


ENVIRONMENTAL DATA FOR GERMANY

ENVIRONMENTAL INDICATORS

2007 edition



Important parameters – a selection from “Environmental Indicators Germany 2007”				
Area	Period		Difference	Page
Greenhouse gas emissions in CO ₂ equivalents	1990	2005	– 18,7 %	6
CO ₂ emissions	1990	2005	– 15,4 %	8
Average annual temperature	1901	2005	+ 0,8 °C	12
Primary energy consumption	1990	2006	– 2,1 %	14
Renewable energy as a proportion of total primary energy consumption (PEC)	1998	2006	+ 3,6 percentage points	16
Renewable energy as a proportion of electricity generation	1998	2006	+ 7,2 percentage points	16
Co-generation in energy generation	1990	2006	+ 19 percentage points	18
Energy productivity	1990	2006	+ 31 percentage points	20
Passenger transport volume	1991	2005	+ 21,9 %	22
Freight transport volume	1991	2005	+ 45,5 %	23
CO ₂ emissions from road traffic				
• motorised individual transport	1991	2005	– 20 percentage points	24
• road freight transport	1991	2005	– 23 percentage points	25
Transport intensity for passenger traffic	1999	2005	– 4 percentage points	26
Transport intensity for freight traffic	1999	2005	+ 10 percentage points	26
Atmospheric pollution index of emissions	1990	2005	– 55 percentage points	28
Class 2 damage to forests (significant thinning of tree tops)	1990	2006	+ 5 percentage points	36
Water quality grading, proportion of moving waters with class II water quality				
• Adsorbable organic halogen compounds (AOX)	1996	2005	+ 8 percentage points	42
• Total nitrogen	1996	2005	+ 1 percentage points	42
Area of land under organic cultivation	1994	2006	+ 3,3 percentage points	46
Nitrogen surplus (total balance)	1991	2004	– 8 %	47
Increase in settlement and transport areas	1993–1996	2003–2006	– 5.2 %	48
Diversity of species – species of birds according to type of main habitat	1990	2005	– 2 percentage points	50
Total waste production	1999	2005	– 18 %	74
Recycling quotas for main flows of waste	2002	2005	+ 0,1 percentage points	76
Raw material productivity	1994	2005	+ 33,5 percentage points	78



Federal Environment Agency

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**A selection from the Federal Environment Agency's
system of core environmental indicators**

www.umweltbundesamt-umwelt-deutschland.de

Preface

Why do we publish environmental data and environmental indicators? In order to inform the public about the state of our environment, for political decision-makers, to help them in the planning and implementation of environmental policies, and for the media, to draw attention to national and global environmental problems.

Current, comprehensive and scientifically based environmental data form the essential basis for all these activities. There are many different sources; a wealth of data is collected by Federal, Land and municipal authorities as well as by research facilities and independent institutes in the framework of measurement and monitoring programmes, research projects, scientific investigations and official statistics.

Environmental indicators are theme-based “signposts in the jungle” of environmental data. They consist in part of highly aggregated parameters, enabling the development of the environmental situation to be more clearly understood. They describe pollution trends and reveal where there is a need for action on environmental policy, as well as its successes and the contribution it is making to sustainable development. For this purpose, environmental trends are evaluated on the basis of the environmental objectives defined by the German government and in international agreements.

The published indicators and texts have been taken from the Federal Environment Agency’s core environmental indicators. In-depth details about developments in the state of the environment in Germany can be found on the internet at www.umweltbundesamt-umwelt-deutschland.de.

We would like to thank all those participating authorities who have assisted in evaluating the indicators and in ensuring their topicality. We owe particular thanks to the Federal Statistical Office, the Federal Agency for Nature Conservation, for its contributions about the protection of biodiversity, the Federal Office for Radiation Protection, the German Meteorological Service, the Federal Office of Consumer Protection and Food Safety and the Federal Institute for Risk Assessment.

The Vice President of the Federal Environment Agency



Dr. Thomas Holzmann

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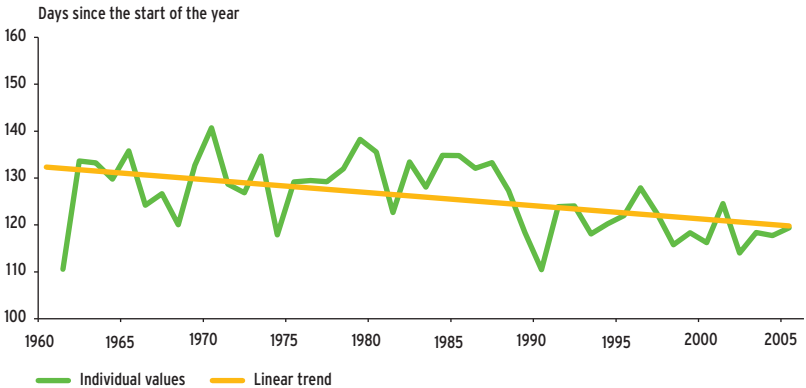
Indicators for the German government's sustainability strategy
are shown in **red**.

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Date on which indicator plants flower

First appearance of apple blossom (regional average for Germany)



Source: German Meteorological Service 2006

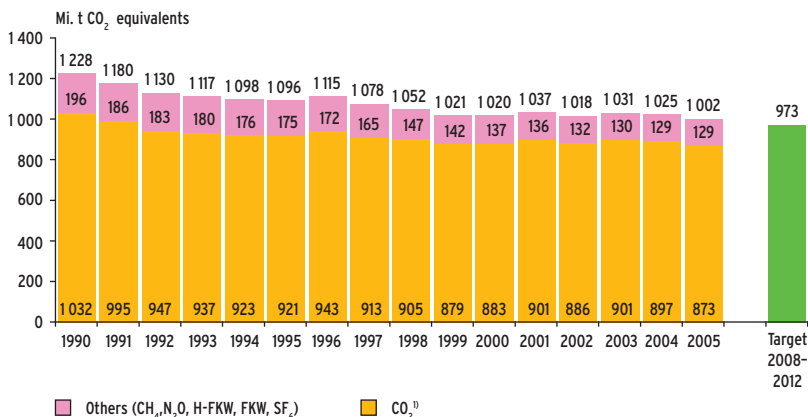
It is evident that the phenological spring phase has advanced significantly over the past half century, clearly reflecting an increase in temperatures in Germany over this period.

Climate change has advanced to such an extent in Germany and in Europe that the initial effects on flora and fauna are now becoming apparent. Snowdrops, an indicator of early spring, and apple blossom, which signifies the full onset of spring, are now appearing earlier (almost 5 days/decade), in many European countries forest trees are putting out shoots earlier (approx. 5 days/decade), while many songbirds are staying almost a month longer than they did in 1970.

While the phenological spring phase is advancing, there is no distinct trend towards delayed phenological phases in the autumn. In contrast to the spring phases, whose onset is largely determined by temperature, the connections with climatological parameters in the autumn are more complex and less pronounced. In addition to the temperature, in this case the amount of summer precipitation is an increasingly important factor, and non-climatological influences such as the occurrence of plant diseases and pest infestation also have an important part to play.

Greenhouse gas emissions

Emissions in Germany of the six greenhouse gases referred to in the Kyoto Protocol



Output quantities for calculating the Kyoto target 2008-2012:

Base year emission 1,232 mi. t CO₂ equivalents; 1,216.4 mi. t CO₂ equiv. for CO₂, CH₄, N₂O (base year 1990), 15.5 mi. t CO₂ equiv. for HFC, PFC, SF₆ (base year 1995). Reduction 259 mi. t CO₂ equivalents (-21 % up to the commitment period 2008-2012 compared with the calculated base year; 18.7% was achieved up to 2005). Amount of emissions in target year: 1,232-259 = 973 mi. t CO₂ equivalents

¹⁾ CO₂ emissions excluding CO₂ land utilisation, changes in land utilisation and forestry

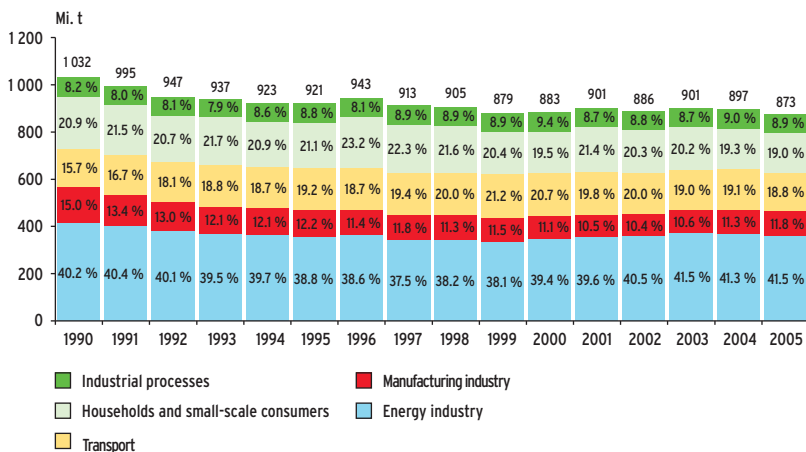
Source: Federal Environment Agency 2006

As a whole there was a substantial reduction in the amount of greenhouse gases released, compared with 1990. With reference to the base year of the Kyoto Protocol (CO₂, CH₄, N₂O: 1990; HFC, PFC, SF₆: 1995) total emissions converted into CO₂ equivalents – excluding CO₂ emissions from land utilisation, changes in land utilisation and forestry – fell by some 230 mi. t or 18.7 % during the period up to 2005. Compared with the base year this is only 2.3 percentage points short of the Kyoto target because, within the framework of burden sharing between the member states of the European Community, Germany's 21 per cent reduction represented an above-average contribution to achieving the EU's commitment within the Kyoto Protocol. This means that Germany is close to meeting the target although constant efforts will still be needed in order to reduce these emissions.

The continuously increasing concentrations of a number of gases in the earth's atmosphere since the start of industrialisation are producing an anthropogenic greenhouse effect, which intensifies the naturally occurring greenhouse effect. Emissions, primarily from the burning of fossil fuels, are the cause. Non-energy production processes and consumer behaviour also play a part. The main anthropogenic greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide/laughing gas (N_2O), CFCs, perfluorated and partially perfluorated hydrocarbons (HFC and PFC) and sulphur hexafluoride (SF_6).

In an effort to attain the objective set by the UN Framework Climate Convention of stabilising greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous anthropogenic interference to the climate system, under the Kyoto Protocol of 1997 the developing countries gave a commitment to reduce the emissions of the named greenhouse gases (excluding CFCs) by 5 %. The European Union undertook to reduce total emissions by its member states at the time by 8 %, and the contributions by individual countries are regulated by an internal burden sharing arrangement within the EU. Between the base year – 1990, or 1995 for the so-called F-gases – and 2005 greenhouse gas emissions by the EU-15 fell by 2.0 % as a whole, those of the EU-25 by 8.3 % and those of the EU-27 by 11.0 %. The influence of the decline in emissions by the countries of Eastern Europe is very evident. Germany, the largest single source of emissions in the EU by far, also achieved the largest quantitative reduction.

However, meeting the reduction obligations of the Kyoto Protocol will not be sufficient to stabilise greenhouse gas concentrations in the atmosphere at a level which would limit the increase in the average global temperature to a maximum of 2 °C above the pre-industrial level. The federal government has therefore proposed that Germany will reduce its greenhouse gas emissions by 40 % by 2020 (taking 1990 as the base year), provided that the EU member states approve a 30 % reduction in European emissions over the same period.

Development of CO₂ emissionsEmissions of carbon dioxide (CO₂) according to source groups

Carbon dioxide emissions: excluding land utilisation, changes in land utilisation and forestry

Transport: excluding agricultural and forestry transport

Households and small-scale consumers: with agricultural and forestry transport and the military

Source: Federal Environment Agency 2006

There has been an almost continuous decline in CO₂ emissions since 1990. The reductions are almost equally attributable to economic restructuring in the new states (former East Germany) accompanied by a decrease in the use of lignite, and the federal government's active climate protection policy. Cold winters have led to intermittent slight increases. The higher emissions in 1996 were also due to the weather.

As in the past, in 2005 the largest share of CO₂ emissions, 41.5 %, was accounted for by the energy industry. Each year this sector releases between 330 and 370 mi. t of CO₂. Between 1976 and 1991 increased production and structural difficulties affecting fuels and installations meant that annual emissions even exceeded 400 mi. t. The source groups, comprising households/small scale consumers and road transport/other transport, both with around 19 %, and manufacturing industry/industrial processes, which together accounted for about 20 %, currently carry a similar weight with regard to CO₂ emissions.

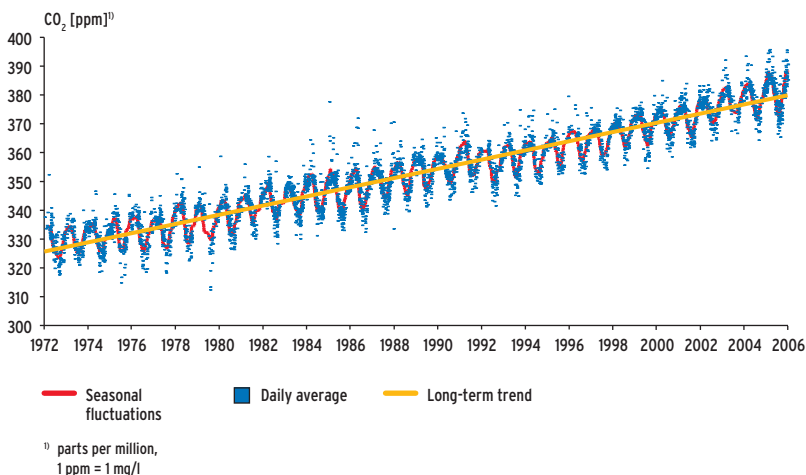
Between 1990 and 2005 the intensity of emissions produced by the economy as a whole, i.e. emissions relating to domestic economic output, and expressed in terms of the gross domestic product, fell by some 30 %, with the sharpest reduction being in manufacturing industry and the smallest being in transport.

Carbon dioxide (CO₂) is by far the most important climate gas, accounting for approximately 87 % of all greenhouse gas emissions in 2005. Compared with the base year 1990 this represents an increase by some 3.5 percentage points and is the result of a sharp decline in emissions of methane (CH₄) and nitrous oxide (N₂O), compared with CO₂.

Carbon dioxide is almost entirely a by-product of the combustion processes taking place in factories and industrial plants and in engines. Emissions also occur in the non-metallic building materials sector as a result of the burning of limestone during the production of cement and building materials. Thus, in Germany too, emissions occur in accordance with energy consumption and taking into account the shares accounted for by the various groups of fuels. In terms of the unit of energy applied, emissions are highest for solid fuels, which consist predominantly of carbon, and lowest in the case of gaseous fuels, because of the substantial amounts of hydrogen that they contain. Liquid fuels occupy a position in between the other two types.

Concentration of CO₂ in the atmosphere

Atmospheric concentration of CO₂ at the Federal Environment Agency's Schauinsland monitoring station



Source: Federal Environment Agency 2006

The atmosphere CO₂ concentration has risen by around 35 % since 1750 and has now reached a value of some 379 ppm. Current CO₂ concentrations are unprecedented at any time during the last 650,000 years, and probably not in the past 20 million years. The present annual rate of increase is the highest in the past 20,000 years. Since 1750 approximately 65 % of anthropogenic emissions can be attributed to the burning of fossil fuels.

Compared with previous decades there has been an obvious increase in concentrations during the past decade. Whereas the average growth rate during the period 1960–2005 amounted to 1.4 ppm/year, during the past decade it reached 1.9 ppm/year. Since 1958 this trend has been confirmed by the regular measurements obtained on Mauna Loa on Hawaii. The trend is also indicated by regular measurements obtained at the Federal Environment Agency's stations, for example at the Schauinsland monitoring station.

In quantitative terms CO₂ is the most important greenhouse gas and therefore its concentrations in the atmosphere can be used as an indicator for the anthropogenic greenhouse effect.

Rising concentrations of CO₂ in the earth's atmosphere are the main cause of the anthropogenic greenhouse effect. Approximately three quarters of the anthropogenic emissions produced over the past 20 years can be attributed to the burning of fossil fuels. To avoid a dangerous, anthropogenic interference with the climate system it is to be avoided in the long term the global temperature increase must be limited to about 2° C above the pre-industrial level. More recent scientific findings about climate sensitivity, i.e. the increase in temperature that will be triggered by a doubling of the greenhouse gas concentration, suggest that, in all probability, temperatures can only be kept below this limit if greenhouse gas concentrations can be stabilised at 400 ppm CO₂ equivalents (according to calculations by the UBA). Such a stabilisation would require that global emissions continue to rise for no more than 10 to 20 years, falling subsequently to half of the present-day level by 2050. There must be substantial reductions, not only in the amount of carbon dioxide, but also in other greenhouse gases and substances that indirectly affect the climate.

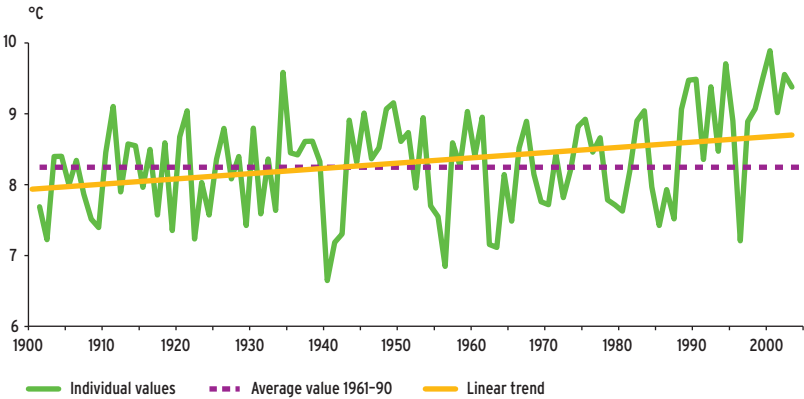
Based on burden-sharing the industrialised nations have assumed that an 80 % reduction in greenhouse emissions is needed by 2050 compared with 1990 levels.

