Energy efficiency in Germany: How to crunch the numbers to find meaningful indicators?

Verena Graichen, Sabine Gores, Gerhard Penninger, Wiebke Zimmer, Dr. Katja Schumacher & Vanessa Cook
Öko-Institut
Schicklerstr. 5-7
DE-10179 Berlin
v.graichen@oeko.de
s.gores@oeko.de
g.penninger@oeko.de
w.zimmer@oeko.de
k.schumacher@oeko.de
v.cook@oeko.de

Barbara Schlomann & Tobias Fleiter
Fraunhofer Institute for Systems and Innovation Research
Breslauer Straße 48
DE-76139 Karlsruhe
barbara.schlomann@isi.fraunhofer.de
tobias.fleiter@isi.fraunhofer.de

Dr. Hans Joachim Ziesing
Fasanenstraße 62
DE-10719 Berlin
HZiesing@t-online.de

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Abstract[1]
The EU Energy Services Directive 2006/32/EC (ESD) mandates Member States to develop National Energy Efficiency Action Plans (NEEAPs) that reveal insights and demonstrate measures on how Member States plan to achieve energy efficiency targets. Additional ambitious targets for energy efficiency improvement have been established by the European Union and by some Member States, including Germany. To evaluate whether energy efficiency really follows such ambitious paths, it is essential to closely monitor its development, not only on the macro level but also on a sectoral level. A detailed sectoral analysis helps to reveal the causes and effects of efficiency improvements, i.e. it also allows evaluating countervailing factors that may undermine the success of efficiency measures. Such a detailed sector analysis needs to be based on a system of pinpointing, up-to-date and well documented numbers and indicators.

The purpose of this paper is to present such a system of meaningful sectoral and macroeconomic numbers and indicators for the case of Germany. The paper will depict the current state of energy efficiency and past trends in Germany based on a consistent data base and aggregated informative indicators on key figures. The paper aims to inform on the quality of different sets of data, aggregation methods, indicators and will clearly show the discrepancies this may imply for estimation of future trends and projections.

The authors conclude that a harmonized set of indicators based on both macro and sectoral analysis by all European countries is highly desirable in order to monitor the progress made on EU level. Those indicators would need to be selected with view of existing statistical sources at national level as comprehensive and frequently updated statistics are a prerequisite to determine meaningful indicators. Therefore, mandating comparable studies in all EU countries would be an important step to generate a European set of energy efficiency indicators to be recommended by the European Commission to Member States. Regular and coherent reporting (requirements) on the national level would facilitate a stringent and consistent impact analysis of efficiency policies on the aggregated EU as well as national levels.

Introduction
The German Federal government's and the European Union's two main strategies for achieving their ambitious climate policy targets and being able to guarantee a sustainable energy system in the future, are a decisive expansion in the use of renewable energies and, above all, an increase of energy efficiency.

In the new Energy Concept of the German Federal Government from September 2010, a reduction of primary energy consumption by 20 % in 2020 and by 50 % in 2050 compared to 2008 is aimed at. This calls for an annual average gain in energy productivity of 2.1 %, based on final energy consumption. For electricity consumption, the respective saving targets are around 10 % by 2020 and 25 % by 2050. The goal set in the National Sustainable Development Strategy of the Federal

1.The paper is based on a study carried out by the authors for the German Federal Environment Agency (UBA) "Energieeffizienz in Zahlen (Energy efficiency in numbers)" within the research project FKZ 3708 41 121.

Government from April 2002 is even more ambitious. Here, a doubling of energy productivity was stipulated in 2020 compared to 1990, which requires a yearly increase by at least 3 % from today, taking into the development of the past years. The European Union is committed to saving 20 % of primary energy consumption by 2020 compared to a business-as-usual scenario.

Recent studies for Germany (Öko-Institut et al. 2009; Prognos/Öko-Institut 2009; Prognos et al. 2010) and for the European Union (Fraunhofer ISI et al. 2009; Ecofys/Fraunhofer ISI 2010) have shown that ambitious targets on energy savings and efficiency improvement can be reached, provided that continuous efforts are made to improve energy efficiency and to expand the use of renewable energies.

The emission reduction necessary to limit the global rise in temperature is inconceivable without a long-term increase in energy productivity. All sectors must be involved in working together towards this goal, whether these are final consumers from industry, trade, commerce and services, private households or transport, the transformation processes of coal mines and refineries up to power stations and cogeneration plants. It is indisputable that a sustainable energy system for Germany will require the highly-efficient use of energy at every stage: from energy generation right through to its consumption. Energy conservation and increasing energy efficiency must be at the heart of any climate protection efforts. Saved energy conserves the environment when both extracting and combusting fossil energy sources; lower energy demand can help to achieve the expansion targets set for renewable energies.

Not only the environment stands to profit from this, but consumers and industry as well, because increasing energy efficiency has other positive co-effects: these include falling energy costs for private households and lower production costs for industry; the creation of jobs, for example, in small businesses and incentives for innovations. On top of this, the dependency of domestic industries on price trends on the global markets for coal, oil and gas can be reduced as can the reliance on imports.

To examine whether the development of energy productivity and energy efficiency in Germany is in line with targets set by policy, a series of energy efficient indicators and parameters have been developed on the national and sectoral level, the required data can be regularly updated and documented. For example, with the relevant empirical analysis, it is possible to observe that the increase in energy productivity so far has already contributed significantly to reducing emissions. Without this increase, the CO_2 emissions in Germany would have been around 300 million t higher in 2008 than was actually the case. It is not sufficient to carry out this analysis on a national macro level; rather it is necessary to use an approach that differentiates between sectors as accurately as possible. Only in this way can the reasons for changes in efficiency and the factors which could have compensated the impact of measures be clearly shown.

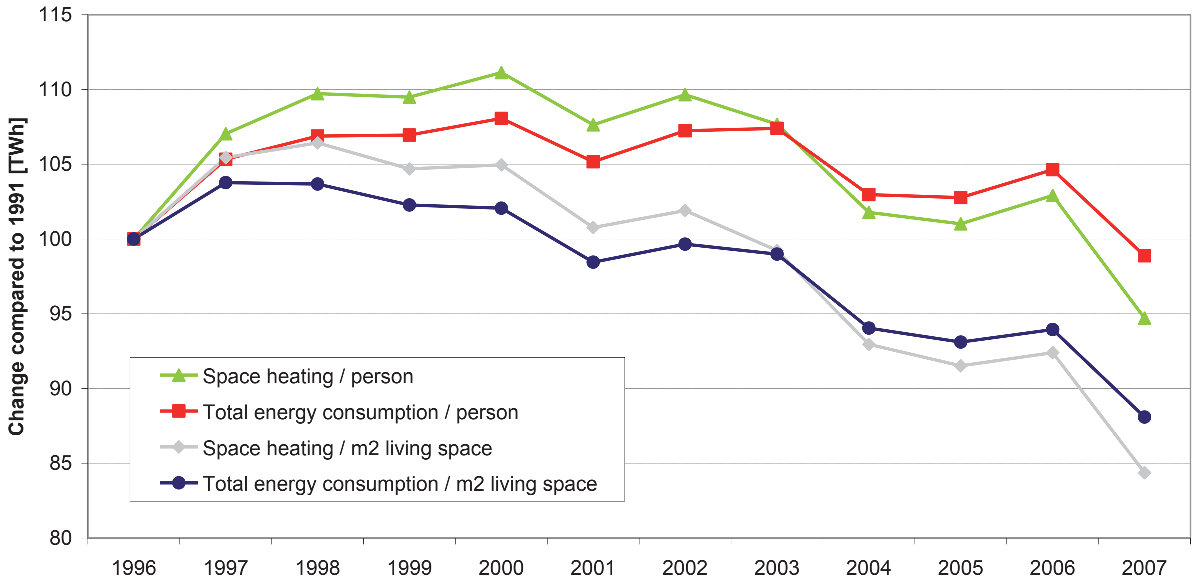
The energy balances published by Arbeitsgemeinschaft Energiebilanzen (AGEB) were chosen as the main data source as it collects statistical data from all areas of the energy sector to provide a comprehensive picture. The total primary energy consumption is given at macro level and final energy consumption additionally differentiated into four sectors: households, industry, tertiary sector and transport. Among sectors the data quality is best in the industrial sector. Statistical surveys find it not always easy to distinguish between households and tertiary sector e.g. in the case of buildings with mixed use (e.g. flats and offices). This leads to high uncertainties especially in the tertiary sector. Fuel consumption for CHP is attributed to the generation of heat and power according to the convention set in directive 2004/8/EU. The final energy consumptions in the sectors are further disaggregated into five categories in the end-use balances published by AGEB/BDEW. In general the uncertainties are higher in the end-use balances than in the energy balances. Additional data sources are included in the sectoral analyses below.

