In: Journal of Industrial Ecology, Volume 4, 2000:4, New Haven.

Nanduri, M. (1996): an assessment of energy intensity indicators and their role as policy-making tools, Vancouver.

(Rørmose Jensen, P., Olsen, T. (2003): Analysis of Changes in Air Emissions in Denmark 1980-2001 – Time series • Bridge tables • Decomposition analysis, Copenhagen.

UN (2003): United Nations (2003): Handbook of National Accounting: Integrated Environmental and Economic Accounting, Series F, No.61, Rev.1, New York.

Schoer, K. Schweinert, S. (2005): Use of Primary Material in Germany by Branches and Material Categories, 1995-2002, Wiesbaden.

Seibel, S. (2003): Decomposition analysis of carbon dioxide-emission changes in Germany – Conceptual framework and empirical results, Luxemburg.

SERI (2007): http://www.materialflows.net, Wien.

Sheerin, C. (2002): UK Material Flow Accounts, in: Economic Trend, No. 583, June 2002, pages 53-61.

Wadeskog, A., Palm, V. (2003): Structural decomposition of environmental accounts data – the Swedish case, Stockholm.

Wiebe, K. (forthcoming): Resource productivity and economic performance, Osnabrück.