Global climate changes over the past 100 years

- There has been a rise of 0.74 (0.56–0.92)°C in the global average surface temperature during the past 100 years (1906–2005). This warming trend has intensified in recent decades, and eleven of the past twelve years have been among the warmest since 1861, when systematic worldwide temperature recordings first began.
- The rate at which the sea level is rising and at which glaciers and ice caps are melting has accelerated. Between 1961 and 2003 there was an annual rise in sea levels around the world of some 1.8 mm and a 3.1 mm increase between 1993 and 2003.
- Climate changes affect entire continents and ocean basins.

Development of the annual mean temperature

Annual mean daily temperature in Germany 1901-2005



Source: German Meteorological Service 2006

In Germany and around the world the final ten years of the 20th century were the warmest decade of the century. Nine of those years, as well as every year so far in the 21st century, have been above the long term average (8.3 °C), and six of the ten warmest years occurred during this same period. The warmest year in Germany since 1901 was 2000 (9.9 °C). There was an overall rising trend in annual mean temperatures of 0.8 °C in 100 years which, with an error probability of 5 %, is statistically significant. However, this rise was not evenly distributed throughout the time series, being largely based on a rise up to 1911 and a very warm period after 1988.

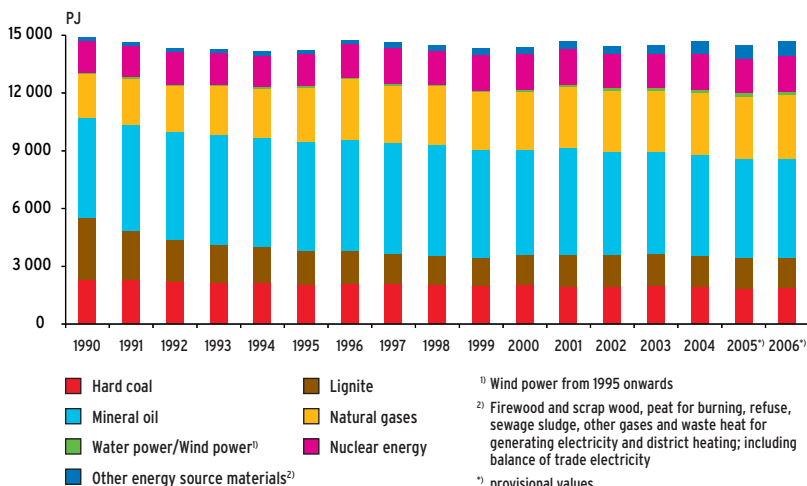
The temperature rise was also seasonally affected. Spring temperatures reveal only a relatively weak, statistically insignificant rise, although the years since 1990 have been particularly warm. Five of them (in descending order: 2000, 1993, 1990, 1999, 2003) were among the ten warmest since the start of the 20th century. The summers contributed considerably more than the springs to the annual mean temperature trend. Here too there was a statistically significant rise of approximately 1.1 °C, due above all to the increase in temperatures since 1955. This trend attained its highest values so far during the “summer of the century”, 2003, which was more than 1 degree warmer than any previous summer. Since 1990 summer temperatures have only dropped below the average in 1993 and 1996. Six of the ten warmest summers occurred during this period (2003, 1994, 1992, 2006, 2002 and 1997).

A noticeable and statistically significant autumn temperature rise has also been evident, due largely to a rapid warming between 1922 and 1929. Since that time autumn temperatures have remained remarkably constant.

There has been no overall increase in the winter trend. The time series is characterised by an increased frequency of particularly cold winters and the absence of very warm winters during the middle of the 20th century. Here too the years from 1990 onwards were again very mild. Of these seventeen winters, thirteen were above the average, while four of them (1989/1990, 1994/95, 1997/98 and 1999/2000) have been among the ten warmest of the century.

Primary energy consumption (PEC) according to energy source materials

Development of primary energy consumption in Germany according to energy source materials



Source: Working Group on Energy Balances 2007

Despite the general economic growth, primary energy consumption (PEC) in Germany has displayed a slight downward trend since the early 1990s. In 2006 it was 2.1 % below the 1990 figure. Fluctuations in the downward trend in past years can be mainly attributed to the weather, with cold winters leading to a substantial increase in the demand for heating.

In 2006 the consumption of primary energy in Germany totalled 14,588 PJ, of which 35.4 % was obtained from mineral oil products, 22.5 % from natural gas, 12.9 % from hard coal and 10.8 % from lignite. The contribution by nuclear energy to meeting primary energy requirements declined to 12.5 %. The proportion of renewable energy sources, which include water power, wind power, geothermal energy, biomass and solar energy, has risen significantly since 1990, reaching 5.8 % by 2006. Since 1990 the biggest changes in the mix of energy source materials has been the reduction by half in the amount of lignite used (between 1990 and 1997, after which time lignite consumption remained relatively constant) and the increase of around a third in the amount of gas consumed.

Renewable energies have displayed an upward trend over the past ten years. In 2006 their share of total consumption of primary energy amounted to 5.8 % (according to the efficiency method), made up of electricity generation (2.5 %), heat generation (2.2 %) and fuel consumption (1 %).

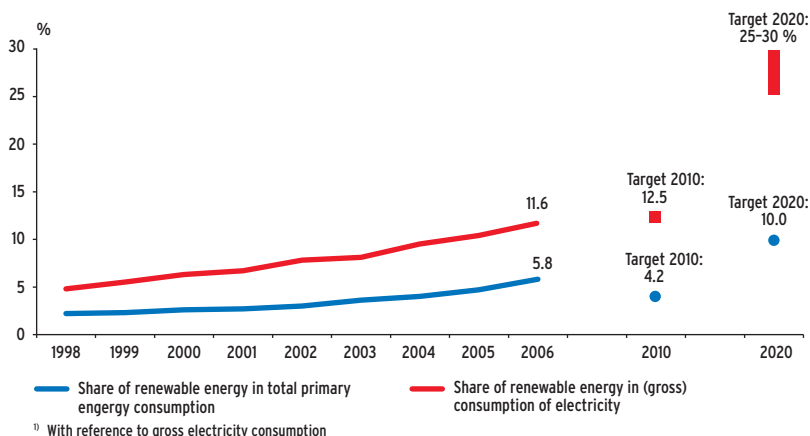
If loaded on the railways in the form of coal, the amount of energy consumed in 2006 would require a train 410,000 km in length, a distance that would reach almost ten times around the earth.

Primary energy is used to provide useful energy in the form of light and heating, for driving machinery and for the exchange of information. With increased energy consumption the many different environmental influences associated with the generation and use of energy have been responsible for substantial pressures on the environment over the past century, such as atmospheric pollution, acid rain and the greenhouse effect.

Given the current energy mix, primary energy consumption provides a clear indicator both of the consumption of finite resources as well as of the causes of greenhouse gas emissions.

Renewable energy

Proportion of total energy consumption and of electricity generation ¹⁾ provided by renewable energy (according to the efficiency method)



Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety 2007

Energy-related environmental pollution, in particular the harmful effects on the climate and the increasing consumption of non-regenerative energy sources, are forcing people living in industrialised nations to cut back their energy consumption in all sectors. In addition to conserving energy and using it more efficiently, increased use could be made of renewable energies, thereby enabling energy-related environmental pollution to be significantly reduced. It is particularly important to achieve decisive advances in the use of solar energy, wind and water power, biomass and geothermal energy.

The German government is encouraging the expansion of renewable energy through its Renewable Energy Law (EEG) as well as through research and development. The EEG law imposes a requirement on the operators of power supply networks to give immediate priority to the connection of renewable energy installations, and to also give priority to the use and transmission of the electricity that they generate, for which they are required to pay a minimum reimbursement. The federal and state authorities have also set up various programmes to encourage investment in renewable energy.

Renewable energy as a proportion of primary energy consumption

The German government has set a target for renewable energy, stipulating that it should provide 4.2 % of primary energy consumption by 2010, and at least 10 % of primary energy consumption by 2020. Ambitious targets have also been set at European Union level too. In March 2007 the Council of the European Union, under German chairmanship, made a binding decision to augment the contribution by total energy consumption to 20 % by 2020, a threefold increase compared with the 2005 level. Various targets will be allocated among the member countries, based on existing usage and the available potential for renewable energy in the respective member states.

Proportion of electricity generation provided by renewable energy

In 2006 the amount of electricity being generated from renewable energy already accounted for just under 12 % of all available electricity supplies. The German government's target, calling for renewable energy to account for at least 12.5 % of gross energy consumption by 2010, was achieved by 2007, well ahead of schedule. National expansion targets are to be adjusted in accordance with the decision reached in Meseberg in August 2007. The German cabinet has decided to increase the 2020 target for electricity generation from renewable energy from the previous figure of "at least 20 %" to between "25 and 30 %". The intention is that further, continuous increases should take place after 2020.

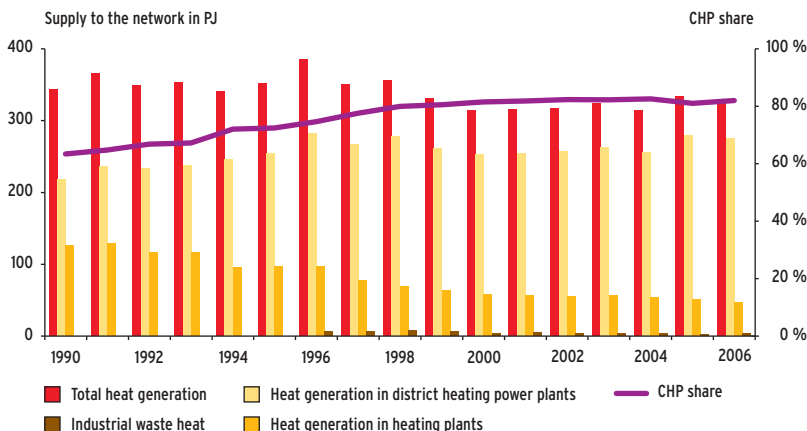
In recent years a major contribution to the increase in the electricity generated using renewable energy has come from wind power in particular, with a rise in the installed capacity from 56 MW in 1990 to 20,622 MW in 2006. As a result the amount of electricity generated using wind power has risen from 40 GWh in 1990 to 30,500 GWh in 2006, and by 2004 it had superseded hydroelectric power as the single most important renewable energy source for the production of electricity. Depending on the location and the height of the rotor hub, a modern wind farm in Germany with a generating output of 2 MW can produce an average of around 4 mi. kWh of electricity, which is equivalent to the average amount consumed by 1100 households.

In 2006 the electricity utilities and private sector plant operators generated some 74 TWh of electricity using water and wind power, biomass, solar energy (photovoltaics) and geothermal systems.

Renewable energy sources can be used as a substitute for the limited availability of fossil and nuclear energy source materials. Renewable energy sources make a significant contribution to saving resources and combating the greenhouse effect. In 2006 for example, their use in supplying energy avoided the production of some 68 mi. t. of CO₂ emissions. Including methane (CH₄) and nitrous oxide (N₂O), the reduction over the same period amounted to 68.6 mi. t of CO₂ equivalents, representing an 8.5 % share of all energy-related CO₂ emissions.

The use of combined heat and power for generating energy

Generating district heating - supplying the network from district heating and other heating plants¹⁾



¹⁾ Adoption of different method of apportioning district heating generation in district heating power plants and heating plants 1995/1996.

Source: Working Group on Heating and Heating Plants 2007

Between 1990 and 2006 the contribution made by combined heat and power to the generation of heat increased from 63 to 82 %. These details only cover those district heating supply companies that have furnished data for the respective AGFW (*Working Group for Heating and Heating Plants*) Main Report on the Supply of District Heating. With reference to the maximum heat output capacity the AGFW estimates that this represents some 86 % of the total.

At the present time only about 9 % of the total electricity that is generated is obtained from CHP.

The expansion of heat distribution networks (long distance and local district heating) is of major importance in connection with the use of cogeneration (CHP). Only about 7 % of the end energy consumption for room heating and hot water in German homes is obtained from district heating. Just under 80 % of the district heating is provided by the environmentally acceptable method of cogeneration and around 2 % by using industrial waste heat.

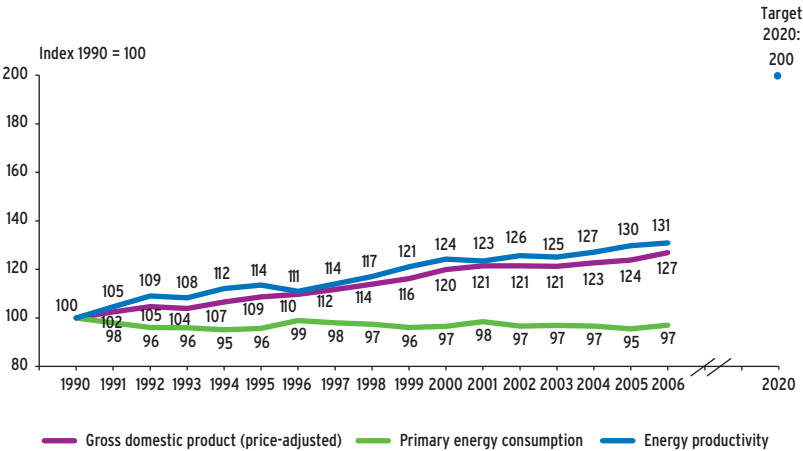
Within the framework of the national sustainability strategy the federal government has given a commitment to modernise and expand CHP. The main instruments for encouraging the use of cogeneration to provide a larger share of energy production are the Combined Heat and Power Law of 12 May 2000 for protecting the generation of electricity from combined heat and power (KWKG 2000), the Law on the Maintenance, Modernisation and Expansion of CHP, from 19 May 2002 (KWKG 2002) and special arrangements for CHP supported by the use of natural gas as part of ecological tax reform. The KWKG 2000 helped to prevent the reduction in the amount of CHP facilities which, in the absence of legal protection, would have otherwise occurred as a consequence of the liberalisation of the electricity market.

There is a direct link between the KWKG 2002, passed in 2001, and the agreement that took effect on 19 December 2003 between the government of the Federal Republic of Germany and German industry to supplement the Climate Agreement of 9 November 2000 by reducing CO₂ emissions and encouraging cogeneration. Under the terms of this agreement the energy industry gave an undertaking to cut emissions by up to 45 mi. t CO₂/year by 2010. This is to be achieved by retaining, modernising and extending cogeneration plants with the aim of attaining an overall reduction of 23 mi. t CO₂/year compared with 1998, and to meet the target of at least 20 mi. t CO₂/year by 2010. This target is also enshrined in the German sustainability strategy. The KWKG 2002 is intended to enable around half of the reduction target for cogeneration to be met, i.e. approximately 5 mi. t CO₂ by 2005 and between 10 and 11.5 mi. t CO₂ by 2010.

As a rule the conversion of fuels used in conventional electricity generating plants only achieves efficiencies of 30–45 % because the heat that is generated by this process is released unused into the environment. CHP plants utilise this heat to supply end-users with heat or cooling. As a result the fuels are used more effectively, with efficiency degrees of between 80–90 %. Large district heating plants can be used to supply entire regions, or alternatively, there are also unit-type heating plants to meet the needs of individual buildings, settlements or business premises. There is an increasing trend for conventional, centralised electricity generation to be supplemented by decentralised plants, the intention being that more electricity should be generated at sites where the process heat can be used directly for heating or cooling purposes.

Energy productivity

Energy productivity and economic growth



Source: Federal Statistical Office, Working Group on Energy Balances 2007

Between 1990 and 2006 energy productivity increased by just under 31 %. Although improved productivity indicates a more efficient use of energy, this only led to a relatively weak decline in energy consumption, in absolute terms, by 3 %, because the efficiency increases were largely cancelled out by economic growth of around 27 %. Recent years (2000 to 2006) have seen a slower increase in energy productivity. A return to the previous average rate of increase would be insufficient to attain the Federal Government’s objective of a doubling of energy productivity by 2020.

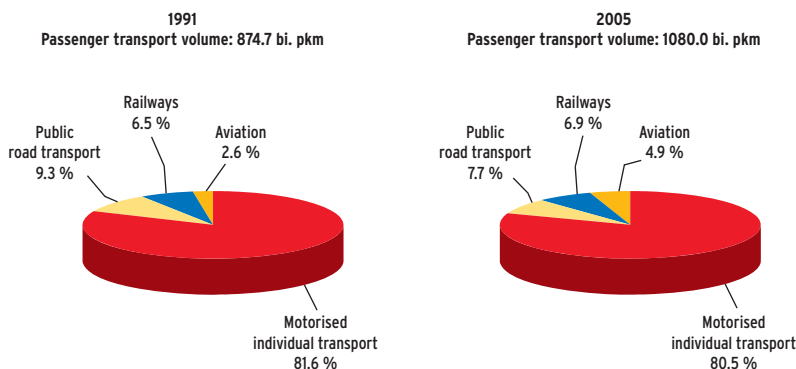
In 2005 over 42 % of domestic energy consumption was accounted for by the production of goods and services, 29 % by private households and 29 % by the transport sector.

For many years primary energy consumption in Germany has remained largely stable and at the present time it is 3 % below the 1990 figure, whereas GDP has risen by some 27 % over the same period, indicating that energy consumption has largely been decoupled from economic growth.

In particular improvements to power stations (new and converted plants, increased efficiency) and the exploitation of energy saving potentials in all areas of the economy and in private households have helped to boost energy productivity. For example stricter demands on the quality of the energy systems of buildings (total energy requirements for the outer shell of the building and the installation engineering) lead to energy savings and a reduction in CO₂ emissions in and around buildings.

Approximately two thirds (64.4 %) of the primary energy deployed in 2006 was destined for the end energy sectors of industry, households, transport and manufacturing, trade and services, while 7.7 % was used for non-energy purposes (e.g. material utilisation of crude oil). Losses and private consumption in the generation and provision of electricity and other secondary energy sources in the energy conversion sector (power stations, refineries, coke plants and underground as well as open-cast mining) accounted for 27.8 % of primary energy consumption.