Households

Approx. 27 % of the total final energy consumption in Germany in 2008 is attributed to households. The amount of energy a household consumes depends mainly on the number of inhabitants, living space, the energy efficiency of the building, the type and efficiency of the heating systems, and the features and efficiency of the domestic appliances used. However there is not sufficient statistical data available to calculate the final energy consumption for a bottom-up approach to be undertaken: Firstly the analysis of necessary input factors (like room temperature, number, duration and intensity of appliances used) is strongly dependent on behavioural factors, which is very difficult to estimate. Secondly, data on final fuel and energy consumption can only be collected on an annual basis. A more detailed analysis on the share of each application would depend on underlying estimations, as energy carriers are frequently used for various purposes (e.g. fuel oil is used for both space heating and hot water generation).

Consequently a top-down approach was chosen for the calculation and presentation of final energy consumption. The end-use balances published each year by AGEB/BDEW (1996-2007) will be used as a key data source for establishing the final energy consumption in the residential sector. The end-use balances are sub-divided in five different categories of end use (space heating; hot water generation; cooking; electric appliances/pumps and lightening), energy source, and additionally contain corrected inventory data. Moreover, the data was adjusted to the current energy balance and the temperature in the share of space heating was corrected. By relating this data to residential population, residential units and living space, conclusions could be drawn on final energy consumption. Data of the German Federal Statistical Office (Statistisches Bundesamt) was used for population, households, living space, and residential units. Furthermore, the development of heat generation systems, sales of thermal insulation composite systems, and household appliances were taken into account, all of which showed increasing energy efficiency.

In 1996 the final energy consumption of households amounted to 738 TWh. Following an increase of 8.8 % by 2000, a decreasing trend can be observed: In 2007 final energy consumption amounted to 721 TWh, which is 2.3 % below 1996 levels. Space heating remained stable at approx. 75 % of total energy consumption in the period considered, thereby constituting by far the largest share of final energy consumption in the residential sector. The factors which substantially influence the major



Sources: AGEB/BDEW 1996-2007, AGEB 2009, Statistisches Bundesamt 2004+2008a+d+2009a+b+d+e, Calculations: Öko-Institut

Figure 1. Development of total energy use and for space heating in private households per person and per m² living space (adjusted for temperature).

increases in final energy consumption are the ones determining the levels of domestic space heating: the size and number of apartments as well as the energy efficiency of buildings and heating systems.

From 1991 to 2007 the total living space in residential and non-residential buildings increased by 23 %, the number of residential units by 17%, while population growth was only 4 %. Since 1998 a steadily decreasing final energy consumption per accommodation unit (AC) can be observed: from 23.0 MWh/AC in 1998 to 19.6 MWh/AC in 2007 (see Figure 1). Thanks to the improved energy efficiency of residential buildings, the final energy consumption attributed to space heating decreased as well: 200 kWh/m² was consumed in 1998, falling to 161 kWh/m² in 2007. Therefore, the decreasing final energy consumption can be explained by an increasingly efficient consumption of energy. In spite of the continued increasing trend in terms of living space and one-person households, the average final energy consumption of households has been falling since 1998 due to improved energy efficiency.

Although a time-series of data on the energy efficiency of buildings is not available, the savings potential in Germany can be regarded as very high: If the entire stock of residential buildings were subject to extensive rehabilitation, bringing them into line with the standard of new buildings under the current German Energy Saving Ordinance (EnEV) of 2009 (i.e. giving them an average specific final energy demand of 60 kWh/m²), the final energy consumption attributable to space heating would fall by 60 %. For new buildings the amount of energy consumed for space heating purposes could be further reduced by approximating passive-house standards by means of the EnEV.

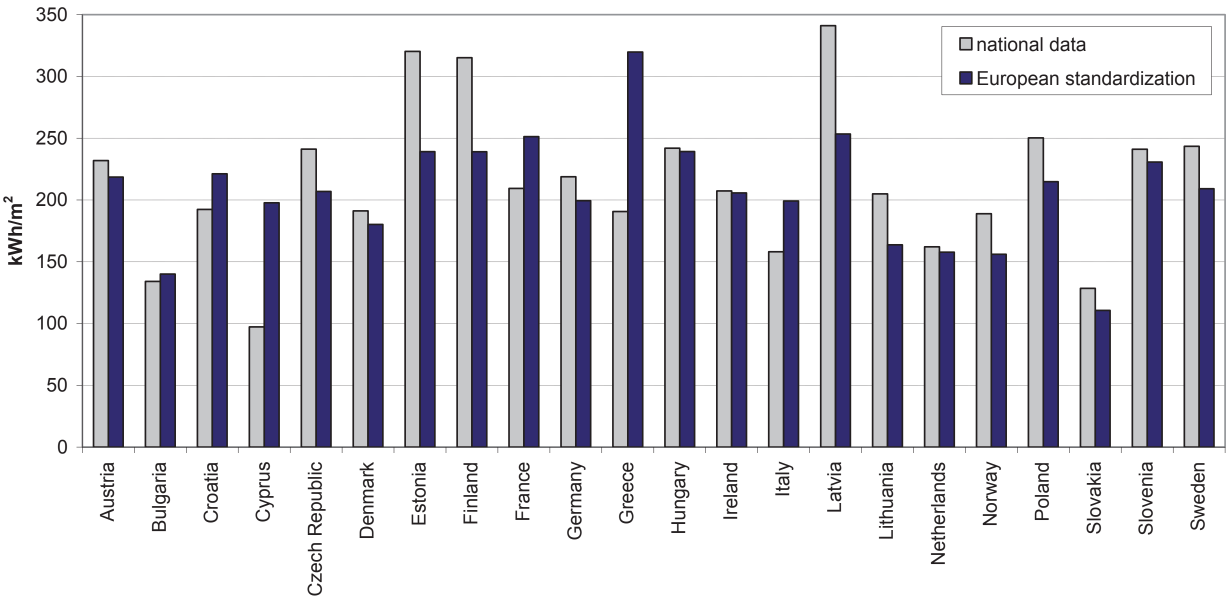
Furthermore, boiler technology has made substantial progress in recent years with the result that the energy efficiency of new boilers has improved by up to 35 %. The rehabilitation potential is very high, as the average age of oil- and gas-fired boilers is 24 years in Germany. The share of renewable energies used overall for space heating purposes has substantially increased, amounting to 11 % in 2007, which represents a decrease in CO_2 emissions of approx. 18 %.

About 11 % of the final energy consumption of households is attributed to hot water generation, with an almost parallel development in space heating. The final energy consumption attributable to cooking and electrical appliances/pumps is covered mainly by electricity and – to a lesser extent – by natural gas; it has increased by approx. 27 % and 24 % respectively in the period considered. As an individual living in a two-person household consumes only 74 % of the specific energy of a one-person household, the significant increase of one-person households can be regarded as the main reason for the increased electricity demand. A steadily increasing stock of electrical appliances can also explain this rise. On average the energy efficiency of such appliances has increased, which is chiefly due to the introduction of efficiency categories for most white products. Only televisions show a continued increase in energy consumption since 2005. At the same time the final energy consumption attributable to lighting has decreased despite the continuous increase of living space per residential unit.

HOUSEHOLD ENERGY CONSUMPTION IN EUROPE

The energy consumption in households varies considerably throughout Europe. While, in Cyprus, only 97 kWh per square metre were consumed in 2007, Latvian households consumed three and a half times this amount with 341 kWh/m². Latvia's Baltic neighbours' Finland and Estonia show similarly high consumption rates.

However, this is not only due to differences in energy efficiency; household energy consumption depends essentially on the energy consumed for heating and thus on the prevalent



Source: Odyssee 2009

Figure 2. Household energy consumption across Europe with national data and European standardization of temperature.

temperatures in a country. For example, houses in countries with harsh winters are usually better insulated than those in warmer regions, but they still require more energy for heating.

Any reasonable comparison among countries with different climates has to take this fact into account. The perspective changes if the figures are standardized based on European average temperatures. Latvia then still consumes more energy based on the size of the household in terms of area, but the difference is now only 30 %.

The consumption figures in Slovakia and Bulgaria are particularly low both as original values and after scaling. If the temperature differences in Europe are taken into account, Greece has the highest household energy consumption. Even after standardization, Germany is still ranked as average with around 200 kWh/m² final energy consumption. There were no data available for seven countries (Belgium, Luxembourg, Malta, Portugal, Rumania, Spain and the United Kingdom).

Industry

Of all sectors in Germany, industry shows the highest annual data coverage. This holds for data provided on the energy consumption of the total industry and for single industrial sectors as well as for other relevant factors like gross value added, production index and the physical production of various energy-intensive products like paper or steel. This data is annually collected and provided by the German Federal Statistical Office within the scope of their energy consumption and production statistics. However, for the analysis of energy consumption it is proposed that the national energy balance data - which is derived from the energy consumption statistics of the Statistical Office, and differentiates between 14 industry sectors - be used first of all to enhance sector-to-sector comparability.

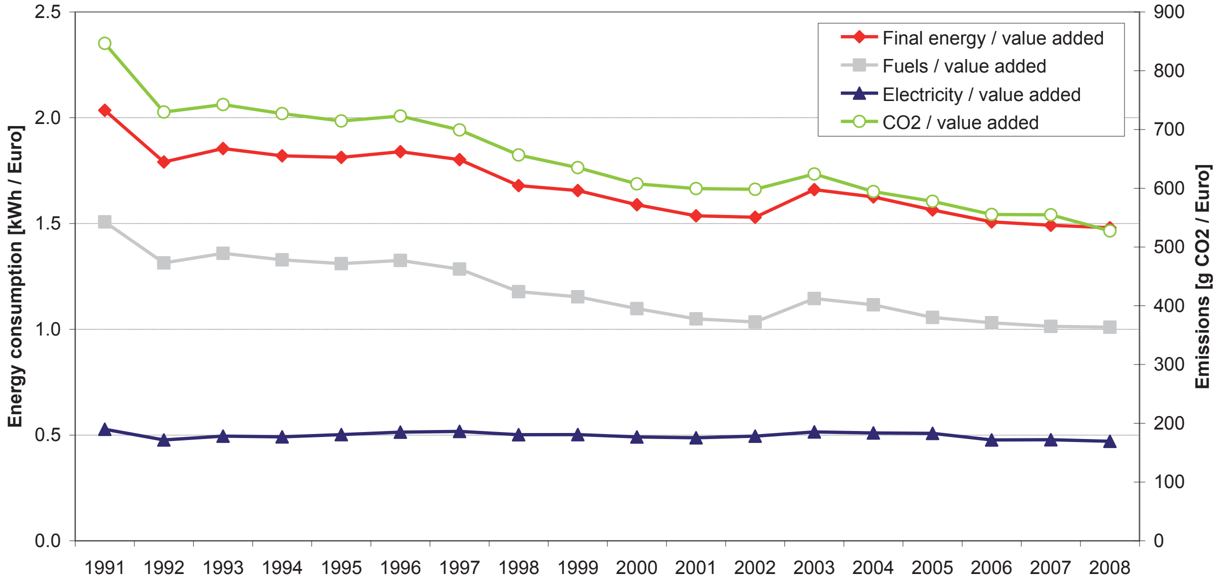
Based on this data, the following indicators for the industry sector can be calculated:

- Simple indicators of energy consumption, for which the energy consumption or CO_2 emissions of the total sector as well as different sectors of industry and products/processes will be related to the following factors: real gross value added, production index and physical production in tonnes.
- An indicator containing the decomposition analysis for energy consumption, for which the change in energy consumption can be traced back to the following factors: change in production (activity effect), change in the structural composition of the industry sector (structural effect) and other changes, in particular the technical efficiency of energy use (efficiency or intensity effect).
- A re-aggregated indicator, for which determined efficiency improvements (in terms of energy used per production index or per tonne) are added together on the segment level (ODEX Industry).

Between 1991 and 2007 the industrial gross value added and the production index have risen significantly, whereas the final (specific) energy consumption shows a decreasing trend in the above-mentioned period, with a falling final energy consumption from 748 to 735 TWh per year.