Modal split in passenger transport services

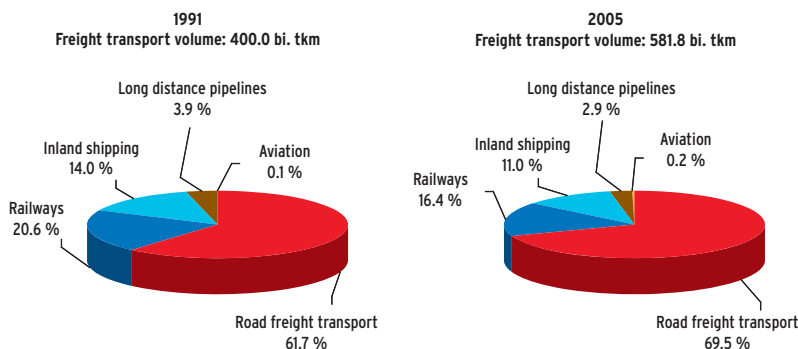


Source: Federal Ministry of Transport, Building and Urban Affairs 2006

The increase in transport volume between 1991 and 2005 amounted to 23.5 %, with individual motorised transport retaining its dominant position with a 21.9 % rise. Its share of total passenger transport volume declined slightly between 1991 (81.6 %) and 2005 (80.5 %).

By far the largest growth rates among all forms of passenger were those for air transport. Between 1991 and 2005 the transport volume in aviation over Germany rose by 132.7 %. During the same period the transport volume of public road and rail transport grew by 13.7 %. There was a 1.2 percentage point decline in the share of the overall transport volume accounted for by these relatively less polluting forms of transport. If non-motorised transport (pedestrians, cyclists) is included in the transport volume, a closer examination of passenger transport volume reveals that individual motorised transport dominated in 2004 with an 76.4 % share, well ahead of the ecomobility sector (pedestrians, cyclists, rail and road passenger transport) with 19.4 %. Focussing on the purpose of the journey, holiday and leisure travel with 43.1 % and travel for business and training with around 21.6 % account for the largest shares of personal transport volume. Business and official journeys make up 12.7 % and buying trips a further 17.2 % of passenger transport. 5.2 % of passenger transport volume takes the form of accompanied journeys.

Modal split in freight transport services



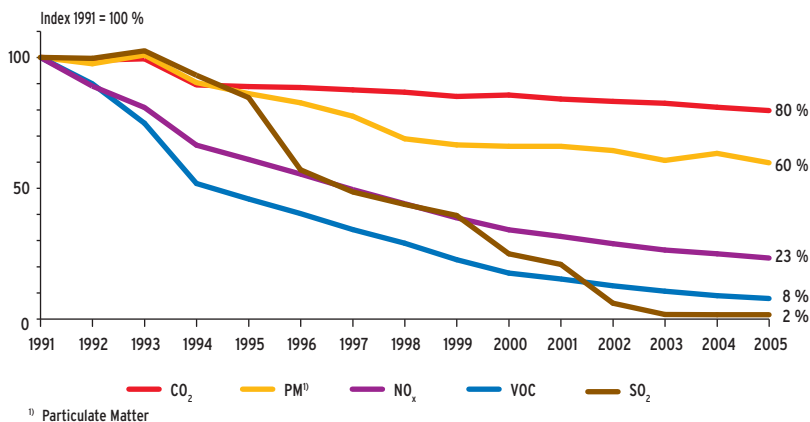
Source: Federal Ministry of Transport, Building and Urban Affairs 2006

Between 1991 and 2005 there was a 45.5 % rise in freight transport volume (excluding long distance pipelines).

The largest increases were in road freight transport (+ 64.6 %). Starting from a very low level, air transport volume more than doubled. The share of freight transport volume on the roads rose from 61.4 % (1991) to 69.5 % (2005). The increase took place largely at the expense of the railways and inland shipping, which impose less of a burden on the environmental, and accounted for roughly the same share as road freight transport in 1980, although this has since fallen to under 30 %.

Specific emissions in road transport (individual motorised transport)

Specific emissions by cars (emissions by cars/transport volume of cars)



Source: Federal Environment Agency 2006

The considerable reductions in SO₂ to 2 % or in VOC to 8 % contrast with a much smaller decline in CO₂ levels to 80 %. The emissions of fine particulates declined by 40 % to 60 % opposite to 1991.

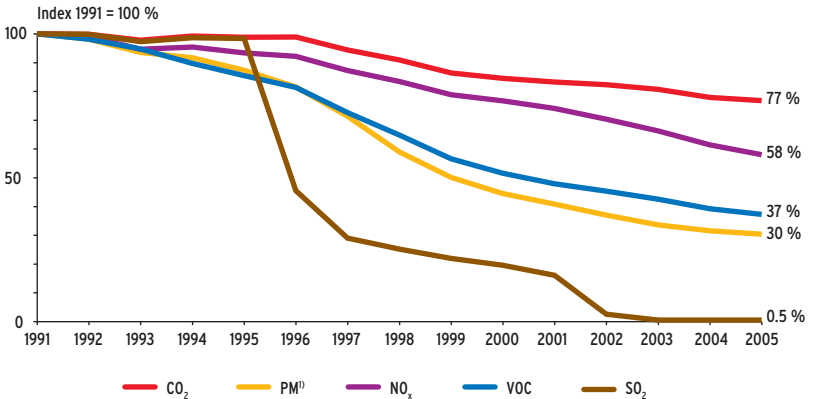
Compared with 1991 levels, specific emissions per transport volume (passenger kilometres) have been reduced in all sectors due to the technical improvements resulting from the phased imposition of stricter exhaust gas regulations for newly registered cars, the retrofitting of catalytic converters to older cars and higher quality fuels.

However, when we consider total emissions by passenger cars it is apparent that the reductions in emissions per passenger kilometre resulting from technical improvements have been almost completely cancelled out, in the case of CO₂, or partially, for other pollutants, by a general increase in the transport volume.

Between 1992 (47 %) and 2005 (98 %) there was a sharp rise in the proportion of less polluting cars. This trend is also reflected in the reduction in the specific emissions of pollutants produced by road traffic in Germany.

Specific emissions in road traffic (road freight transport)

Specific emissions by goods vehicles (emissions by goods vehicles/transport volume of goods vehicles)



¹⁰ Particulate Matter

Source: Federal Environment Agency 2006

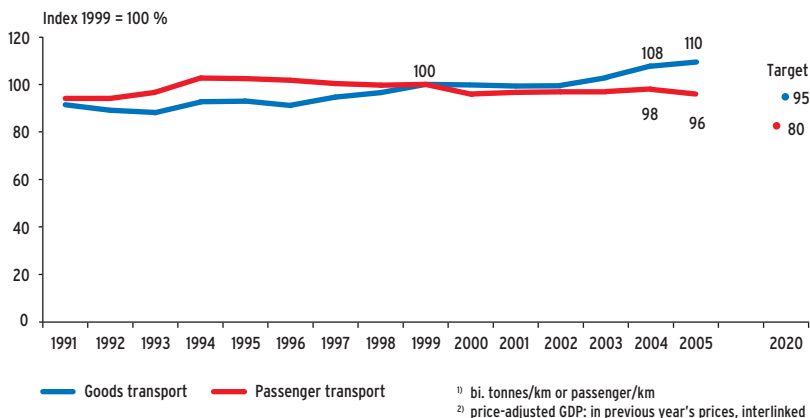
Considerable reductions in SO₂ to less than 1 % contrast with a much smaller decline in CO₂ levels to 77 %.

In almost all areas of road freight transport too the specific emissions per transport output (kilometre/tonne) compared with 1991 have fallen as a result of improvements in automotive technology and in the quality of fuels. Despite all the technical improvements that have been made, in 2005 total CO₂ emissions from road freight transport were 23 % higher than in 1991.

Turning to total emissions by road freight transport it is evident that, with the exception of SO₂ emissions, the reductions per kilometre/tonne produced by technical improvements have been cancelled out by a substantial increase in transport volume (to 160 % compared with 1991), either partially, (particulates and VOC) or almost completely (NO_x), and in the case of CO₂ these reductions have actually been outweighed.

With the climate gases and atmospheric pollutants that they emit, cars and goods vehicles have an adverse impact on the environment. Technical improvements to vehicles and fuels could reduce the specific emissions per motor vehicle. The impact of technical improvements can be shown by placing the total emissions per car/goods vehicle in relationship to their transport volume.

Transport intensity for passenger and goods transport

Transport intensity (transport volume¹⁾ per 1,000 EUR GDP²⁾)

Source: Federal Ministry of Transport, Building and Urban Affairs,
Federal Statistical Office 2006

At around 96 % the transport intensity of **passenger transport** in 2005 was slightly below the 1999 base value. However, the pace at which passenger transport volume is being decoupled from gross domestic product is still too slow.

In recent years freight transport volume has risen at a faster rate than the gross domestic product (GDP), and there has been a further increase in **freight transport** intensity to 110 % compared with the 1999 figure. Current developments show that there is actually a movement away from the desired objective of decoupling.

The transport intensity places the transport volume for passenger and goods transport in relation to the gross domestic product, the underlying idea being to decouple transport and economic development from one another.

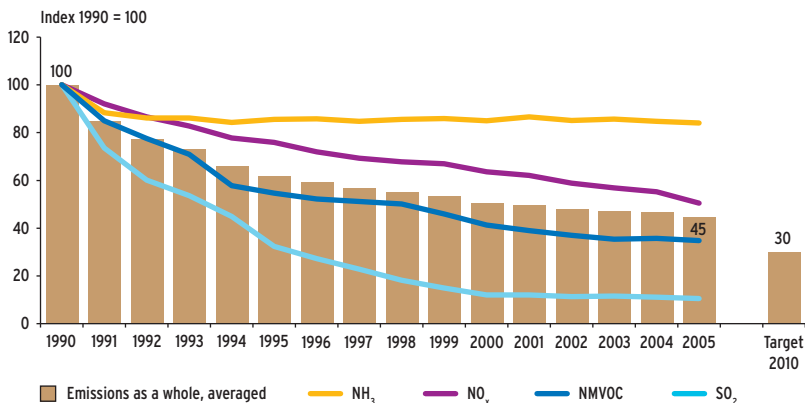
A decoupling of transport and economic development has thus still not occurred.

Road transport impacts in many ways on the environment and health. The share of CO₂ emissions accounted for by transport and that have an effect on the climate has now risen to one fifth of total emissions. Consequently, as far as climate protection is concerned, transport remains very much a problem area and one that requires additional political input both domestically and on a European-wide scale.

Despite declines, especially in the levels of pollution produced by lead, particulates, nitrous oxides and ozone, the airborne pollutants caused by traffic continue to pose a significant hazard to the environment and human health. Diesel soot particulates have been shown to increase the risk of lung cancer, while the combined effects of the various airborne pollutants are thought to be responsible for the increase in chronic respiratory ailments. The highest concentrations of airborne pollutants can be found in densely populated urban areas with high traffic volumes. Consequently a large proportion of the population is exposed to the aforementioned health risks. Traffic noise continues to be a major nuisance too. Acute and chronic exposure to traffic noise can result in disturbed sleep and, as a result of largely non-specific autonomous reactions, it heightens the general risk factors leading to cardio-vascular ailments. Health can be significantly impaired if night-time sleep, even below the waking threshold, is disturbed.

Airborne pollutant index of emissions

Airborne pollutant index of emissions



Source: Federal Environment Agency 2007

The airborne pollutant index shows the average value for the relative development of these four types of emission. Compared with 1990 it reveals a decline of some 55 % in the averaged percentage emissions of the observed gases, thereby enabling 79 % of the indicator target to be attained.

Following international agreements, the German sustainability strategy specified a reduction in airborne pollutants for emissions of sulphur dioxide (SO₂), nitrous oxides (NO_x), ammonia (NH₃) and volatile organic compounds excluding methane (NMVOC) by an average of 70 % by 2010 compared with 1990 levels. Readings are obtained of the pollutants SO₂, NO_x, NMVOC and NH₃ as percentage changes in emissions compared with 1990 in order to establish the extent to which the targets are being met.

Between 1990 and 2005 the emissions of sulphur dioxide were reduced by 90 % as a result of power station desulphurisation, the adoption of different fuels and the imposition of statutory limits on the sulphur content of liquid fuels. Other substantial reductions, by some 65 %, were achieved with volatile organic compounds (excluding methane), mainly through the introduction of catalytic converters in road traffic and the use of products with a lower solvent content as well as the reduced use of solvents in industry and manufacturing. The reduction by some 50 % in emissions of nitrous oxide is also mainly due to the installation of catalytic converters in vehicles, as well as the use of denitrification plants in power stations. Ammonia emissions mainly occur in agriculture, and in this area there were only slight reductions resulting from a decline in the numbers of livestock (by around - 16 %). Consequently, since the mid-1990s emissions of ammonia from agriculture have also been the dominant factor among the emissions of the combined acidifiers, i.e. sulphur dioxide, nitrous oxide and ammonia. In calculating the potential for acidification of these three pollutants, the much more pronounced decrease in emissions of SO₂ and even of NO_x, means that NH₃, and thus agriculture itself, have had a much greater influence. From a level of 16 % in 1990 the emissions from this source as a proportion of all acidifiers rose to over 42 % by 2005.

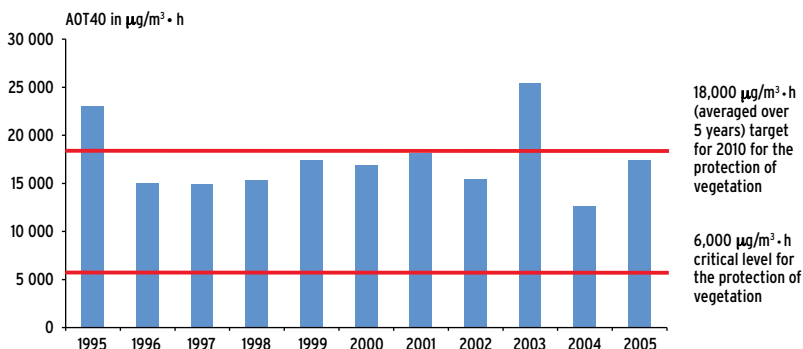
Effects on health and eco-systems

The link between respiratory ailments and airborne pollutants was made a long time ago. Protective measures concentrated initially on reducing the emissions of pollutants as a means of countering the risks to human health. The global problems associated with the emission of pollutants were recognised back in the 1970s. The gases, smoke, dust and soot that were released were distributed around the world in clouds and by the wind. Traces can even be found in the "permanent" masses of ice and snow in the Antarctic and Arctic.

Atmospheric pollution contributes significantly to the pressures on ecosystems and on the diversity of species. The existence of trans-boundary acid rain has been known since the 1970s, and it clearly shows that environmental problems can only be addressed through international efforts, in order to arrive at a European-wide solution to the problem areas of near-ground ozone, acidification and eutrophication caused by deposits of airborne nitrogen.

Exceedance of critical levels of ozone for vegetation

Ozone AOT40 average values (protection of vegetation) in $\mu\text{g}/\text{m}^3 \cdot \text{h}$, averaged over all rural background stations



Source: Federal Environment Agency 2006

AOT40 average values were measured at rural background stations for the years 1995 to 2005. These values are well above the critical level and do not indicate any distinct trend. The powerful influence of meteorological conditions on ozone pollution was evident particularly in 1995 and 2003. Unusual weather conditions existed in the summer of 2003, with intense radiation levels, providing conditions that favoured the creation of ozone. A very high ozone base was formed, with peaks during which the threshold values were exceeded. The full effects of this unusual pollution on the crown condition of forests first became apparent in 2004, as revealed by the findings of the nationwide survey of the state of German forests in that year.

The very complex conditions leading to the creation of high levels of ozone pollution from other airborne contaminants meant that, despite the decline in emissions of precursor substances in Germany that has been observed since 1990, only a very indistinct reduction in the corresponding reduction in ozone pollution occurred.

Near-ground ozone is harmful to vegetation. This damage can assume a direct form, leading to reductions in yields and in physiological function (for example leaf discolouration and die-back) or, in the case of trees, it can also have long term effects (such as increased sensitivity to pests).

The most sensitive receptors in Central Europe include beech, larch, pines and other forest trees as well as agricultural plants such as wheat and potatoes.

Ozone is formed near the ground from such precursor substances as nitrogen oxides (NO_x) and volatile organic compounds (VOC). Motor vehicles are an important source of emissions of precursor substances. In particular power stations are responsible for emissions of nitrogen oxide, while volatile organic compounds are produced through the use of paints and solvents. Some emissions also originate naturally.

Due to its high concentrations during periods of fine weather ozone is the main constituent of summer smog which is characterised by high concentrations of the so-called photo-oxidants such as ozone itself, as well as peroxides, aldehydes and organic nitrogen compounds. They are not emitted directly but are initially formed in the atmosphere through complex photochemical reactions.

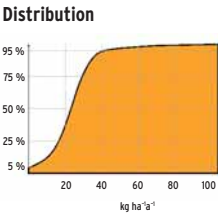
The extent and frequency of the short-term peak concentrations of ozone is determined by a number of factors, including the climatic record for the summer as a whole. Episodes of particularly high ozone concentrations occur in those years with long periods of fine summer weather. An episode is defined as at least 2 days of continuous situations during which the value of $180 \mu\text{g}/\text{m}^3$ is exceeded over wide areas.

Exceedance of critical loads for nitrogen

Exceedance of critical loads for eutrophying nitrogen 2004



Key	
kg ha ⁻¹	Proportion
none	4.27 %
0-10	7.84 %
10-20	24.94 %
20-30	40.21 %
30-40	17.9 %
40-50	2.52 %
> 50	3.02 %



Source: Federal Environment Agency 2007

Whereas recent years have seen a decline in the airborne deposition of nitrogen resulting from traffic and industry, the deposition of ammonia and ammonium derived from livestock farming have remained at a high level. Despite the slight fall in nitrogen deposition, the critical loads for eutrophying nitrogen are currently being exceeded across almost the entire range of sensitive ecosystems in Germany. It is mainly those parts of north western Germany where there is intensive livestock farming on sensitive soils that are affected by the deposition of (predominantly ammonium) nitrogen, thus causing the critical loads to be exceeded.