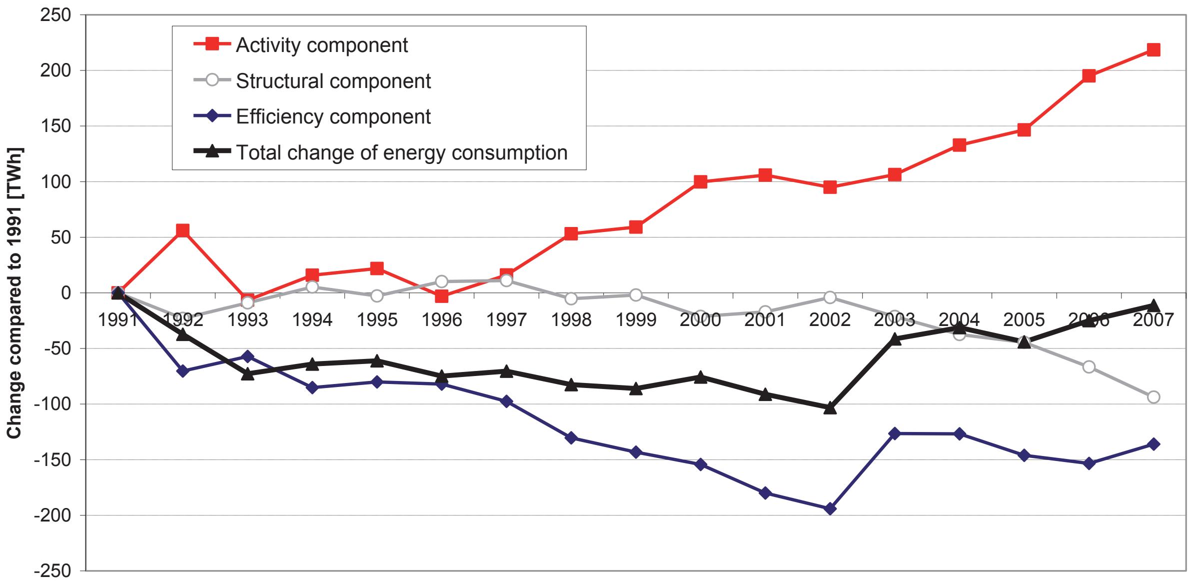
The energy consumption based on the real gross value added of industry, the so-called energy intensity, correspondingly showed a decreasing trend in this time frame; i.e. growth in industrial production and growth in energy consumption were decoupled. Due to a substitution of hard and brown coal with more CO_2 efficient natural gas, the indicator based on industrial CO_2 emissions decreased even more.

As can be seen in the decomposition analysis of energy consumption (Figure 4), the observed decrease of specific energy consumption in Germany was chiefly due to improved energy efficiency in the individual industry segments. Structural change between industrial branches (inter-industrial structural change) only contributed to a smaller degree.



Sources: AGEB 2009; Statistisches Bundesamt 2009a, Calculations Fraunhofer ISI

Figure 3. Energy consumption per value added in German industry.



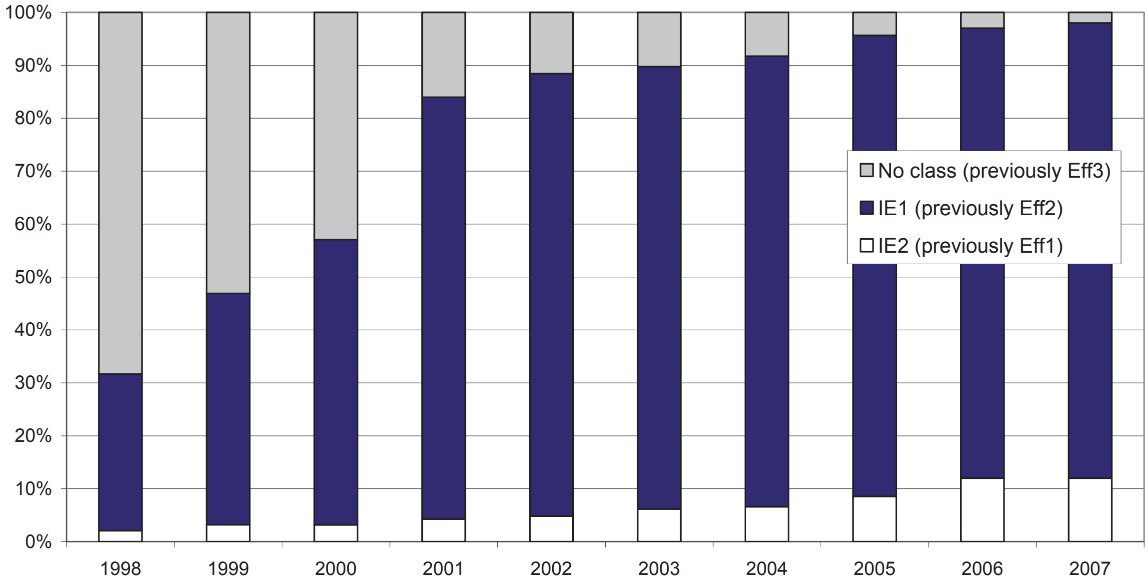
Sources: AGEB 2009, Statistisches Bundesamt 2009a, Calculations Fraunhofer ISI

Figure 4. Decomposition analysis of energy consumption in German industry.

Without these consumption-reducing factors, energy use would otherwise have increased by almost 220 TWh between 1991 and 2007 based on production growth alone. The observed decrease in energy intensity can be mainly ascribed to improved energy efficiency in the different industrial branches, which brought about a reduction in consumption of 136 TWh between 1991 and 2007.

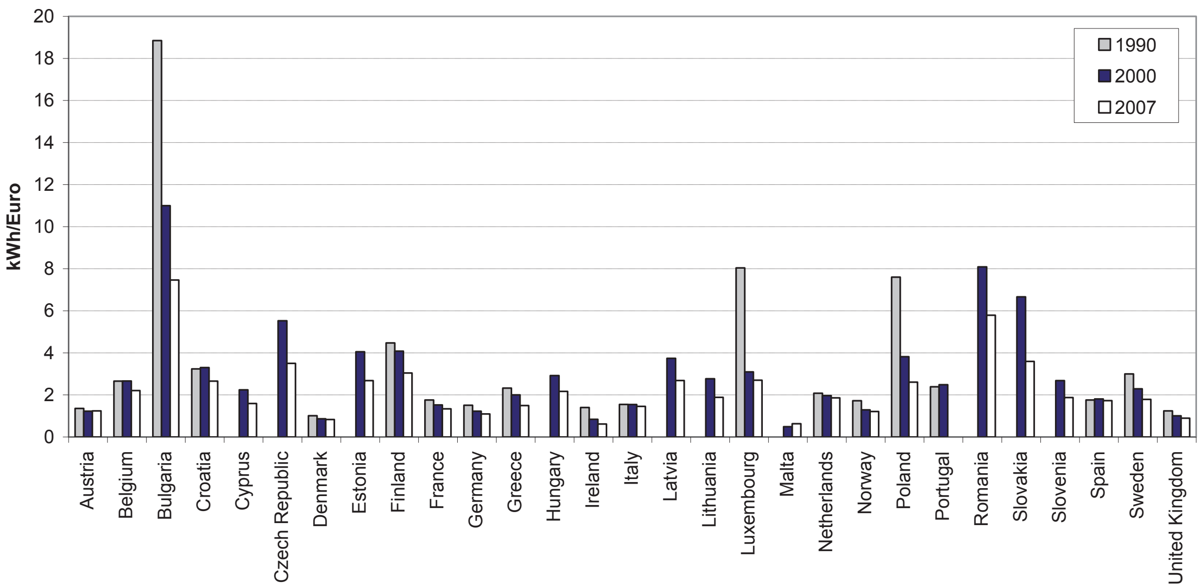
In addition to the above-mentioned indicators, empirical data on the diffusion and dispersion of energy-efficient technologies represent an important basis for developing and evaluating political measures to promote energy efficiency. However, such diffusion indicators are only available for a few key technologies in industry. The annual publication of the European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) on the market shares of electric motors can be considered one of the few examples of diffusion indicators in the industry; they are, however, only available on a European level.