In the absence of any significant decrease in emissions of ammonia a further, widespread eutrophication of near-natural eco-systems can also be expected over the next years. There is consequently a pressing need for action to be taken to minimise widely distributed emissions of nitrogen.

Eutrophying nitrogen deposition in eco-systems cause long-term, chronic damage to plants, including nutrient imbalances and increased sensitivity to frost and pests. They can also lead to a loss of biodiversity. Plants and plant communities which are forced to rely on deficient sites are already on the Red List of world-wide endangered species of animals and plants. In the long term they have no chance of survival given the air pollution (immissions) to which they are they currently exposed and will be displaced by nutrient-loving (nitrophile) species. Because most species of animal are dependent on special types of plants, the decline in the diversity of plant species that continues to be observed in Germany also affects the diversity of animal species.

The critical loads for eutrophication are the critical rates of airborne deposition of nitrogen. If they are met, there will be neither an acute nor a long term harmful impact on such sensitive ecosystems as woodlands, heaths or bogs, according to present knowledge. In each case the concentration or deposition that can be tolerated is determined solely by the properties of the ecosystem under observation. The aim of the effect-based critical loads approach is to obtain a spatially differentiated comparison of the resilience of an ecosystem with actual rates of deposition of airborne pollutants.

Mapping critical loads forms an important part of European clean air policy, especially within the framework of the UNECE "Convention on Long Range Transboundary Air Pollution" (LRTAP Convention) and the EU National Emissions Ceiling Directive (NEC Directive).

Exceedance of critical loads for acid deposits

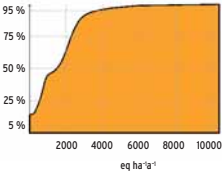
Exceedance of critical loads for acid deposits 2004



Key

eq ha ⁻¹	Proportion
None	14.18 %
0-1000	30.84 %
1000-2000	19.00 %
2000-3000	27.22 %
3000-4000	4.74 %
4000-5000	1.84 %
> 5000	2.18 %

Distribution



Source: Federal Environment Agency 2007

Deposition of acidifying sulphur and nitrogen compounds have declined in recent years. However, the critical loads for acidification are still being exceeded over a substantial part of the area occupied by sensitive ecosystems in Germany, where acidification is an ongoing problem. By the mid-1990s the highest deposition of acidifying substances and the highest critical load exceedances occurred in woodland areas of Thuringia and Saxony that are close to the sources of emissions. In the meantime the maximum levels were attained on sensitive soils in the lowland areas of northern Germany as a consequence of the high deposition of ammonium nitrogen from agricultural sources, especially from intensive livestock farming.

An economically and ecologically efficient reorganisation leading to the introduction of emission-reducing measures is therefore needed, aimed at the main emitters of ammonia (livestock farming).

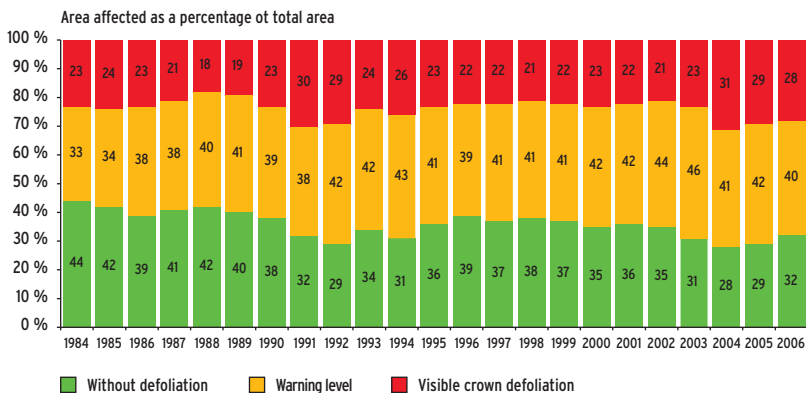
Acidifying airborne contaminants (immissions) are not only responsible for acute and chronic damage forests but also cause extensive changes in soil conditions leading to a levelling of very high acidic conditions. This can contribute to a reduction in the diversity of species. In the long term plants and plant communities which have to cope with neutral soil conditions have no hope of survival in the face of the current predominant immissions. They will be displaced by species that are better equipped to compete under acidic conditions. Because most species of animal depend on special types of plants, the decline in the diversity of plant species that continues to be observed in Germany also has an adverse effect on the diversity of animal species. In particular continued, drastic reductions should be made to the predominant and widely distributed nitrogen immissions in Germany, which are the cause of soil acidification and eutrophication.

Critical loads for acidification indicate the risk potential for the long term damage that sulphur and nitrogen deposition can have on sensitive ecosystems such as woodlands. The aim of the effect-based critical load approach is to provide a spatially and quantitatively differentiated picture of the stresses imposed on ecosystems by airborne pollutants.

Mapping critical loads is an important part of European clean air policy, especially within the framework of the UNECE "Convention on Long Range Trans-boundary Air Pollution" (LRTAP Convention) and the EU National Emissions Ceiling Directive (NEC Directive).

The development of forest damage

Forest damage of defoliation class 2 and above (all tree species)



Source: Federal Ministry of Food, Agriculture and Consumer Protection 2006

As revealed by the findings of the nationwide survey of the state of Germany's forests, by 2006 there had been a slight recovery compared with 2004, when crown defoliation was at its highest level since the survey was first conducted, but taking a long term view levels are still comparatively high.

The proportion of forest areas with visible crown defoliation (classes 2–4) amounted to 28 %.

The proportion of trees without crown defoliation rose by 3 percentage points between 2005 and 2006 to 32 %.

The proportion of forest at warning level (slight defoliation) fell by two percentage points to 40 %.

This situation exists in all the German states, with regional differences. It has deteriorated considerably in the Saarland (+ 14 percentage points), in Rhineland-Palatinate (+ 5 percentage points), Brandenburg and Mecklenburg-West Pomerania (+ 4 percentage points).

The crown condition of forest trees has been recorded annually since 1984, providing information about the state of their health.

The characteristic state of the treetops is attributable to the combined effect of various environmental factors. The weather, fructification, harmful organisms and the consequences of pollutant inputs over many years all have reciprocal effects. Drought stress and high ozone levels in 2003 also affected forest ecosystems, which had already been subjected to prior stresses as a result of long periods of input of acidifying and other substances from the atmosphere.

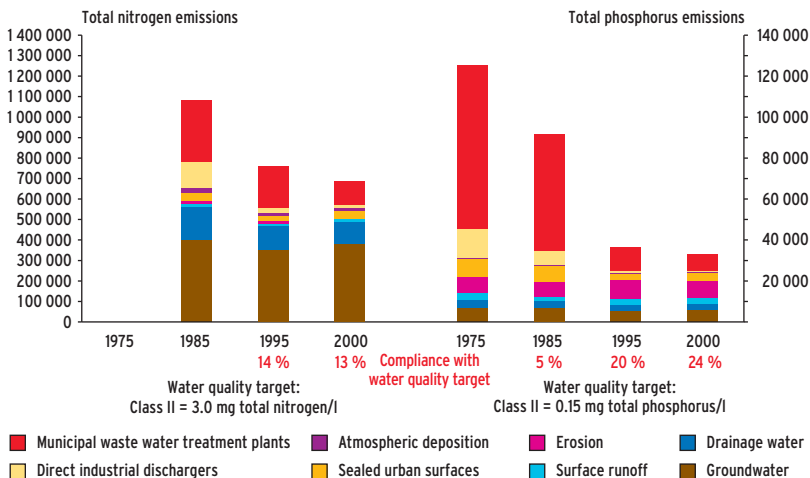
Reliable statements about the ecological state of forests and about their development are necessary in order to ensure that they can continue to fulfil all the functions that are important to us in the future. Environmental monitoring of forests was established in order to record and evaluate the state of forests using various indicators, so that the correct measures can be derived from this information and the effects of such measures can be correctly estimated. Forest ecosystems are influenced by various factors. In addition to natural influences (weather, attack by insects etc.) these also consist of inputs of pollutants as a result of human activity. These factors and the current state of the forests have reciprocal effects, which may intensify or weaken, with pollutant inputs from the atmosphere playing a key role.

Airborne pollutants derive mainly from industrial plants, power stations, traffic, homes, the activities of small scale consumers and (the most important source) intensive livestock farming. Among airborne pollutants, the groups of substances that are of particular significance for the state of forests are ammonia (NH_3), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ground-level ozone. Acting individually or in a complex interaction, these pollutants have varying effects on forest ecosystems. The following has been noted in particular: excess nitrogen in the overall system, acidification and base impoverishment of forest soils, as well as direct damage resulting from the effects of ozone. Case studies have also shown changes in the make-up of plant species in the ground vegetation.

Regular observations show with increasing clarity just how far-reaching the influence of airborne pollution is on forest ecosystems. Decades of sulphur and nitrogen inputs, for example, have led to long term changes in the soils of the forest floor, including a massive loss of nutrients and acidification. This is also accompanied by contamination of seepage water by nitrates, heavy metals and other pollutants. The extent to which forest ecosystems have been weakened is revealed by extreme situations such as those that occurred in 2003 (drought stress, high ozone levels).

Nutrient emissions in surface waters in Germany

Nitrogen and phosphorus emissions from point sources and diffuse sources in surface waters in t/a



Source: Federal Environment Agency 2003

Between 1998 and 2000 nitrogen emissions in Germany's surface water amounted to 688 kt/a, having fallen by 400 kt/a compared with the period 1983–1987, thus failing to attain the internationally agreed target of halving nitrogen emissions in the seas between 1985 and 2000. The actual 37 % reduction was achieved mainly through the sharp decline of 70 % in nitrogen emissions from point sources. Compared with this a decline of only 15 % was recorded for nitrogen emissions from diffuse sources.

During the period 1998–2000 phosphorus emissions into surface waters in Germany amounted to approx. 33 kt/a. Compared with the period 1983–1987 phosphorus emissions fell by approx. 59 kt/a or 64 %, thereby meeting the target of a 50 % reduction in phosphorus emissions into the oceans in all river basins. The decline in phosphorus emissions is also largely attributable to the reduction in emissions from point sources, which alone fell by 86 %. A reduction of only 13 % was achieved in the case of diffuse phosphorus emissions. This resulted in particular from the above-average decline of 59 % in emissions from urban areas.

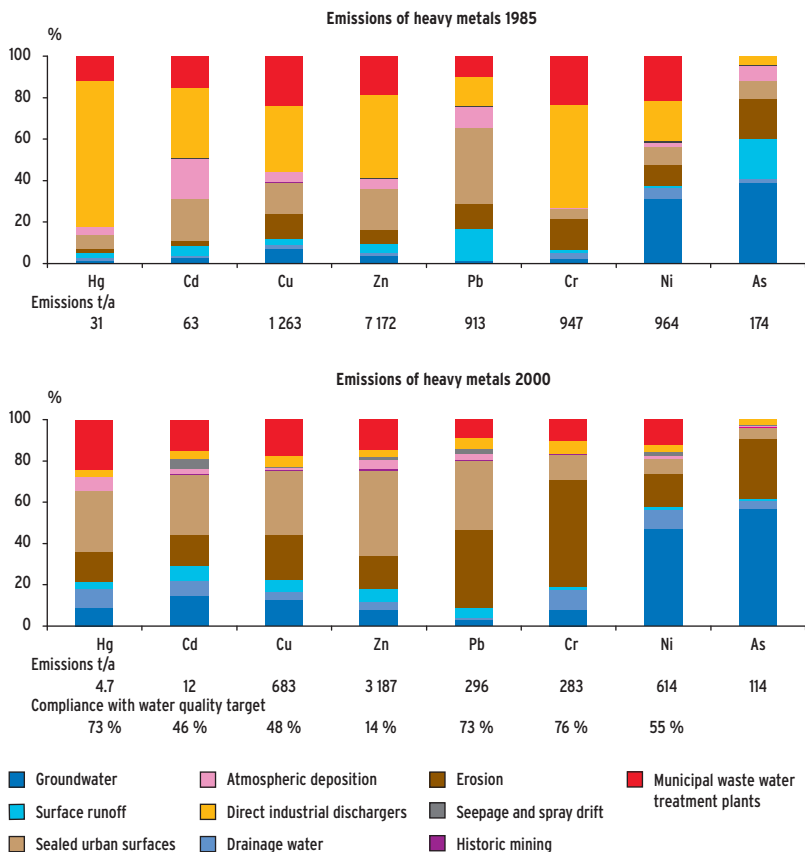
Inputs of biodegradable materials can adversely affect the oxygen balance of waters. Nutrients inputs can lead to the formation of algal blooms, affecting use of the water for bathing, drinking water extraction and similar purposes. A distinction is made between natural (geogenic), point and diffuse sources.

There is an increasing shift in the bulk of nutrient emissions to diffuse sources. Between 1985 and 2000 the nutrient sources attributable to agriculture declined by only around 15 % in the case of nitrogen, and increased slightly with regard to phosphorus (7 %). Diffuse nutrient sources are at their maximum at those places where high densities of livestock are kept on discharge-prone land. In the case of phosphorus this occurs in the far northwest with its swampy soils, and in the case of nitrogen throughout the entire northwest (sandy soils) and to certain areas in the foothills of the Alps (high run-offs). Although there was a sharp decline in the nutrient emissions into surface water up to 2000, their discharge remains at a very high level. Consequently in 2000, under the chemical classification of water quality (Federal States' Working Group Water LAWA 1998), quality class II and higher was reached for ammonium at only 54 % of 152 LAWA monitoring stations, for total phosphorus at 24 % of 151 LAWA monitoring stations, for nitrates at 13 % of 149 LAWA monitoring stations and for all nitrogen at 13 % of 138 LAWA monitoring stations.

The main reason for the observed nitrate enrichment of ground and surface water is the intensified agricultural use of the soil and cattle husbandry, with the ensuing production of excess nitrogen. Many of the developments taking place in agriculture and their consequences for nutrient emissions in waters can be seen in the national nutrient balance. The surplus shown by the balance is an indicator of the potential discharge to in ground and surface water. By comparison the surpluses in the total measure balance in agriculture represent the scale number for the potential, total environmental pollution arising from the agricultural use of nutrients. Due to losses in gaseous form into the atmosphere this is some 30 kg N/(ha • a) higher in the case of nitrogen. The nitrogen surplus in the farm gate balance has fallen by 27 % from its maximum in 1987, while the phosphorus surplus has declined by almost 80 % since 1980. Pollution currently remains static but at a high level.

Emissions of heavy metals in surface waters in Germany

Emissions of heavy metals into surface waters from point sources and diffuse sources



Source: Federal Environment Agency 2002

The input of heavy metals into surface waters has a negative impact on aquatic communities, requiring selective measures in order to reduce such inputs to inland waters and the oceans. Between 1985 and 2000 a sharp decline in emissions of heavy metals in surface waters was observed in Germany.

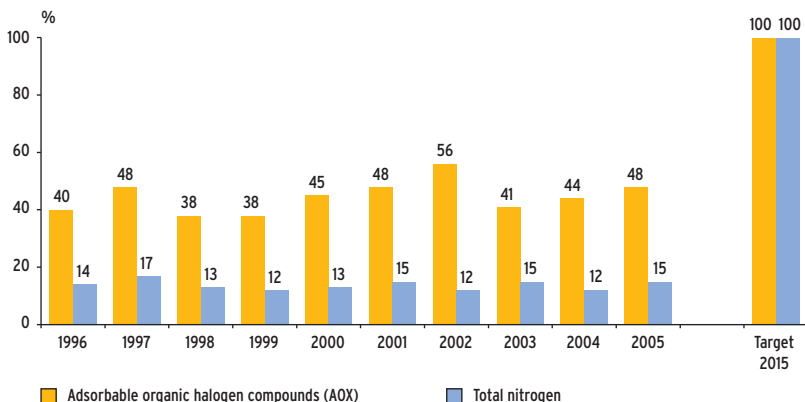
With the exceptions of arsenic and nickel, whose very high geogenic proportion cannot be influenced, the reductions specified by the International Convention for the Protection of the Sea, amounting to some 50 % (Cr, Cu, Ni, Zn and the metalloid As) or 70 % (Cd, Hg, Pb) have been attained or exceeded for the heavy metals named. They range from 36 % for nickel to 85 % for mercury and can be attributed above all to a drastic reduction in industrial discharges, by 74 % for nickel and up to 95 % for mercury. A decisive contribution to easing the pressure on the environment in this case has been made by the measures taken by industry, caused by tightening in the statutory requirements, and above all by the decline in industrial activity that has taken place since 1990 in the new federal (former East German) states. Direct discharges by industry only played a minor role in 1990. Although discharges from municipal waste water treatment plants continued to be important, in 2000 water pollution was dominated by diffuse sources.

The reduction in emissions from diffuse sources (farm seepage and spray drift, groundwater, surface runoff, drainage, erosion, atmospheric deposition onto surface waters, urban areas (combined sewers, separate sewers, residents not connected to a municipal sewage works or sewers)). Since the mid-1980s this has ranged from 5 % for copper and 72 % for cadmium, and is directly related to the decline in atmospheric emissions. In addition to the reduction in direct atmospheric deposits onto surface waters, which only account for a small part of the overall emissions, atmospheric deposition also has a direct influence on the inputs from surface runoff, especially from paved urban surfaces. No significant changes in the emissions into waters have been observed since the mid-1980s for other diffuse input paths such as erosion and groundwater.

The highest pollution from surfaces in 2000 was found in the Rhine catchment area. This can be explained by the high population density (approx. half of the German population lives in the Rhine area, although this only accounts for 30 % of the total area of the country) and by the concomitant high level of urbanisation and industrialisation. Thus cadmium, copper, mercury, lead and zinc form the main components of the emissions in the Rhine catchment area, from urban sources such as municipal waste water treatment plants, sewers and industry. In the Elbe and Oder river basins of eastern Germany the industrial decline following German reunification in 1990 has meant that no further increase in pollution has been observed.

Water quality class II for all nitrogen and adsorbable organic halogen compounds (AOX)

Proportion of monitoring stations with Grade II or better chemical water quality



Source: Federal Environment Agency 2006

Readings for **AOX** with a specified target of 25 µg/l (water quality class II) reveal an improvement in the composition of the water: the proportion of flowing waters (monitoring stations) where class II chemical water quality was maintained rose from 40 % in 1996 to 56 % in 2002, and in 2005 class II water quality was maintained at 48 % of monitoring stations. However, there are substantial annual fluctuations, which can also be accounted for by climatic influences.

Climatic influences also apply to total nitrogen, but the pollution that this causes is higher: only at an average of 14 % of monitoring stations was Grade II water quality maintained for total nitrogen (3 mg/l) during the period 1996–2005. Since 1996 readings have been fluctuating annually between 12 % (1999, 2002, 2004) and 17 % (1997), and are currently at 15 % (2005). This shows that measures to maintain water purity will be needed in future, especially with regard to the diffuse substance inputs, e.g. from agriculture. If we examine the distribution of grades for total nitrogen at 137 identical monitoring stations for the period 1996 to 2005 a slight decline is observable at those monitoring stations with increased pollution (class II and worse). This can be attributed above all to the impact of improved waste water treatment by industry and municipalities.

During the period 1996 to 2005 water quality was determined for the parameters AOX at 82 and total nitrogen at 137 identical monitoring stations belonging to the network of stations for monitoring flowing water that are operated by the Working Group of the Federal States on water issues (LAWA). In evaluating the data it should be borne in mind that, although the two parameters AOX and total nitrogen are important areas, they by no means encompass all the material aspects of the composition of water. Moreover intervention in the structure of waterways (e.g. by shipping, use of waterborne craft or flood protection), which can significantly reduce the ecological quality of waters, is not taken into account. AOX and total nitrogen should therefore be seen as examples of water quality parameters. The two summary indicators primarily enable industrial pollution from point sources (AOX, adsorbable organic halogen compounds) and diffuse pollution from agriculture and transport (total nitrogen) to be registered.

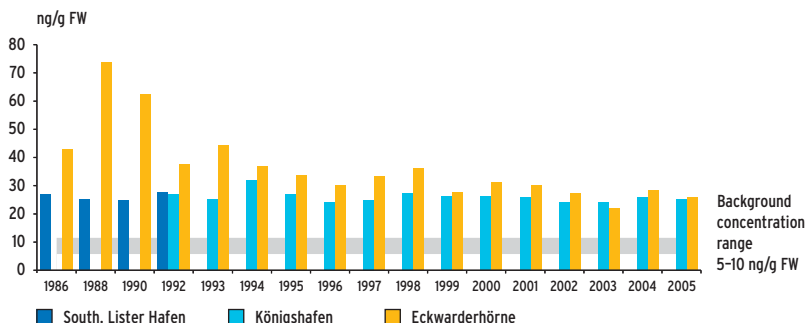
In conducting an evaluation it should be taken into consideration that the effects on waters of the measures already undertaken by agriculture will not become apparent for another 5–30 years, due to the slow rate of flow of groundwater. Consequently the successes that have already been achieved may not be immediately evident.

The increased contamination of rivers and lakes by nutrients and pollutants poses a threat to the natural functions and uses of waters.

Water contamination by organic environmental chemicals (such as AOX) and other pollutants (such as heavy metals and nutrients) has declined in recent decades as a result of measures to keep rivers and lakes clean (e.g. construction of waste water treatment plants).

Concentrations of heavy metals in organisms in the North Sea

Mercury in common mussels



Source: Federal Environment Agency 2006, German Environmental Specimen Bank

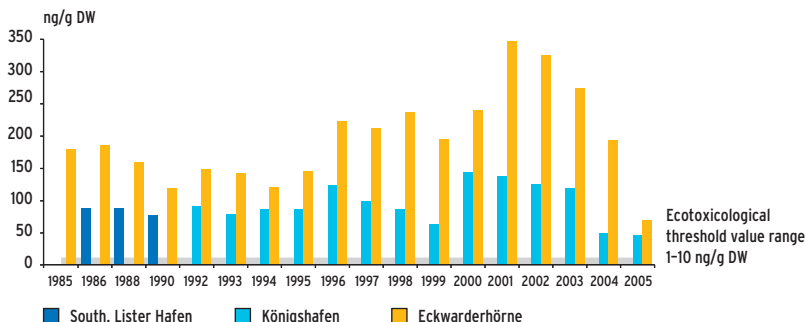
A comparison over a period of time revealed that common mussels obtained from the bay known as Jadebusen (near Eckwarderhörne) from 1985 to 1993 were much more highly contaminated with Pb, Cd and Hg than those from the Sylt-Römö mudflats (List/Königshafen). During subsequent years (1994 to 2005) this distinction became less pronounced because of the tendency for mussels from Jadebusen to be less contaminated, while the contamination of mussels from the Sylt-Römö mudflats remained much the same or increased slightly.

The concentration ranges for the natural background for metals in common mussels as determined by OSPAR (Convention for the Protection of the Marine Environment of the North-East Atlantic) for the entire northeast Atlantic (including the North Sea) were used in the evaluation. They amount to Hg 5–10 ng/g, with reference in each case to the fresh weight (FW). Although the mercury content of common mussels at the two places in the North Sea where samples were obtained has fallen since the late 1980s, it is still significantly above the background concentration. For flatfish such as flounders OSPAR only provides a background value for Hg in fish flesh of 0.03–0.07 mg/kg fresh weight (FW). Compared with this background value the concentrations measured in flounders are also higher.

In evaluating concentrations of pollutants with regard to “human health” the relevant maximum amounts in foodstuffs for Pb (1.5 µg/g FW mussels and 0.2 µg/g FW fish flesh) have been laid down by the European Communities. The concentrations of Pb and Hg in mussels and Hg in flounders that have been shown to exist along the German North Sea coast are significantly below these maximum amounts.

Organic tin compounds in organisms in the North Sea

Tributyl tin in common mussels



Source: Federal Environment Agency 2006, German Environmental Specimen Bank

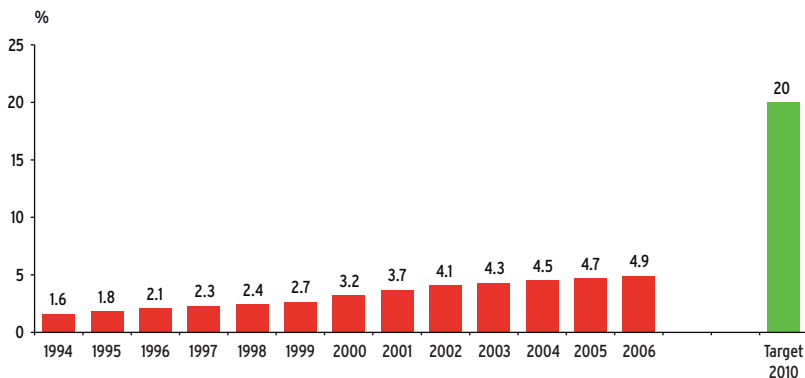
Between 1985 and 1999 there was a very significant decline in the marine sector in the contamination of biota by triphenyl tin compounds, while the concentrations of tributyl tin (TBT) in tissue remain constant and at a high level. By the early 1980s the far-reaching damage to marine organisms caused by organic tin compounds was already evident, and this manifested itself in particular in the impaired reproductive capability of snails and oysters or even their complete sterility.

In order to identify potential problem areas OSPAR applied an ecotoxicological threshold range of between 1 and 10 ng/g DW for TBT in common mussels. During the observation period (1986 to 1999) the TBT concentrations in common mussels obtained from List/Königshafen exceeded this indicator value for potential problem areas by a factor of between 5 and 11, and in the mussels from Eckwarderhörne by between 10 and 20 times. Comparative observations of the concentrations of organic tin compounds in common mussels, the muscle tissue of breeding eels and herring gull eggs provide no hint of any bio-magnification of these substances within the marine ecosystem under investigation.

The constant level of contamination with TBT is likely to be the result of continuing, undiminished use of antifouling paints containing TBT in commercial shipping. Results indicate that the ban on its use on leisure craft in marinas has had a positive effect. A significant reduction in the pollution of marine ecosystems outside this local area as a result of this measure cannot be expected because leisure craft only account for some 10 % of all sales of antifouling paint.

Organic farming

Area under organic cultivation as a proportion of the entire cropland



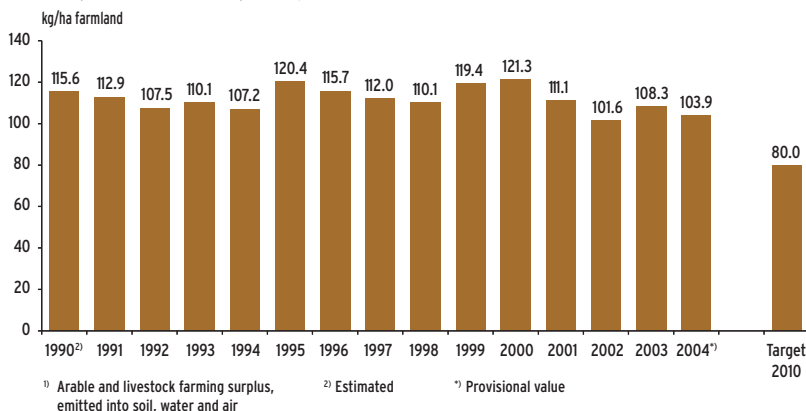
Source: Federal Ministry for Food, Agriculture and Consumer Protection 2007

In 2006 in Germany 4.9 % of the area under cultivation was being worked in accordance with the principles of organic farming. In a European-wide comparison, in terms of area Germany is therefore above the EU average (as per 2006), approximately in the middle of the range, but below Austria (13 %), Italy (9.0 %), Finland (6.4 %) and Denmark (5.5 %). By the end of 2006 a total of 17,557 holdings were cultivating an area of 825,539 ha in accordance with the EU rules on organic farming. Compared with the previous year this represented an increase in the number of holdings operating in accordance with EU rules by 3.2 % and a 2.2 % increase in the area under cultivation.

Organic farming is a form of agriculture that is particularly resource-efficient, environmentally sound and animal-welfare-friendly. The application of the principles of organic farming avoids the use of mineral nitrogen fertilisers and chemical/synthetic pesticides. The amount of livestock is limited by the area available. This kind of farming strives to maintain closed nutrient cycles as a way of avoiding pressures on the environment. Humane animal husbandry and diverse crop rotation are other features of organic farming.

Nitrogen surplus

German gross balance nitrogen surplus¹⁾



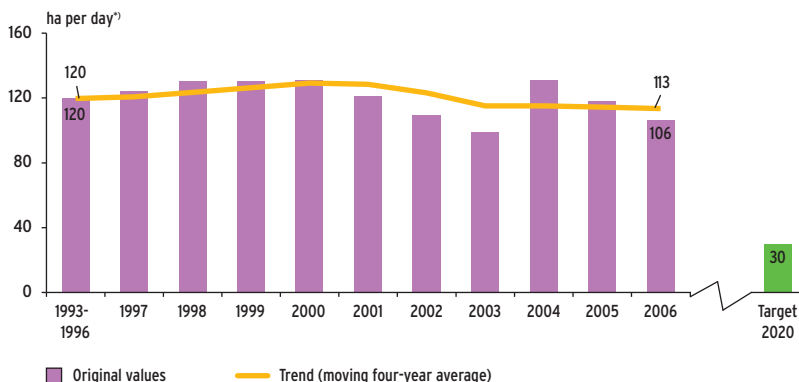
Source: Federal Environment Agency, details supplied by M. Bach, University of Giessen 2006

Nitrogen surpluses have declined overall by 8 % since 1991. The Federal Government's objective of reducing the surpluses to 80 kg per ha annually by 2010 can only be achieved if there is an average annual decrease of 4 % from 2004 onwards. Stricter limits on nitrogen surpluses can be expected in future under the provisions of the Fertiliser Ordinance of 2007, which lays down requirements for the use of fertilisers in agriculture.

In 2004 mineral fertilisers accounted for 66 % of the nitrogen entering the German agricultural sector, 21 % being derived from livestock feed imports; 6 % being obtained via the air (deposition, e.g. from vehicle exhausts); and the remainder being attributable to nitrogen that is fixed biologically by legumes (e.g. clover or peas), which have the ability to bind large quantities of nitrogen from the air. Between 1991 and 2004 the annual amount of nitrogen entering the system rose slightly (7 kg/ha decline in the case of feeds, but a 13 kg/ha increase for fertiliser), while the amount removed via harvested crops increased by 10 kg/ha (20 %). This can be accounted for above all by increased plant yields and greater utilisation of feeds accompanied by a reduction in the numbers of livestock. We can therefore conclude that nitrogen is being dealt with more efficiently.

Land use

Expansion of settlement and transport areas



^{*)} The land survey is based on an evaluation of the land registers of the *Laender*. Due to the conversion work carried out in the official registers (recoding of types of use in the course of digitalisation) the way that the increase in area is presented is distorted at the current margin.

Source: Federal Statistical Office, Federal Office for Building and Regional Planning 2007

Compared with the period 1997–2000 the daily demand for land during the period 2003–2006 declined from 129 ha to 113 ha but remains at a high level. The nationwide increase amounts to some 74 ha per day in the former West German *Laender* and approx. 39 ha per day in the new *Laender* (including Berlin).

In 2006 settlement and transport areas amounted to 46,438 km² (equivalent to 4,643,800 ha) or 13 % of the land area of Germany (357,115 km²). Settlement areas accounted for 28,811 km² or 8.1 %, and transport areas for 17,627 km² or 4.9 %.

The decline is mainly due to a reduced investment in construction, a consequence of the economic situation. Thus no real reversal of the trend is assured. Economic recovery can be expected to lead to an increase. A wide-ranging re-orientation of settlement and transport policy at national, state and municipal level is required in order to reduce the daily increase in settlement and transport areas to 30 ha per day by 2020.

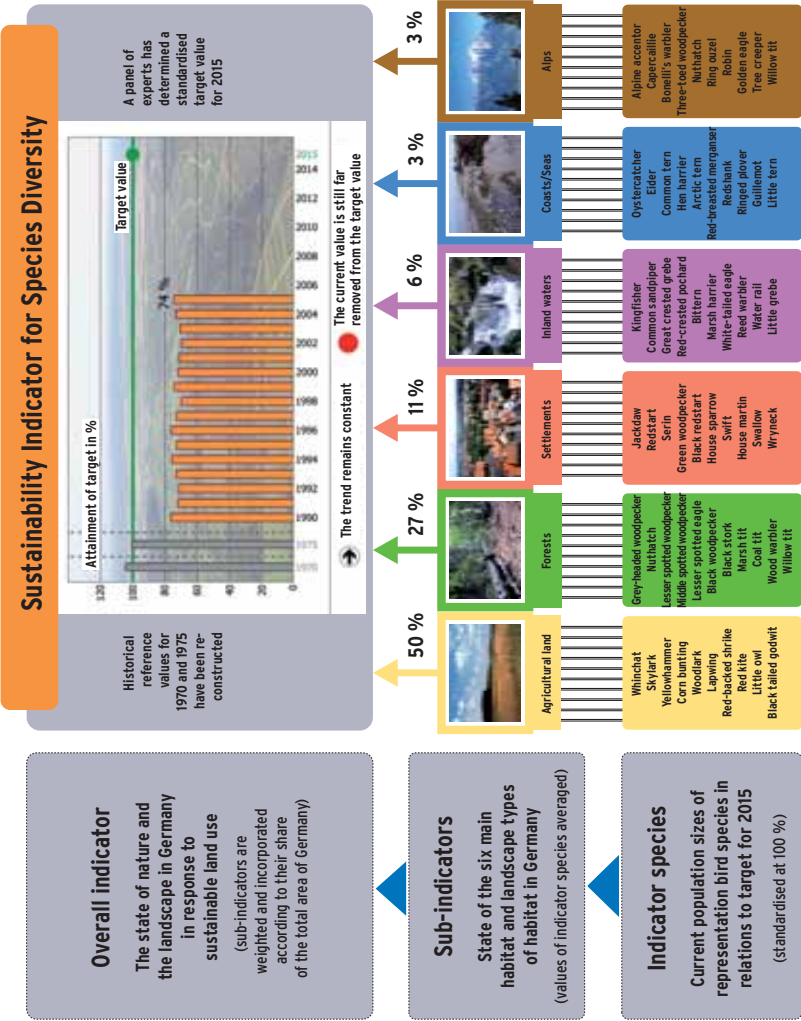
The indicator "land use" represents a potentially negative impact on natural areas and natural soil functions as a consequence of sealing and urban sprawl. Moreover, at a highly aggregated level, it indicates a departure from sustainable housing, consumption and mobility.

Both qualitatively and quantitatively, land should be treated in a way that enables it to provide future generations with a sufficient range of options. In such a densely populated country as Germany it is vitally important to retain the ecological functions of the soil as the basis for life, as a habitat for humankind, animals and plants, and as a component for maintaining the balance of nature, with its hydrological and natural cycles. At the same time there must be further development of existing and future land use in order to promote the sustainability of various different functions, e.g. for settlements, recreation and transport, for the production of foodstuffs and renewable raw materials, for economic and public uses and for nature conservation.

Therefore sustainable land use is aimed not only at reducing any additional demand for land and making efficient use of existing land, but also at achieving improvements in an ecological sense.

Proposed measures and instruments should therefore concentrate primarily on curbing the expansion of settlements and the increased transport links that this implies. A large number of coordinated measures are therefore needed in order to achieve an effective, long term reduction in the constant demand for new areas for settlement purposes. On the other hand the expansion of the areas required for supra-local transport routes is important, in particular with regard to land fragmentation.

Diversity of species - Species of birds according to type of main habitat



Source: Federal Agency for Nature Conservation 2007

The sub-indicators for farmland, forests and coast/sea have remained more or less stable since 1990. Since 1990, there has been a slight downward trend in the sub-indicators for settlements and Alps. In the sector of settlements this negative trend is attributable to losses of near-natural areas and village structures through building activity and the sealing of land areas. In the Alps, increasing settlement activity, intensified agriculture and the abandoning of traditional farming methods (e.g. on Alpine pastures) have had a negative impact. In contrast, the sub-indicator for inland waters reveals a slightly positive trend, which is linked with the significantly improved water quality at many locations.