European motor manufacturers voluntarily agreed in 1999 to classify and label motors according to their energy efficiency. The most efficient motors were labelled Eff1 and the least efficient Eff3; these labels are now being replaced by an international classification (IE1 to IE4). The goal of the voluntary agreement was to force the least efficient motors out of the market. This proved to be successful, as the share of Eff3 motors dropped from 68 % in 1998 to 2 % in 2007 (see Figure 5). But



Source: CEMEP 2009

Figure 5. Market shares of efficient electric motors in the EU.



Source: Odyssee 2009

Figure 6. Industrial energy intensity in Europe.

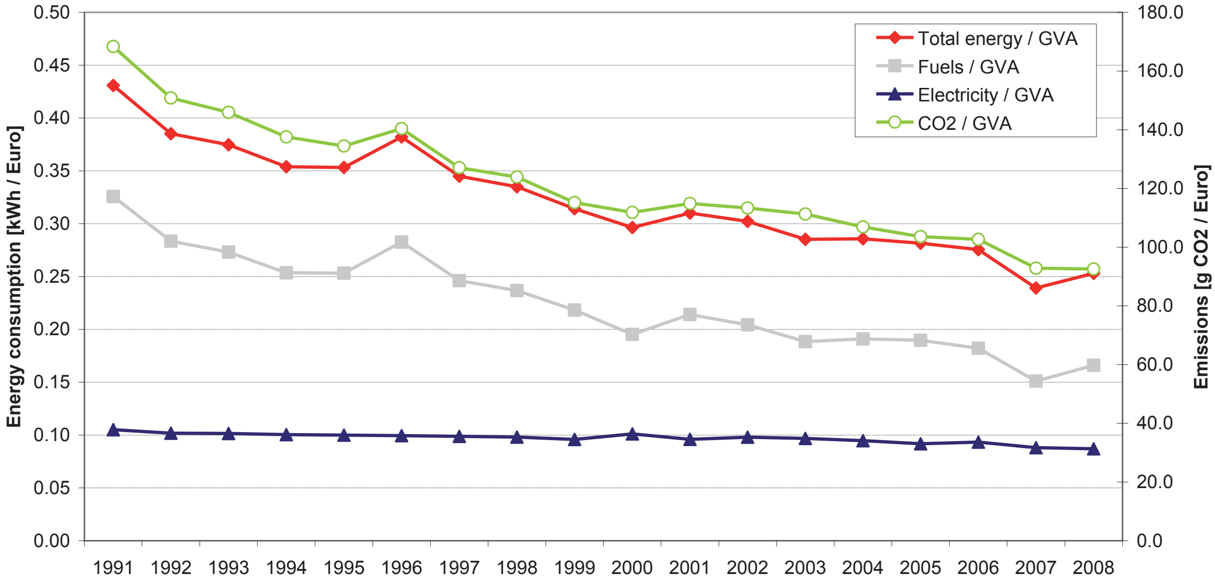
the Eff3-motors were mostly replaced by Eff2-motors and the share of very efficient Eff1-motors remains low (12 %).

INDUSTRY ENERGY INTENSITY IN EUROPE

The energy intensity of industry has fallen in all European countries since 1990. Energy intensity measures the energy consumption per unit of gross value added at constant prices. The drop is most obvious in the Eastern European countries. The development in Bulgaria is particularly striking. Whereas still almost 19 kWh per Euro gross value added were consumed in 1990, this had fallen to only 7 kWh in 2007, which represents a decline to almost one third.

Reasons for the decreasing energy intensity can be found in more efficient production processes on the one hand, and in a structural shift of industry on the other, i.e. energy-intensive sectors become less significant and sectors with lower energy consumption and higher gross value added become more relevant. In most European countries, a structural change is taking place away from heavy industry.

The industry in four European countries - Ireland, Malta, Denmark and the UK – had an energy intensity of less than 1 kWh per Euro gross value added in 2007. While in Malta, for example, there is no kind of heavy industry present at all, in the UK, energy-intensive products such as crude steel, cement, glass and paper are still being manufactured, but their share are counterbalanced by other industrial branches. The same is true for Germany, which held fifth place in the list of countries in 2007, with 1.1 kWh per Euro gross value added.



Sources: AGEB 2009; Statistisches Bundesamt 2009c; Calculations Fraunhofer ISI.

Figure 7. Energy consumption per gross value added in the German tertiary sector.

Tertiary sector

The tertiary sector encompasses a highly heterogeneous spectrum of segments, which differ significantly with regard to the amount and structure of their energy consumption. Alongside the whole service sector (trade, hotel and restaurant industry, banks, insurance companies, public institutions, health care services, child-care, education, and private services), also agriculture and forestry, military services and the building industry are covered by this sector in the German energy balance. Within the energy balance this highly heterogeneous sector is defined as a residual value; the highest data uncertainties in the national energy statistics are to be found in the tertiary sector. Data on energy consumption differentiated by segment are not published for this sector in the national energy balance. However such data has been regularly collected by the tertiary sector in recent years within the scope of its data collection (for 2001, 2004, and 2006 to date). By using statistic-based estimations for the years not covered, the segment-specific energy consumption can be determined from 2001 onwards.

Due to the heterogeneity of the tertiary sector, the determination of suitable factors which can accurately show the development of energy consumption is more difficult than for other sectors. On an annual basis, possible factors for the tertiary sector consist of real gross value added and national employment figures included in the national account of the German Federal Statistical Office. In addition, suitable segment-specific factors (e.g. the number of pupils and students, the size of swimming baths and the number of hotel stays) were collected for the different segments, which are also published annually by the Federal Statistical Office. For the segments of the tertiary sectors that are intensive in terms of space heating, the (heated) space is assumed to correlate best with energy consumption, and in particular fuel consumption, thereby representing a valid technology-based indicator. However, this indicator is not available on a regular basis from official published statistics; instead it can only be determined for certain years on the basis of survey results.

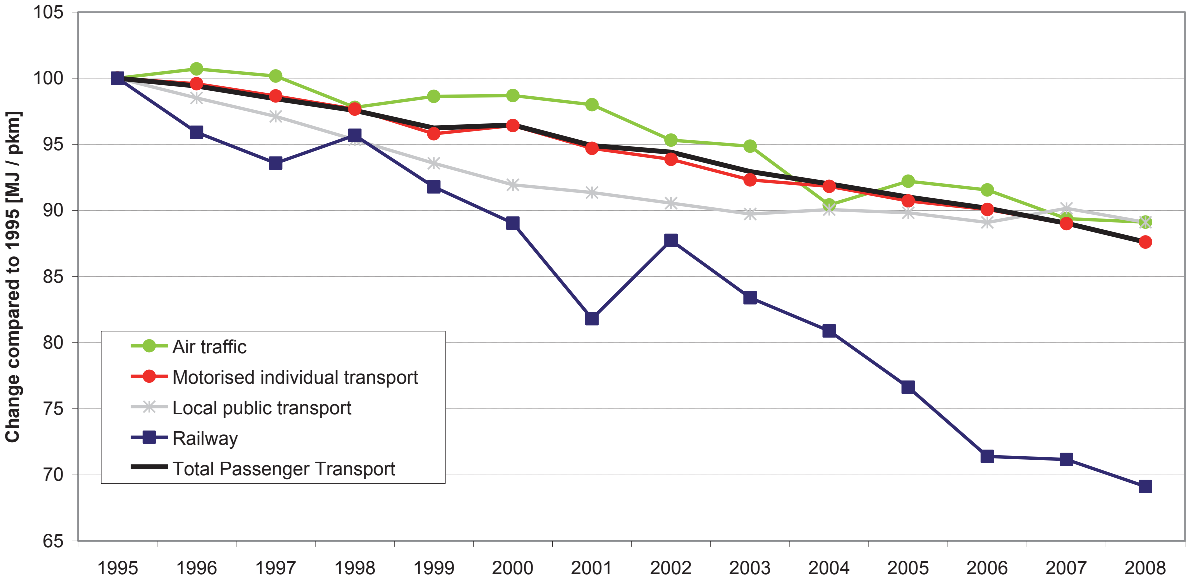
Based on this statistical foundation, the following indicators can be calculated for the tertiary sector:

- Simple indicators of energy consumption, for which the energy consumption or the CO_2 emissions of the total sector and different segments can be related to the following factors: real gross value added, employment figures, segment-specific activities (for different segments), as well as the space in square meters for individual years.
- Corresponding temperature-corrected indicators, for which the share of space heating in the total energy consumption is adjusted using daily temperature data in the light of the impact of differences in weather.

From 1991 to 2007 the gross value added in Germany grew by approx. 40 %, whilst the increase in employment figures amounts to only 18 %. Even though it is not possible – due to the heterogeneous nature of the tertiary sector – to determine a reference value for energy consumption which can be applied to all segments, the employment figures are more likely to correlate better with energy consumption than the gross value added. The final energy consumption of the tertiary sector decreased by approx. 20 % between 1991 and 2008. This trend can be traced back solely to fuels, as electricity consumption increased by 15 % during the same period. Unfortunately the data reliability for electricity is especially low as all statistical differences in the energy balance are included here. The development of CO_2 emissions mostly followed the trend of final energy consumption, although the decline was slightly sharper for CO_2 emissions.

A comparison of actual and temperature-corrected consumption shows that there is barely an impact on electricity consumption, mainly because of the small share of space heating. At the same time the temperature-corrected development of final energy consumption, fuels and CO_2 emissions is more steady.

The energy consumption per unit of gross value added decreased by approx. 50 % between 1991 and 2008, whereas elec-



Source: TREMOD 2010; Calculations Öko-Institut

Figure 8. Energy consumption per passenger kilometre travelled for different transport modes.

tricity only shows a moderate reduction of 17 % (see Figure 7). The reason for this is to be found in the increase of power applications, in particular for Information and Communication Technologies (ICT) in offices and air-conditioning and cooling in office buildings as well as in trade and the hotel and restaurant industry; this development compensated the simultaneous improvement in energy efficiency somewhat. Related to the employment figures, the specific reduction in fuel-based consumption of approx. 40 % between 1991 and 2008 was lower than in relation to the gross value added. Electricity consumption per employee remained more or less constant in the time period.

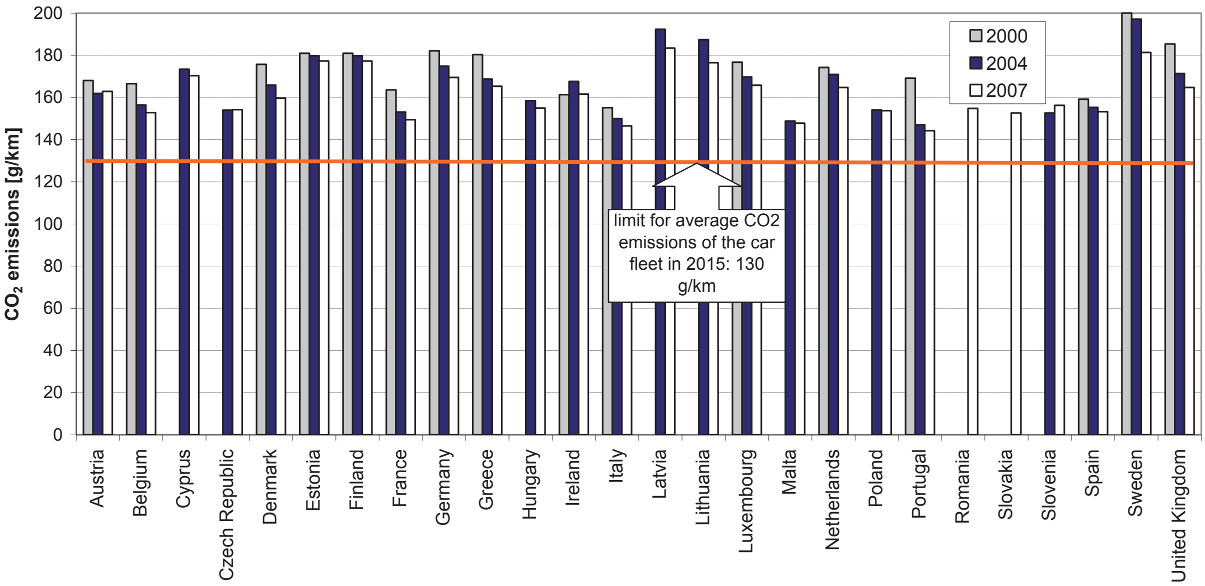
Transport

The key factors for the transport sector are average annual kilometres travelled per vehicle, transport volume (tonnes of shipped goods and number of passengers) and kilometres travelled (in passenger-kilometres/tonne-kilometres). The main statistical sources for data in the German transport sector are provided by the DIW (German Institute for Economic Research) publication "Verkehr in Zahlen" ("Transport in numbers"), data of the German Federal Statistical Office, and the publications of various transport companies and associations. To aid the comparability of indicators on passenger and freight transport for the different modes, it is important to take all relevant information from a single model. Based on a number of different statistical data, which are largely collected independently of each other, there are basically two models for the transport sector as a whole: Transport Emission Model TREMOD and DIW. The main advantage of using DIW data is that the calculation of kilometres travelled by vehicles is very detailed and updated annually, as well as the annual updating and publication in the above-mentioned "Transport in Numbers" being guaranteed. By contrast, the main advantage of the TREMOD model is that the information on each vehicle category from 1990 onwards is detailed and harmonised with all other vehicle categories. Additionally it is used as the official tool used in the reporting of the German Federal Environmental Agency (Umweltbundesamt, UBA). For this reason the TREMOD model was used as the basis for determining energy efficiency indicators in the transport sector.

For the German transport sector the following parameters can be used as input factors for energy efficiency indicators: transport volume and kilometres travelled differentiated according to passenger and freight transport, total kilometres travelled as well as subdivided into passengers and freight transport, transport types and modes, ratio for each energy unit: i.e. km/10kWh (for a bus, tram, train, car, motorcycle, aeroplane), inventory data on different transport modes, and socio-economic trends such as population data and GDP.

The key outcome of the period between 1990 and 2008 is that the final energy consumption in the transport sector increased by approx. 8 %, from 2379 PJ to 2575 PJ. Reasons for this can be found in the increasing number of total kilometres travelled in passenger and freight transport as energy efficiency significantly improved in this period. Energy consumption per passenger kilometre travelled decreased by approx. 12 % between 1995 and 2008 (see Figure 8). This parameter shows the efficiency gains of different transport modes as well as a shift towards more efficient modes and an increase in utilisation of capacity (the number of passengers per vehicle). It is dominated by the development of the motorized individual transport by car. Differentiated analysis shows that there have been efficiency gains of approx. 10 % since 1995 for all transport modes. Rail transport leads the field in the German transport sector with efficiency gains of approx. 30 %. The specific real consumption of the passenger car fleet in Germany decreased by approx. 18 % compared to 1990; and by approx. 10 % between 2000 and 2008 in the case of newly registered passenger cars.