The Sustainability Indicator Species for diversity is intended to reflect the state of nature and the landscape and the changes occurring to them in Germany. It is based on the trends of the population size of 59 selected species of birds, which serve as indicator species for the quality of their habitats and thus represent developments in the landscape in general. The selected bird species are representative of the changes in the population sizes of many other species, the quality of habitats and the suitability of the landscape for other species.

The indicator is made up using sub-indicators for the main types of habitats and landscape in Germany: farmland, forests, settlements, inland waters, coast and sea, and Alps. In cooperation with the Bird Protection Offices of the Länder and the Federation of German Avifaunists (DDA), 10 or 11 representative bird species were selected for each of the main habitat types, illustrating the various characters and uses.

Area and number of undissected areas with low traffic intensity

Distribution of undissected areas with low traffic intensity (UAT) in Germany

Federal Land ¹⁾	In-habitants per km ² 2)	UAT ³⁾ (in km ²)	UAT (in % of Land area)		Number of UAT ⁴⁾	
			1998	2003	1998	2003
Baden-Wuerttemberg (BW)	299	3 328	11	9	25	22
Bavaria (BY)	176	10 775	20	15	76	61
Brandenburg (BB)	87	14 625	53	50	80	75
Hesse (HE)	288	2 289	12	11	16	14
Mecklenburg- West Pomerania (MV)	75	12 256	54	53	67	63
Lower Saxony (NI)	168	10 223	19	21	58	59
North Rhine-Westphalia (NW)	530	868	3	3	6	4
Rhineland-Palatinate (RP)	204	3 062	16	15	22	19
Saxony (SN)	235	2 325	24	13	28	14
Saxony-Anhalt (ST)	123	6 378	29	32	34	33
Schleswig-Holstein (SH)	179	1 780	10	11	12	12
Thuringia (TH)	147	5 476	41	34	36	33
Germany	231	73 541	22	21	480	422

¹⁾ Due to their small size, Saarland (SL) and the city states do not appear in the table

²⁾ Source: Statistical Offices of the Federal Government and the Laender (2004)

³⁾ Total area incl. UAT spaces that span Land borders

⁴⁾ Due to some UAT spanning Land borders, the total of the UAT in the Laender does not match the number of UAT in Germany

Source: Federal Agency for Nature Conservation 2004

Some 21 % of the total land area of Germany still consists of UAT, with a minimum area of 100 km² (as of 2003). Expressed as a percentage, in the East the UAT occupies 13 % of the land area in Saxony and up to 53 % in Mecklenburg-West Pomerania, which is substantially higher than in the lowland states of the West, i.e. North Rhine-Westphalia with 3 % and Lower Saxony with 21 %.

The proportion of the total area of Germany which is taken up by settlements and transport infrastructure is constantly increasing. This should be seen not only as a conversion of open spaces into sealed settlement and transport areas but also as a far-reaching restriction on the ability of the balance of nature and the landscape to function effectively and efficiently. Further fragmentation and the creation of scattered “islands” in the landscape means an irreversible loss of habitat for most species of animals and plants. Set up as nationwide collective indicators, the UATs are also ideally suited for registering other functions of the balance of nature such as the accumulation of groundwater and natural soil functions. Those open areas of landscape with low traffic densities which are located in the immediate vicinity of densely populated urban areas can also have a positive effect on the urban climate by assisting with the circulation and exchange of air. It is also important to retain areas which are largely unfragmented and silent in order to enable people to experience nature. This is therefore, in the vicinity of intact UATs with the corresponding natural assets, plans for infrastructural development, settlements and industry should be rejected, as should large scale tourism projects.

The Federal Agency for Nature Conservation defines UAT as areas

- with a minimum size of 100 km²,
- which are not intersected by any roads with an average traffic density exceeding 1,000 veh./24 hrs,
- which are not intersected by any railway lines (single or multiple track) and
- which do not contain any areas of water occupying more than half the total area.

Smaller unfragmented UAT of less than 100 km² are also vitally important in more densely developed areas and in immediate proximity to conurbations. According to a proposal submitted by the Federal Environment Agency, in addition to large, open areas of UAT in excess of 100 km², the number of existing unfragmented areas measuring more than 140, 120, 100, 80 and 64 km² should also be retained in the future.

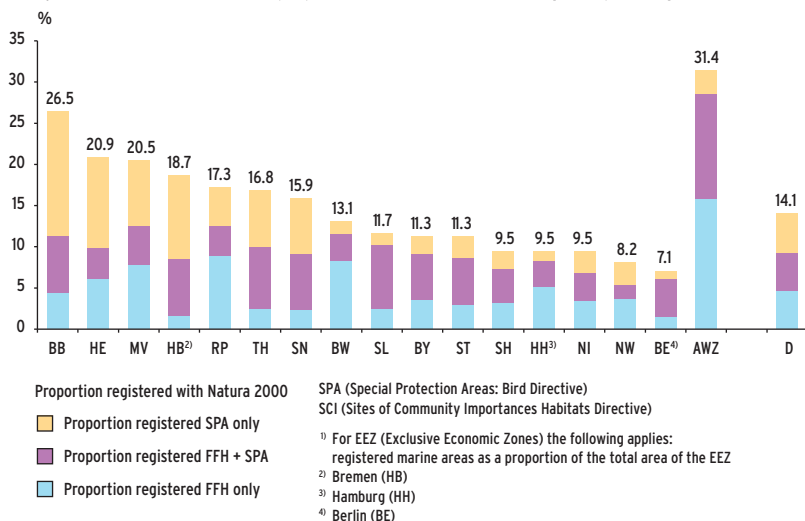
The UMK (Conference of Ministers of the Environment) indicator “Landscape Fragmentation” supplements the UAT with the addition of a sub-indicator “effective grid width (m_{eff} in km²)”, showing the average degree fragmentation. The effective grid width is a calculated average value for the size of the transport network grid, according to a method developed by Jaeger, J. (2002), and in addition to the size of all subspaces it also takes into account the structure of the fragmentation of the entire area under consideration.

The use of two sub-indicators combines the advantages of these two methods

- UAT – large unfragmented areas > 100 km² with low traffic density are considered to be particularly deserving of protection and easily placeable,
- M_{eff} – provides a spatially inclusive statement and is particularly relevant in those regions where there are few remaining large, undissected areas with low traffic intensity.

Designation of sites in Germany for Natura 2000

Designated terrestrial sites as a proportion of the area of Germany¹⁾ (as per: May 2007)



Source: Federal Agency for Nature Conservation 2007

So far designated of 14 % of the terrestrial area of Germany has been proposed or registered as NATURA 2000 areas.

In the Exclusive Economic Zone (EEZ) ten areas covering 1,039,270 ha, corresponding to 31.4 % of the German EEZ, have been designated as NATURA 2000 sites, with 15.6 % of German EEZ being occupied by SPA's and 28.6 % of German EEZ taken up by SCI's.

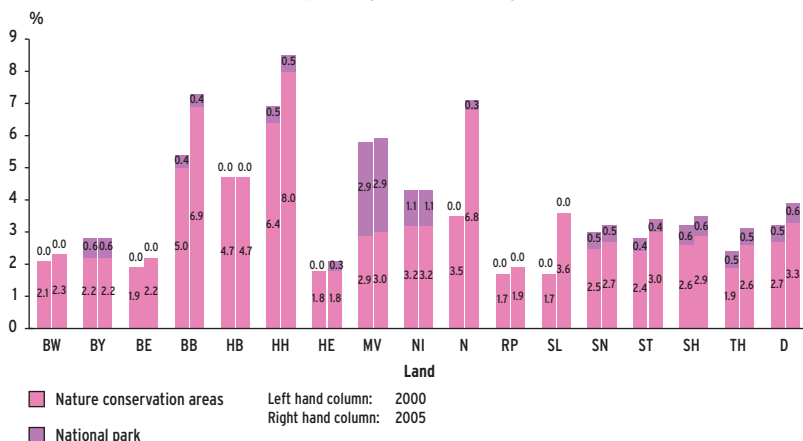
The indicator “Designated Natura 2000 sites in Germany” shows the proportion of the sites in Germany which enjoy protection within the scope of the implementation of the two European nature conservation directives – the Bird Directive and the Habitats Directive. Natura 2000 is a EU-wide, ecological network of protected areas which have been nominated and designated in accordance with the two directives. These sites are of importance for the whole of Europe with regard to habitats and animal and plant species meriting special protection. There have been wide differences in the implementation of the two directives in the EU, and the state of nominations in Germany has been uneven too.

The approval of the Habitats Directive by the European Community (FFH Directive, 92/43/EEC) in 1992 provided the first comprehensive European basis for the protection of species and biotopes. The Bird Protection Directive (79/409/EEC) for safeguarding birds and their habitats came into force in 1979.

The main objective of the Habitats Directive is to provide lasting protection for and preservation of biodiversity throughout the territory of the European Union by means of a system of reserves set up in accordance with a set of uniform criteria. However, biodiversity cannot be maintained solely through the protection of individual sites but also requires the preservation and creation or restoration of a network of biotopes. For this purpose the Directive lists natural habitat types (Appendix I) and species (Appendix II) whose distribution and range are to be used as criteria when choosing sites suitable as areas of conservation.

In Germany they comprise a total of 91 habitat types and 133 species of animals and plants (excluding birds), distributed across three bio-geographical regions (alpine, Atlantic, continental). Germany bears a special responsibility for protecting these habitat types and these species of plants and animals. According to the directive, areas suitable as reserves must be selected for all types of habitat and species. German nominations for the SCI's have now been completed, and subsequent registrations for SPA's from a number of Laender are expected in 2007 and 2008. Because the site designation process and its progress is so important, not only for Germany but also for the European Commission, the “Designation of sites in Germany for Natura 2000” is also vital, especially with regard to Germany's position in international nature conservation work.

Strictly protected areas

Nature conservation areas/national parks by area in Germany and in the Laender¹⁾

¹⁾ Excluding areas of water in national coastal parks in NI, HH, SH, MV

Source: Federal Agency for Nature Conservation 2007

During the period shown there was a sharp rise in the allocated nature conservation areas in the following Laender: North Rhine-Westphalia, Brandenburg, Saarland and Hamburg. This increase in the area of nature conservation areas can be interpreted in different ways: the causes can be seen in the growing threats to species, biotopes and sections of the countryside, or in the increased efforts being made by the Laender to protect species and biotopes.

So far there have been considerable differences between the efforts made by the various *Laender* to safeguard ecologically valuable areas by designating nature conservation areas and national parks, the so-called strictly protected areas. In the case of the national parks this is linked with a number of factors including the existence of relatively few large, contiguous, natural areas of landscape in Germany. The designation of nature reserves correlates among other things with the extent of the threat facing certain sections of the landscape and to some extent with the political will of the responsible administrative authorities.

Only the terrestrial areas of the individual national parks have been included in the calculations. The Waddensee tidal mudflats and coastal national parks in the *Laender* of Lower Saxony, Schleswig-Holstein, Mecklenburg-West Pomerania and the city of Hamburg, a Land in its own right, occupy large areas of coastal waters in the North Sea and the Baltic. No allowance has been made for these marine areas, because otherwise it would not be possible to make an effective comparison with the inland *Laender*.

However, particular attention should be drawn to the efforts of the coastal *Laender* in recent years to incorporate the ecologically valuable, unique habitats of the mudflats and coastal waters within the overall protection of national parks, thereby making a significant contribution to safeguarding the biodiversity of these types of habitat in Germany.

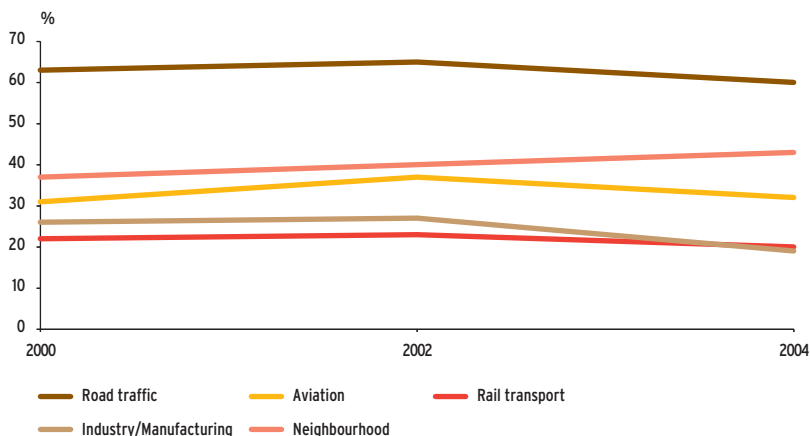
Moreover, looking at the country as a whole, it is evident that a number of low-land *Laender* such as Rhineland-Palatinate, Baden-Wuerttemberg and Saarland have not yet designated any national parks, while the restricted land areas of the city-*Laender* generally do not offer sufficient natural space.

However, when making comparisons, it becomes apparent that Hamburg and Bremen, both of them cities which are also *Laender*, do contain a larger than average share of nature conservation areas. In the case of the larger *Laender* the areas occupied by nature conservation areas in North Rhine-Westphalia and Brandenburg can be classed as above average. With nature conservation areas occupying an above-average area, the last-named Land is leading the way for other *Laender*. Smaller areas are occupied by nature conservation areas in Hesse, Rhineland-Palatinate, Bavaria, Berlin, Baden-Wuerttemberg, Thuringia and Saxony.

So far the increase in the areas designated as nature conservation areas and national parks has not prevented the loss of other areas suitable for this purpose elsewhere (e.g. through intensified land use, direct loss of available land or the abandonment of the forms of extensive land use that help to promote nature conservation). No reversal of the trend, indicating more sustainable protection for biodiversity, is yet apparent among species and biotopes featured on the Red List.

Noise pollution

Proportion of the population claiming to be adversely affected by noise



Source: Federal Environment Agency 2005

As in previous years the predominant source of noise in residential areas is road traffic, which is regarded as an annoyance by more than half of the population, and as a severe annoyance by 10 %. Aviation is second only to road traffic as the main cause of noise produced by transport in Germany. Throughout the country one in three people feel disturbed by aircraft noise, while rail transport is regarded as causing an annoyance by around one fifth of the population.

Noise from neighbours is also listed among the main causes of undesirable noise, and is reported by more than 40 % of the population.

Industry and manufacturing cause annoyance to one fifth of the population.

Every sound that can result in disturbance, annoyance, interference or harmful effects is referred to as noise. Noise cannot be registered using physical measurement methods because it is the result of a cognitive exposure to sounds. However, the physical properties of sounds can be measured in terms of the acoustic pressure, spectrum of sounds etc. The disturbance produced by the noise is shown by the acoustic pressure level, in decibels (dB(A)). Hardly anyone in Germany remains unaffected by noise, as revealed by a representative survey of some 2,000 adults on the subject of "Environmental Awareness in Germany 2004".

Sounds can not only cause an annoyance, they can also interfere with communication and intellectual work, as well as presenting a health hazard through chronically impaired sleep and recreation.

Scientists regard serious annoyances as an indicator of states of stress.

The noises produced by road and rail transport can provoke vegetative and endocrine reactions (extra-aural effects). With open windows, night-time levels in excess of 45 dB(A) can be expected to result in disturbed sleep, and at levels above 65 dB(A) during the day there is an increased risk of cardiovascular diseases, for example.

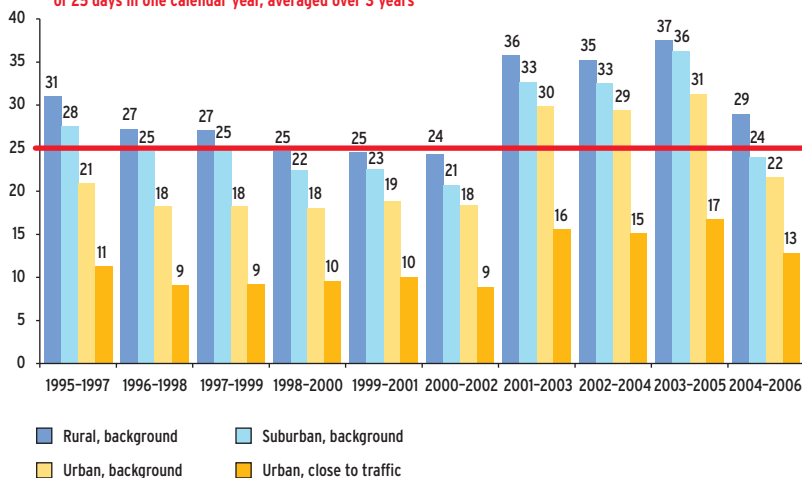
Epidemiological studies suggest a link between traffic noise and ischaemic heart diseases (e.g. angina pectoris, infarction). According to model calculations by the Federal Environment Agency it is thought that some 12 mi. people in Germany are at increased risk of ischaemic heart disease due to traffic noise. Currently we can expect a substantial increase in risk at a daytime immission level of 65 dB(A) and a night-time level of 55 dB(A). Consequently, noise below this level is an indication that the desired environmental quality objective has been attained. Compared with the findings of earlier investigations, newer studies, conducted in 2004, do not reveal any threshold value for an increased risk. This means that, even at moderate immission levels, there is a slightly increased risk of cardiovascular problems.

Near-ground ozone – frequency with which threshold values are exceeded

Number of days on which target ozone value ($120 \mu\text{g}/\text{m}^3$), for protecting human health, is exceeded

Number of days averaged over 3 years, and the respective type of monitoring station

$120 \mu\text{g}/\text{m}^3$ as an 8-hour average value may be exceeded on a maximum of 25 days in one calendar year, averaged over 3 years



Source: Federal Environment Agency 2007

The highest number of days on which the levels are exceeded is registered at rural and suburban monitoring stations. Emission levels are lower (for example nitrous oxides) in these regions, with the result that the decomposition of ozone takes place more slowly. Averages are taken over a 3 year period in order to take the meteorological variability of recent years into account. The desired target value has been exceeded in many areas of Germany over the past 6 years. The aim is that, by 2020, the 8-hour average value of $120 \mu\text{g}/\text{m}^3$ during a calendar year should no longer be exceeded. In 2006 this value was exceeded almost everywhere in Germany.

The concentrations of near-ground ozone in Germany were monitored by the Federal and *Laender* authorities at 286 stations in 2006.

From 2010 onwards a target value for ozone will be established to protect human health. $120 \mu\text{g}/\text{m}^3$ as an 8-hour average may not be exceeded more than 25 times in any calendar year, averaged over three years. The intention is that the 8-hour average value of $120 \mu\text{g}/\text{m}^3$ during a calendar year should no longer be exceeded by 2020.

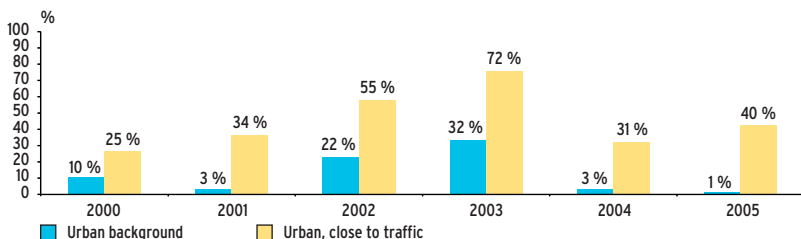
Due to its high concentrations during periods of fine weather ozone is the main substance in summer smog, which is characterised by high concentrations of the so-called photo-oxidants such as ozone itself, as well as peroxides, aldehydes and organic nitrogen compounds. Photo-oxidants are not emitted directly but initially form in the atmosphere from nitrogen oxides and volatile organic hydrocarbons, the ozone precursor substances, as a result of complex photochemical reactions.

Peak ozone pollution has fallen significantly since the early 1990s. This is due to the decline in emissions of ozone precursor substances since 1990, by 54 % in the case of nitrogen oxides, and by 65 % for volatile organic compounds. However, since the mid-1980s the decline in peak pollution has been accompanied by an increase in background ozone pollution. In all probability this is a consequence of the growing background contribution from the northern hemisphere and of the reduction in NO_x emissions in Germany. The decline in NO_x emissions leads to higher ozone values in the lower concentration range.

Changes in lung function parameters (e.g. decline in the volume of forced exhaled air, increase in resistance in the airways) in schoolchildren and adults were observed, at between 160 and $300 \mu\text{g}/\text{m}^3$ following vigorous physical activity in the open air, and in clinical exposure trials at $160 \mu\text{g}/\text{m}^3$ following six hours exposure and at $240 \mu\text{g}/\text{m}^3$ following one to three hours exposure with intermittent (alternating between exertion and rest) physical activity. Restricted lung functioning has already been shown by a number of epidemiological studies with ozone concentrations of $100 \mu\text{g}/\text{m}^3$, although various other harmful substances probably contribute, in addition to ozone. In general these functional changes and impairments largely return to normal over a period of one to three hours following exposure. However, slight deviations are still apparent between 24 and 48 hours later in cases of particularly high exposure. The effects become progressively less pronounced if exposure takes place on several successive days.

Fine dust contamination in the air

Proportion of monitoring stations where the 24-hr limiting value ($50 \mu\text{g}/\text{m}^3$) was exceeded more than 35 times, with reference to the respective type of station



Source: Federal Environment Agency 2006

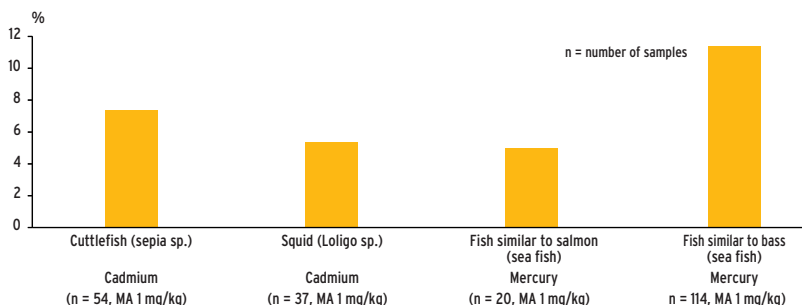
Currently at many places in conurbations the permitted number of days on which the 24-hour limiting value may be exceeded (35 days per calendar year with levels in excess of $50 \mu\text{g}/\text{m}^3$) is not being adhered to. 40 % of urban stations close to traffic registered more than 35 such days in 2005. The large number of days in 2003 when the PM_{10} daily value $> 50 \mu\text{g}/\text{m}^3$ was exceeded can be attributed to nation-wide episodes of high PM_{10} pollution. The 24-hour limiting value is exceeded far less frequently at urban background stations, i.e. further away from vehicle emissions. In 2005 this was only the case at 1 % of stations of this type. The PM_{10} limiting value for the annual average is only rarely exceeded.

Since 2000 the networks of monitoring stations in the Laender have been taking readings of fine dust (PM_{10}) across a wide area. There is a particularly dense network of measuring stations in the conurbations, where the large number and density of the sources of emissions, such as domestic boilers and heating systems, manufacturing business, industrial plants and the transport sector, results in increased concentrations of fine dusts, compared with the surrounding area. Particularly high concentrations of fine dust are recorded by monitoring stations located close to traffic. There are a number of reasons for this, including the high level of emissions from traffic, such as (diesel) soot, the wear on tyres, and the dust that is stirred up. Stricter limiting values for PM_{10} have been imposed since 1 January 2005.

The fractions of dust in suspension PM_{10} and $\text{PM}_{2.5}$ average out at approx. 80 % and 50 % of the total dust mass. The fractions of dust in suspension are important for health reasons, because particles of less than $10 \mu\text{m}$ can enter the airways and even penetrate the bronchial passages, in some cases as far as the alveoli. They can cause bronchitis and various symptoms of the respiratory tract such as coughing. Particles of less than $0.1 \mu\text{m}$ can easily penetrate to the alveoli, where they can either directly or indirectly affect not only the respiratory tract but also the cardiovascular system.

Heavy metals in foodstuffs

Maximum amounts (MA) of heavy metals in foodstuffs exceeded 2004/2005



Source: Federal Office of Consumer Protection and Food Safety 2007

Readings from 2003 to 2005 to determine lead, cadmium and mercury levels revealed that, with a few exceptions, only a small proportion of samples exceeded the permitted levels of the heavy metals referred to above.

Heavy metals can find their way into foodstuffs from the environment. The regulation (EC) No. 466/2001 (replaced on 1.3.2007 by Regulation (EC) No. 1881/2006) specifies the limits on the maximum permitted amounts of lead, cadmium and mercury in foodstuffs.

Increased concentrations of cadmium have been found in products made using squid, with the largest amounts being detected in cuttlefish products from Asia. The presence of excessive amounts of mercury in the fish species referred to above is mainly due to the fact that it is converted into fat-soluble methyl mercury by aquatic micro-organisms. Methyl mercury accumulates in particular in fat-laden, older predatory fish at the end of the food chain.

Methyl mercury can adversely affect normal brain development in infants and in larger quantities it can cause neurological changes in adults. Mercury contamination affects fish and fisheries products in particular. Incorporated lead in children can delay cognitive development and impair intellectual capabilities, as well as leading to high blood pressure and cardiovascular ailments in adults. The amounts of lead in foodstuffs have been substantially reduced in recent decades.

The quality of drinking water at the end user (heavy metals)

Elements contained in drinking water ($\mu\text{g/l}$) in households with 3 to 14 year old children in Germany - Environmental Survey for Children 2003/06

Element	Sample type	BG	N	P50	P95	MAX	GM	KI GM
Lead	Stagnation sample	0.5	1788	1.5	7.8	2 190	1.47	1.40–1.54
	Random sample	0.2	1029	0.6	4.9	83.4	0.61	0.56–0.66
Cadmium	Stagnation sample	0.02	1788	0.05	0.42	7.58	0.055	0.052–0.058
	Random sample	0.01	1029	0.02	0.25	2.88	0.021	0.020–0.023
Copper	Stagnation sample	0.5	1788	166	1 540	6 950	161	150–172
	Random sample	0.7	1029	71.1	805	5 280	69.9	63.4–77.2
Nickel	Stagnation sample	0.5	1788	4.3	34.3	691	4.48	4.23–4.73
	Random sample	0.5	1029	2.5	9	89.7	2.48	2.36–2.60
Uranium	Stagnation sample	0.006	1788	0.21	2.97	26.2	0.155	0.140–0.171
	Random sample	0.01	1029	0.21	2.16	19.4	0.169	0.150–0.191

N = scope of random samples;

P50, P90, P95 = percentile;

MAX = maximum value;

GM = geometrical average;

KI GM = approximative 95 % confidence interval for GM;
values below BG to be considered as BG/2

Source: Federal Environment Agency 2007

The table shows that the amounts of lead, cadmium, copper and nickel are higher in the stagnation samples than in the random samples. The probable reason is that the drinking water used in the sample stagnates on average for longer overnight than in the case of the random sample, giving the metals more time to dissolve in the water.

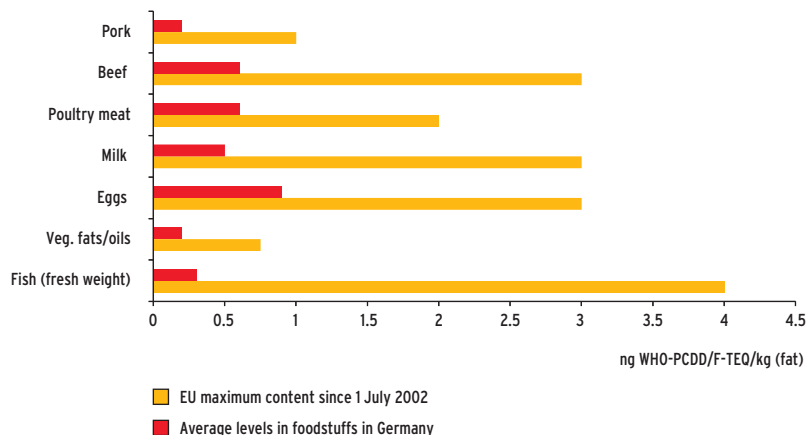
On average, the content is only slight when compared with the limiting values of the Drinking Water Regulation (TrinkwV 2001), but nevertheless the lead concentrations do exceed $25 \mu\text{g Pb/l}$ in 0.9 % of the stagnation samples and in 0.4 % of random samples. The values obtained for copper in 3.0 % of stagnation samples and 1 % of random samples were in excess of $2000 \mu\text{g Cu/l}$. Concentrations exceeding $20 \mu\text{g Ni/l}$ were found in 9.4 % of stagnation samples and in 1.8 % of random samples. No limiting value is given in TrinkwV for uranium. For assessing uranium in drinking water the World Health Organisation (WHO) has published a guide value of $15 \mu\text{g/l}$. This value was exceeded in 0.1 % of the stagnation and the random samples. If there are high concentrations of lead, copper and nickel the first recommended measure for reducing these amounts, especially when preparing food for infants and small children, is to run the water that has been standing in the pipes for a long time, i.e. overnight, until it has reached an even temperature (the water that has been previously run off can be used for cleaning or for watering flowers).

How much lead, nickel and copper is actually released from the domestic installation into the water supply depends largely on the time it has spent in the pipes. Readings of lead, copper and nickel concentrations can differ widely, even at the same tap, depending on the time that the water has spent in contact with the plumbing materials.

When making an evaluation it should be remembered that, even if the safe limits have been exceeded, the limiting values for healthy drinking water as defined by § 6 (1) TrinkwV 2001 are such that daily consumption of the corresponding amount with two litres of water can be tolerated for an entire lifetime without incurring any risk to health. If the healthy limiting or maximum value is temporarily exceeded this also poses only an insignificant health risk. Although temporarily higher concentrations do not represent a direct impairment to health, in accordance with § 9 TrinkwV 2001 the causes for such concentrations must be eliminated without delay to ensure that the drinking water can be consumed again over a long period without any restrictions and without the need for any special monitoring.

Dioxins in foodstuffs

Average dioxin/furan concentrations in foodstuffs in Germany from 2000 to 2003



Source: Federal Institute for Risk Assessment 2004

Observations seldom show that maximum values have been exceeded.

Using data on dioxin levels in foodstuffs between 2000 and 2003 and based on the WHO-TEF as determined by the World Health Organisation (WHO) in 1998, a daily intake of approximately 0.72 pg WHO-PCDD/F-TEQ/kg body weight was calculated for adults in Germany. Compared with the period 1987 to 1990 this represents a decline of between 30 and 40 %.

Approx. 90 % of the contamination of the human body with dioxin comes from food, especially of animal origin. On average in Germany the intake mainly occurs through milk and dairy products, which account for some 40 %, and through meat and meat products, with roughly 20 %. Fish and eggs are responsible for a further 17 % and 8 % of the dioxin intake respectively.

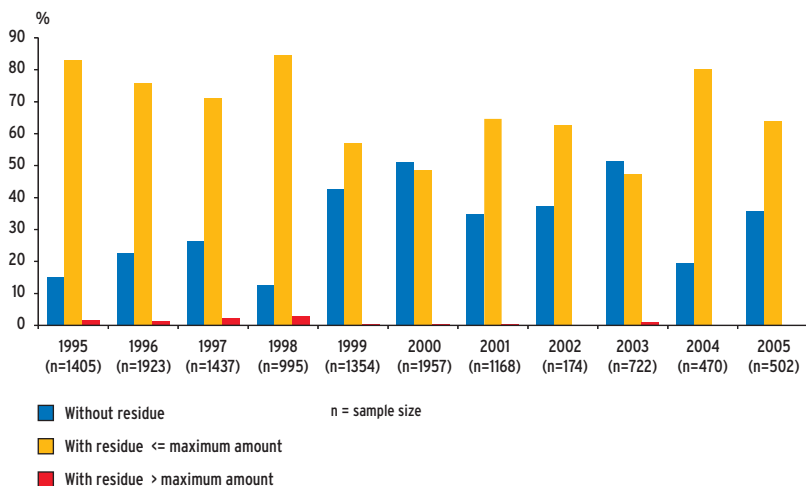
The dioxin congener with the greatest toxic effect is 2,3,7,8-TCDD (Tetra-chloro-dibenzo-p-dioxin), also referred to as the "Seveso poison". The toxicity equivalency factors (WHO-TEF) as laid down by the WHO define the toxicity of other dioxin congeners in relation to that of 2,3,7,8-TCDD. The WHO-TEFs are first multiplied by the concentrations of the individual congeners to determine their toxicity equivalent concentrations, and these are then added up to give the total concentration of dioxin toxicity equivalents (WHO-TEQ).

If dioxin-like PCBs are also taken into consideration, the average daily intake is in the region of 2 pg WHO-TEQ/kg body weight. Children are subjected to higher levels of contamination because they consume more food in relation to their body weight. Breast-fed infants ingest more than 50 times the amount of dioxins through their mothers' milk than adults do through foodstuffs. A reduction in the contamination of infants and of unborn children via the placenta can only be achieved by reducing the amount to which mothers are exposed. More recent data from food monitoring authorities and the Federal Research Institute of Nutrition and Food (BfEL) confirms the continued reduction in the amount of dioxin and PCBs in foodstuffs.

Nevertheless, in view of the fact that the exposure of large sections of the population to dioxins lies within the tolerable daily intake levels as determined by the WHO and the tolerable weekly intake as defined by the Scientific Committee on Food (SCF), efforts are still needed in the areas of chemical and plant safety and in the monitoring of animal feeds and human foodstuffs in order to protect human beings and the environment from high levels of exposure to dioxins.

Persistent organic compounds in foodstuffs

Persistent chlorinated hydrocarbons, bromocycles and musk compounds in foodstuffs of animal origin



Source: Federal Office of Consumer Protection and Food Safety 2007

It is encouraging to note that the occurrence of such contaminants in foodstuffs is in most cases declining and that concentrations are generally low. This is a consequence of the ban that has been in force for many years in Germany on the use of certain persistent organic substances or, in the case of musk compounds, restrictions on their use.

Persistent chlorinated hydrocarbons (also referred to as PCHCs or as organochlorine compounds) represent a group of compounds comprising many different substances, the best-known examples being DDT (dichloro-diphenyl trichloroethane), PCB (polychlorinated biphenyls), HCB (hexachlorbenzene) and HCH (hexachlorocyclohexane). They are among the substances whose use in Germany is banned or, in the case of lindane (gamma-HCH), which may only be used in veterinary or human medicine subject to certain restrictions.

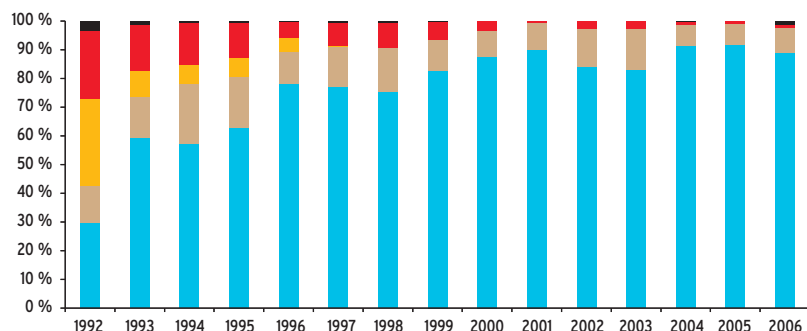
A further decline can be expected since the Stockholm Convention, which came into force on 17.05.2004, bans the use under international law of so-called POPs (persistent organic pollutants), with the aim of providing worldwide protection for human health and the environment against these hazardous substances. In the long run, this will lead to a minimisation of long distance transport via air and water to Germany. A total of 12 substances/groups of substance are currently covered by the terms of this convention: aldrin, dieldrin, endrin, chlordane, heptachlor, hexachlorbenzene (HCB), mirex, toxaphene, polychlorinated biphenyls (PCB), DDT, dioxins (PCDD) and furans (PCDF). The convention also allows the inclusion of other substances with so-called "POP" properties.

Dioxins are a group of substances made up of polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF) with a total of 210 various congeners. Dioxins are not the result of intentional industrial production but are an undesirable by-product of all the chemical processes using chlorine, and of combustion processes where chlorine is present. Being highly stable they are classed among the group of persistent organic compounds and consequently they are proscribed by the Stockholm Convention on persistent organic pollutants.