In Germany in the last 20 years there were substantial efficiency gains (in transported tonne per kilometre) in freight transport, too. For the time frame in question road trans-



Source: European Commission 2008

Figure 9. CO_2 emissions of new vehicles.

port (lorries exceeding 3.5 tons and articulated lorries/trailer trucks) saw efficiency gains of 33 %, whilst there were gains of 29 % in rail transport. In this context, the relative decrease of energy consumption in Germany predominantly comes from road transport. At the same time, the energy consumption per tonne-kilometre travelled of all freight transport decreases by approx. 20 % which, as a result of shifts in transport modes, is substantially less than the decreases realised by the modes of transport individually.

PASSENGER TRANSPORT ACROSS EUROPE

Apart from shifting private car passenger transport to more environmentally-friendly modes of transport, another important starting point for reducing CO_2 emissions from transport is to improve the efficiency of cars. Since April 2009, the emission standards for new cars have been laid down by an EU regulation. This stipulates a reduction of the average CO_2 emissions to 130 g CO_2 / km for the whole of the new car fleet by 2015. The standard is to be reduced still further to 95 g CO_2 by 2020.

The countries with the most efficient new car fleet in a European comparison in 2007 were Portugal, Italy, Malta and France, with emissions ranging between 144 and 150 g CO_2 / km. In six countries, the CO_2 discharge amounts to 170 g/km and more; these include Germany and Cyprus, Lithuania, Estonia and Finland, Sweden and Latvia. Overall, reductions have been achieved in every country since 2000 or 2004. In 2007, the CO_2 average for the EU-25 was 158 g/km – compared to 160 g/km in 2006, a decrease by 1.25 %. The CO_2 average for the EU-27 was also 158 g/km.

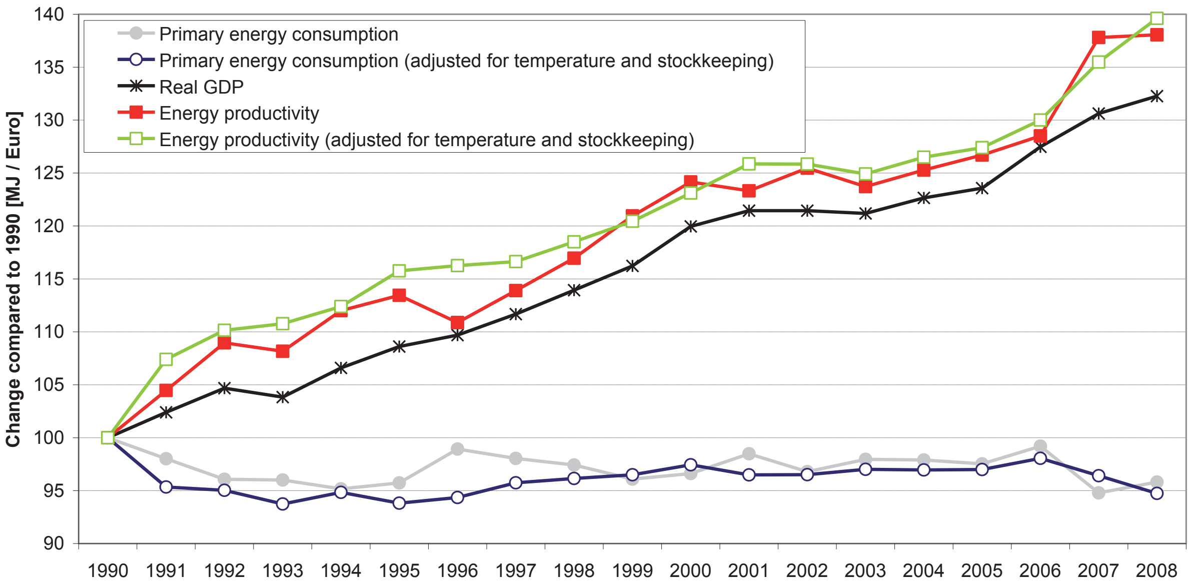
All the figures are based on consumption in a standardized driving test cycle, which makes it possible to compare different types of vehicles. However, the New European Driving Cycle still tends to underestimate the consumption of vehicles under real-life conditions, because, for instance, the fuel consumption of auxiliary systems like the air conditioning is not included in the figures.

Macro level

In contrast to the sectoral perspective, the analysis on the macro level is dominated by the question of the drivers of national energy consumption levels as a whole and the changes in the relation between highly aggregated national energy consumption levels on the one hand and economic and demographic characteristics on the other hand. Indicators on the macro level have the disadvantage that neither different trends in the various end-use sectors nor a multitude of structural factors of influence become visible, although they may underlie the development of highly aggregated indicators of energy consumption. As a result the explanatory power of such indicators is limited and there is also the danger of misinterpretation. However, there are some advantages to using macro indicators: they provide a quick and often more up-to-date overview of highly aggregated trends in Germany that is also easy to communicate and understand. They also enable simple comparisons between countries on an international level. In terms of performance reviews, macro-level energy consumption indicators also have several advantages since they are simple to calculate. The question of whether primary or final energy consumption represents the ideal parameter for such indicators cannot be answered unambiguously; the answer also depends on what targets have been set.

The main data sources for the derivation of macro indicators are the German energy balances, the respective reporting tables of the energy balances, and the emissions inventories of the German Federal Environmental Agency. The relevant data on the demographic and macro-economic development from the German Statistical Office are also important sources.

In order to define the energy consumption indicators, it is necessary to decide which energy consumption factors should be taken as a basis of the analysis. The most commonly used parameter on the macro level is primary energy consumption, which consists of final energy consumption, non-energy consumption, and the total energy consumption in the energy sec-



Source: DWD 2010, Statistisches Bundesamt, AGEB

Figure 10. Energy productivity, primary energy consumption and real GDP in Germany (1990–2008).

tor (consumption from energy conversion and primary energy production, energy conversion losses, other energy losses as well as statistical and assessment differences).

On a macro-economic level, however, final energy consumption is sometimes also used as an indicator. Data on primary and final energy consumption can be found in national and international energy balances; these statistics are easily available. On the one hand primary energy consumption seems very far off from the real decisions made on energy consumption, particularly those taken in the final energy sector. On the other hand the total losses of the energy system are also covered, which is an important factor for forecasts, and the functioning of a performance review on the basis of energy indicators.

In the quantitative measurement of primary or final energy consumption, the various quantities of energy sources are firstly scaled on the basis of their current physical consumption units and in a second step added together to make a global unit with help of a universal conversion factor. Additionally changes in the weather should be taken into account since they can affect energy consumption, which in turn can influence the accuracy of energy consumption indicators significantly.