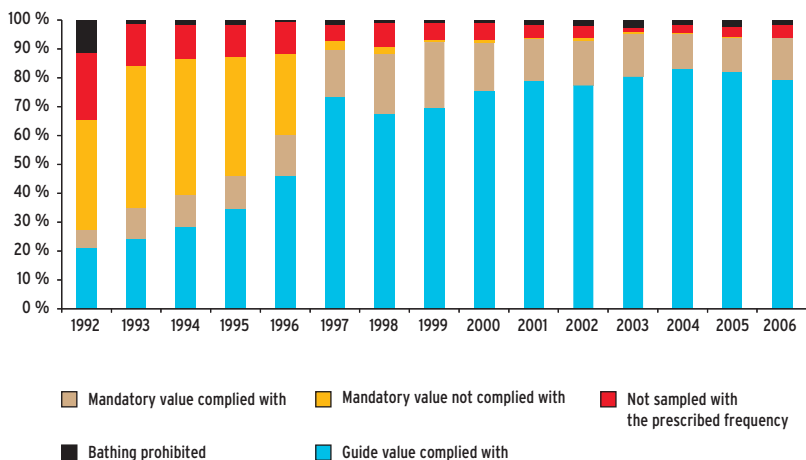
Persistent chlorinated hydrocarbons can enter foodstuffs as contaminants from the environment, and to some extent also through imported animal feeds from countries where these substances are still permitted. The organochlorinated compounds enter the animals through the food chain and, due to their lipophile properties, mainly accumulate in the fatty tissues. Consequently foodstuffs of animal origin are the main carrier of these contaminants.

Pathogenic micro-organisms in coastal and inland waters

Quality of bathing water on Germany's coasts



Quality of bathing water on Germany's inland waters



Source: European Commission 2007

From 1992 to 2001 there was a continuous decline in the number of cases where mandatory and guide values were exceeded, with a consequent reduction in water pollution. The quality of bathing water has remained at a constantly high level since 2001. However, health risks from bathing water cannot be excluded.

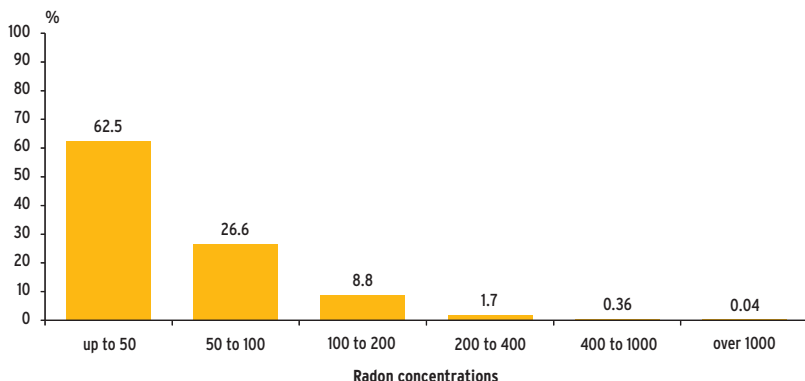
In 2006, 1,563 freshwater bathing areas and 352 coastal bathing areas were monitored in accordance with the EU Bathing Water Quality Directive (76/160/EEC). In 2006 the quality of bathing waters remained roughly at the same high level as in 2005, but nevertheless bans were imposed at a few beaches to protect bathers.

When the mandatory values were laid down in 1975 by the EU Bathing Water Quality Directive it was assumed that, provided these values were adhered to, there would be no significant risk to health, in particular because no noticeable accumulation of bathing-related illness was observed in those countries where similar values already applied. Since then epidemiological studies of the infection risks to bathers have led to the increasing suspicion that the current mandatory values are too high. For example an increased incidence of illness after bathing has also been observed for waters complying with the EU mandatory values. Although there were no cases of severe illness, incidents of slight diarrhoea, lasting several days, did occur, which abated on their own without any treatment.

The Bathing Water Directive has been revised in recent years, taking new scientific findings into account. The new EC Bathing Water Quality Directive (Directive 2006/7/EC) came into force on 24 March 2006 and must be transposed into national law within two years. The new directive contains many positive improvements such as a reduction in monitoring parameters to a number of hygienically relevant indicators, the harmonisation of detection methods, the required active management of bathing waters, and stricter limit values for coastal waters in order to provide more protection for bathers. The new directive also requires that the public be kept comprehensively informed.

Exposure of the public to radon in buildings

Frequency of radon concentrations in buildings with 1 and 2 dwellings (as per 2001)



Source: Federal Office for Radiation Protection 2006

The mean radon concentration indoors in Germany is about 50 Bq/m³.

At present it is assumed that radon concentrations of less than 20 kBq/m³ occur in soil air at ground level in approx. 38 % of the land area of Germany. As a rule, when building in such areas, the professional standard of protection for the building against moisture from the soil also provides adequate protection against soil radon.

The geogenic contribution to the concentrations of radon being measured in residential buildings is comparable with that of other countries. Geological conditions alone can give rise to yearly averages of peak values of some thousands of Bq/m^3 . For purely geological reasons the annual average may include peak readings of several thousand Bq/m^3 . Readings of radon levels in mining areas have revealed that the excavation of underground tunnels in the vicinity of buildings or the creation of slagheaps can lead to substantially higher radon concentrations in houses.

In addition to the measures described above for dealing with moisture, in areas with soil radon concentrations of between 20 and 100 kBq/m^3 (58 % of the land area of Germany), a continuous, reinforced floor slab with a thickness of at least 15 cm must be installed.

Across some 4 % of the land area the radon concentration in soil air exceeds 100 kBq/m^3 . In these areas the floor slab should be replaced by a foundation slab, dimensioned and reinforced in accordance with DIN 1045. Moreover at such locations it is advisable to undertake additional work on buildings, such as the inclusion of radon-impermeable foil and the implementation of drainage measures to prevent penetration by ground radon.

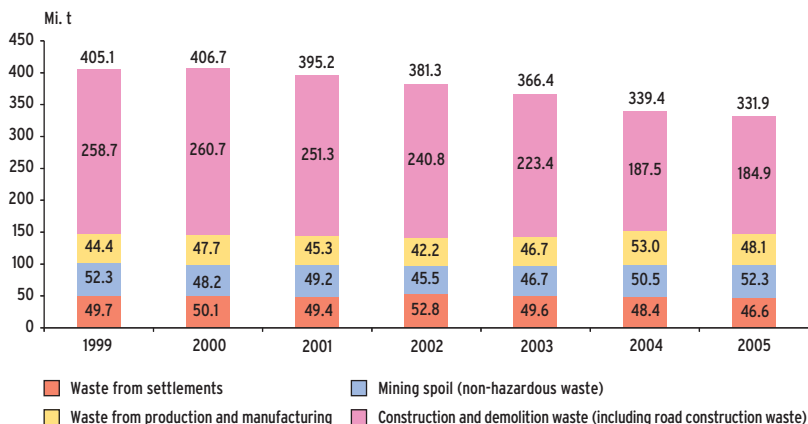
With a total of 1.1 mSv the inhalation of radon indoors and its decay products is the main contributor to radiation exposure of the public from natural sources (effective average annual dose from ionising radiation, averaged across the population of Germany), amounting to 2.1 mSv.

Radon as an important risk factor for lung cancer

Lung cancer currently accounts for by far the largest number of cancer deaths among men in Germany. Among women lung cancer is the third commonest cause but the incidence is rising sharply. Bronchial carcinomas are among the malignant tumors with a very poor prognosis. In almost 90 % all new incidences of the disease death follows within a year. There are no signs of any improved therapy and therefore preventive measures offer the only possibility for reducing the number of cases of the disease. As is widely known, smoking is by far the greatest risk factor. However, it is not generally known that increased radon concentrations in homes are the second most important cause of lung cancer. Since the 1980s, over 20 large-scale epidemiological studies of lung cancer and radon in homes have been carried out in Europe. The totality of the studies' evidence points to a rise of around 10 % in the risk of lung cancer for every 100 Bq/m^3 increase in the radon concentration. This equates to a doubling of the lung cancer risk at 1000 Bq/m^3 .

Total amount of waste produced

Waste production (including hazardous waste)



Source: Federal Statistical Office 2007

From 1999 economic output initially increased in Germany, followed by a period of stagnation, whereas there was a decline in the total amount of waste produced. The gross domestic product began to increase again in 2004, while waste production declined. Waste intensity, i.e. the total amount of waste produced measured against the development of the gross domestic product (price-adjusted), fell between 1999 and 2005 by some 203 kg/thou. e approximate euros to 156 kg/thou euros.

In 2005 waste production in Germany amounted to 331.9 mi. t, an 18 % fall compared with 1999, mainly due to a decrease in the amount of construction and demolition waste.

The creation of closed cycles of materials acquires major importance as part of a sustainable policy aimed at protecting natural resources. The basic principles of this recycling system are laid down in the Recycling and Refuse Law, with priority being given to making as much use as possible of materials obtained from the natural world in order to avoid the production of waste at source. The intention is to decouple the creation of waste from economic growth. Unavoidable waste should be correctly and harmlessly utilised or disposed of in an environmentally acceptable way.

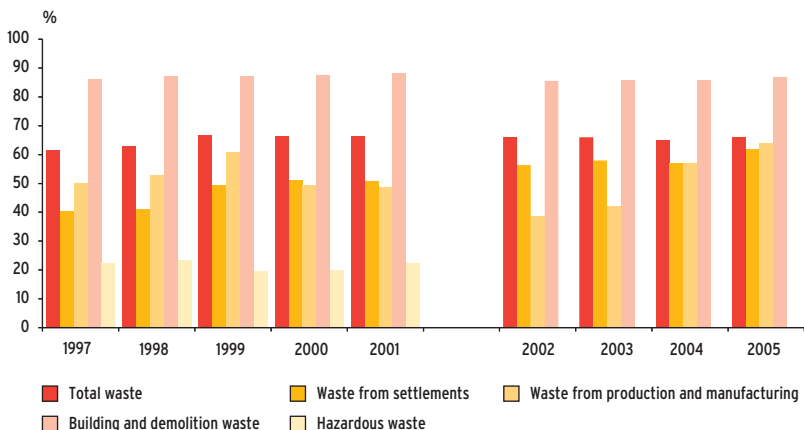
The group comprising "Building and demolition waste (including road construction waste)" which, at 184.9 mi. t, accounted for the largest proportion (56 %) of waste produced in 2005, plays a vital part in the closed cycle economy. Extracted soil accounts for the largest share in this waste group, and the majority of it is utilised, as is much of the remaining mineral construction waste. The development of building and demolition waste largely parallels the economic development taking place in the building industry.

In 2005 approximately 15 % of the waste was derived from production and manufacturing (48.1 mi. t). In 2005 mining spoil amounted to 52.3 mi. t, which is approximately 16 % of all the waste produced, and came predominantly from coal mining. Most of this spoil is deposited on heaps. 46.6 mi. t (14 %) of the waste produced in 2005 came from settlements, and 62 % of settlement waste was utilised in 2005. In 2005 household waste amounted to 41.4 mi. t and accounted for almost 90 % of the waste from settlements. In 1999 the waste produced by households (non-hazardous) amounted to 441 kg/inh., but by 2005 it had increased to 498 kg/inh. Whereas in 1999 around 49 % of household waste was recycled, by 2005 this figure had risen to 64 %. From 1999 onwards hazardous waste was only included in the statistics for information purposes as a sum total. Approximately 6 % of the waste produced in 2005 is included in this waste flow, compared with 3.7 % in 2000. It was produced mainly by industry and the construction sector and 62 % was recycled in 2005.

Waste that cannot be utilised must be disposed of in a way that does not harm the environment or endanger public health. Prior to final storage all organic waste must be treated, either by mechanical and biological means or thermally, in order to render it inert and in particular to significantly reduce the release of seepage water and landfill gas. Since mid-2005 the storage of organic waste that has not been treated beforehand is no longer permitted. Incineration plants have to comply with strict air purity standards.

Recycling quotas for the main flows of waste

Recycling quotas for the main flows of waste



Hazardous waste: Since 2002 hazardous waste has been included in the main waste flows.

Source: Federal Statistical Office 2007

Almost two thirds of settlement waste is recycled. As a result, in 2005 waste bins contained more useful materials than residual waste.

Initially the recycling rate for waste from production and manufacturing rose in the course of the transition in the statistical allocation of types of waste from the formula provided by the Laender Working Group on Waste (LAGA) to the European Waste Catalogue (EWC), and then fell below the 1997 level. It has been rising again since 2003. This movement can be attributed to statistical effects.

Building and demolition waste account for around 56 % of the waste produced in Germany, and for many years a high percentage of this waste has been recycled.

The extensive efforts that have been made to recycle waste have met with considerable success. In 2005 two thirds of the total waste produce in Germany (66 %) was recycled.

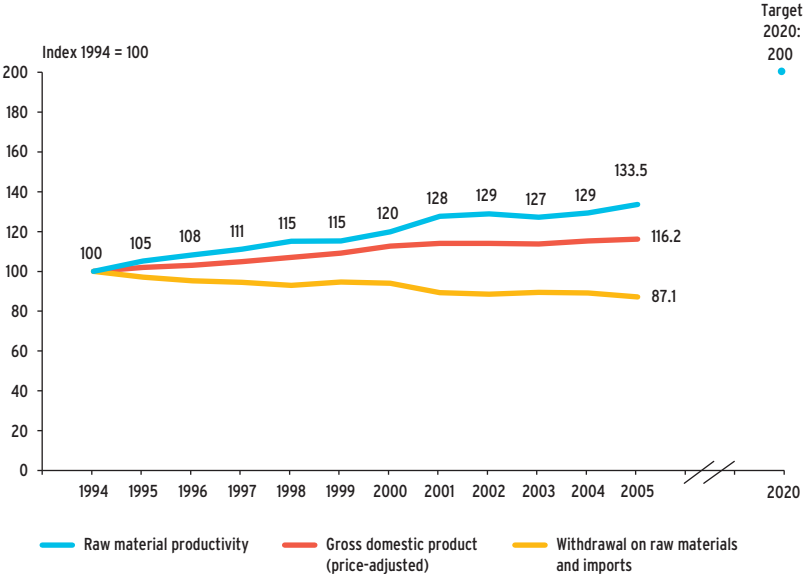
Sustainable development requires that the consumption of resources is decoupled from economic growth. However, a strategy aimed at improving efficiency can only enjoy lasting success if the efficiency gains are not cancelled out by increasing production and greater consumption. A key factor lies in the avoidance of waste and in increased efforts to recycle it. The waste industry must become a source of raw materials and for the production of goods, instead of simply disposing of the refuse from our affluent society as cheaply as possible.

In this respect there are restrictions regarding the comparability of data during the period under consideration as a result of the changeover from the waste catalogue of the Laender Working Group on Waste LAGA (up to 1998) to the European Waste Catalogue EWC (from 1999). This led to a shift in the quantities of waste under certain subsidiary headings, especially settlement waste, waste from production and manufacturing, and building and demolition waste. The EWC was replaced in 2002 by the European Waste Index EWI, resulting in shifts within the category of settlement waste and between non-hazardous wastes. Up to and including 2001 hazardous wastes were listed as a separate waste flow, where in the details for 2002 they are included under other types of waste.

The time series was interrupted again between 1998 and 1999 for waste from production and manufacturing by the fact that, from 1999 onwards, the amounts of waste that were processed internally were no longer taken into account, although recycling and disposal continue to be recorded.

Raw material productivity

Raw material productivity



Source: Federal Statistical Office 2006

Between 1994 and 2005 raw material productivity increased by 33.5 %. Although the input of materials declined (– 13 %) there was a 16 % increase in gross domestic product. Recent years (2000 to 2005) have seen a slowing down in this rate of increase. Although the indicator has developed in the desired direction, the rate of increase achieved so far will be insufficient for attaining the targets laid down in the federal government’s sustainability strategy.

The growth in the development of raw material productivity in recent years can be attributed solely to a structural change in favour of sectors that make less intensive use of raw materials, and not to general efforts to make more economical use of raw materials. Less material-intensive sectors (especially services) have expanded, whereas industries with high material consumption such as the construction industry (accounting for 45 % of total input of primary materials) and other areas in the manufacturing sector tend to have shrunk. The considerable reduction in building activity and the consequent decline in the deployment of raw materials for building (-28 %) have been a major contributory factor. In contrast the use of ores and products derived from them rose significantly in the period under consideration (+29 %). In interpreting the development of the raw material indicator it is also significant that the supply of materials is being met increasingly by imports. While the domestic extraction of raw materials fell by 267 mi. t (-24 %) between 1994 and 2005, imports of raw material and of semi-finished and finished goods rose by 73 mi. t (+19 %). Imported goods as a proportion of the total input of primary materials thus rose from 26 % in 1994 to almost 36 % in 2005. In quantitative terms a significant feature of this shift has been the increase in imports of metallic semi-finished and finished goods (+49 %) and the replacement of domestic hard coal and lignite by imported energy source materials.

Thus the pressures on the environment in Germany continuously are being relieved while the pressures associated with the extraction of raw materials and their processing to make semi-finished and finished products are being transferred abroad.

Withdrawal of raw material (used and unused) and imports amounted to an annual per capita figure of some 46 t in 2005 while in 1994 it amounted to 51 t per capita. More careful use of raw materials is helping to satisfy the needs of present and future generations, but without jeopardising the natural basis for life for future generations too.

The vast flows of materials, for example for the construction sector and energy production (the extraction of coal and lignite), impose severe burdens on the environment.

The domestic extraction of "energy source materials" has fallen, due to the increasing substitution of the domestic energy sources of coal and lignite by imports, particularly of natural gas (which have almost doubled since 1994). This also means that there is a corresponding transfer to other countries of the environmental pollution associated with the extraction and conversion of energy source materials, for example the degradation of the countryside, ecosystems, soil, water and air.

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D-06844 Dessau-Roßlau

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Tel.: +49(0)340/21 03-0

Telefax: +49(0)340/21 03-2285

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