Several different categories of energy consumption can be used as a basis for determining energy efficiency indicators on a macro level. Not only raw values are considered, but also temperature- and inventory-corrected ones:

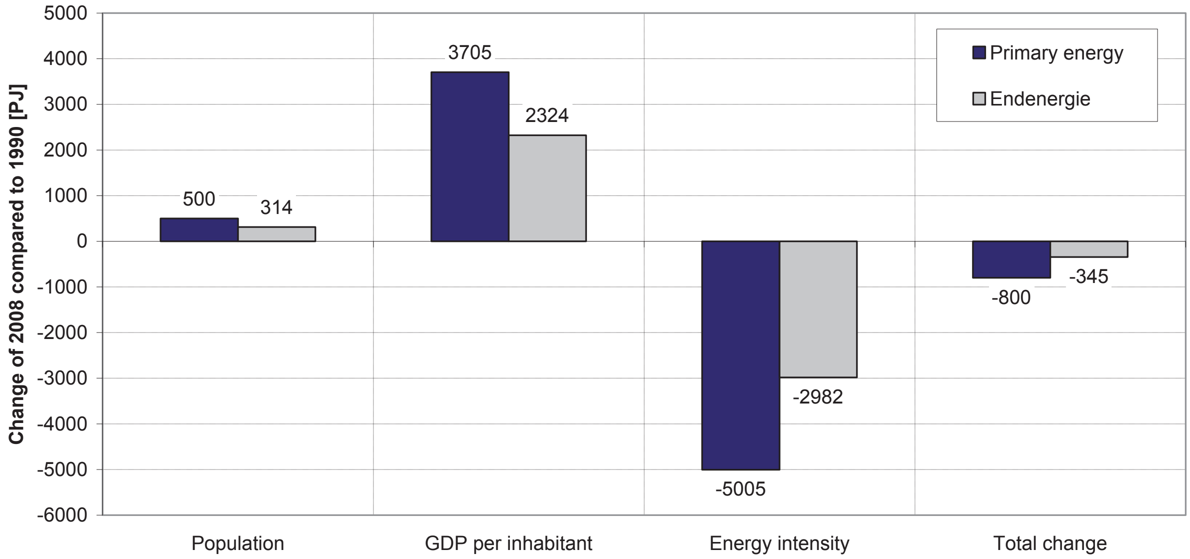
- Primary energy consumption (differentiated by energy source, if applicable)
- Conversion input, conversion emissions
- Total final energy consumption (differentiated by energy source, if applicable)
- Gross power consumption.

In the light of the interest in climate protection, emission-based indicators can also be determined on a macro level:

- Total CO_2 emissions
- Total greenhouse gas emissions.

Generally the following demographic changes (population) and the macro-economic development (price-corrected gross domestic product (GDP)) can be used as reference values. The quotients of the reference parameters can then be used as efficiency indicators of differing significance. Alongside the commonly used productivity and efficiency indicators, on the basis of which a statement can be made on the price-corrected GDP (adjusted for price) per unit of primary energy consumption or per unit of final energy consumption or per unit of gross electricity consumption that is "generated", the per capita ratios as well as primary energy ratios can also be used. Possible examples include the ratio of final energy consumption to primary energy consumption, which gives an impression of the total national conversion losses. Similarly interesting insights could be gained by analysing the level and development of implicit efficiency, which can be derived for every conversion segment (or for the conversion sector overall) from the relation of conversion emissions to conversion input. This category includes the determination of efficiency for electricity production, which can be derived from the relation of gross electricity production to fuel used for electricity production. From a climate protection perspective efficiency indicators which reflect the relation of GDP to greenhouse gas emissions/CO_2 emissions as well as the actual per capita emissions have to be considered as well.

The energy productivity indicator represents the amount of economic activity (measured as real GDP, meaning GDP adjusted for price) which is generated by one unit of primary energy consumed. It is particularly relevant since the German federal government has set in the sustainable development strategy the target of doubling energy productivity between 1990 and 2020. Within the scope of monitoring, this indicator can be determined regularly so as to confirm progress made along the desired productivity path or to identify whether fur-



Sources: AGEB, Statistisches Bundesamt 2009a, DWD 2010

Figure 11. Important drivers for the change of energy consumption (temperature- and stock-corrected values).

ther political measures are necessary. The energy productivity in Germany has increased by nearly 40 % between 1990 and 2008; that is 1.9 % annually. In order to reach the 2020 goal the future annual increase has to rise to 3 %.

Using component analysis, an attempt can be made to decipher which are the most important influences on the changes in primary and final energy consumption (see Figure 11). The size of the population, national economic growth (expressed by the real GDP per capita) and the development of energy intensity can all be regarded as important drivers. In the entire period from 1990 until 2008, the declining energy intensity (id est increasing energy productivity) had the effect of reducing primary and final energy consumption and substantially exceeded any consumption-increasing effects, above all of the rising economic performance per capita (income components).

In the 1990s, the increasing population (demographic components) was also still playing an important role, while, more recently, the decrease in the population has been accompanied by a slight reduction in consumption. The result is that the temperature- and stock-corrected primary energy consumption or final energy consumption in 2008 was lower by around 800 or 345 PJ, respectively, or by 5.3 (3.6) % compared with 1990.

Summary and conclusions

This paper aims to examine whether the development of energy productivity and energy efficiency in Germany is in line with targets set by national and EU policy. In order to do so a set of meaningful sectoral and macroeconomics numbers and indicators is presented. The empirical analysis reveals that the increase in energy productivity so far has already contributed significantly to reducing emissions. Without this increase, the CO_2 emissions in Germany would have been around 300 million t higher in 2008 than was actually the case.

The energy productivity in Germany has increased by nearly 40 % between 1990 and 2008; that is 1.9 % annually. In order to reach the political aims stipulates in the new Energy Concept of the German Federal Government from September 2010 the future annual increase has to rise to 2.1 % and having in mind the goals set in the sustainable development strategy the energy efficiency will need to increase by 3 % every year.

Timely reporting of energy efficiency indicators is key to monitoring the progress made and enable governments to take additional action if needed. Energy efficiency goals are mostly set at macro level, therefore macro indicators such as energy productivity are essential. However, macro indicators can not deliver insights on the underlying reasons for the development of energy efficiency as the total development is likely to be the result of contradictory trends. Therefore energy efficiency indicators at the sectoral level are an important supplement. Additionally decomposition analysis both at sectoral and macro level will help identifying the main drivers for the development.

This requires a comprehensive and frequently updated statistical database. Whereas data on macro indicators is readily available in most countries, sectoral indicators and decomposition analysis requires much more detailed information. In Germany, recent efforts have been made in the residential and tertiary sector, where regular surveys on energy consumption are conducted since some years. Information about the diffusion of energy-efficient technologies e.g. in industries is rare and time-series are only available from non-official sources like industry organisations.

To monitor the progress made on EU level the reporting of a harmonized set of indicators based on both macro and sectoral analysis by all European countries is highly desirable. Those indicators would need to be selected with view of existing statistical sources at national level. Therefore, mandating comparable studies in all EU countries would be an important step to generate an European set of energy efficiency indicators. The ODYSSEE-MURE project[2] provides valuable work in this context,

2. http:\\www.odyssee-indicators.org

despite difficulties arising from different reporting categories, currencies and confidential data. For the regular monitoring of the energy efficiency progress under the ESD, similar top-down energy efficiency indicators are recommended by the European Commission. Regular and coherent reporting (requirements) on the national level would facilitate a stringent and consistent impact analysis of efficiency policies on the aggregated EU as well as national levels.

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