

The contribution of waste management to sustainable development in Germany

- Section on municipal waste -

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In April 2002, the Federal Government adopted its strategy for sustainable development entitled, "Prospects for Germany". Two years have passed since then, and in autumn 2004, the Federal Government will for the first time take stock of its achievements in a progress report. To date, measures and reporting have focussed primarily on action areas such as climate protection and energy, transport, agriculture, and global responsibility.

This report considers waste management in Germany, which has undergone a substantial transformation since the early Nineties, with regard to its contribution to sustainable development.

The Federal Environment Ministry and the Federal Environmental Agency have commissioned the IFEU Institute Heidelberg to conduct research into this area (environmental research plan, project FKZ 203 92 309). The results of the survey of municipal wastes in Germany are now available and are summarised below. The detailed final report will be published in the "UBA-Texte" series.

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Summary

Waste management in Germany has undergone a substantial transformation since the early Nineties. Accompanied by the adoption of the Closed Substance Cycle and Waste Management Act, the move away from the throw-away economy in favour of the closed substance cycle represents a significant change of paradigm. **Waste management has evolved into materials flow management.**

This has prompted us to examine and appraise the **contribution of waste management to sustainable development** in Germany, based on the significant tightening of statutory provisions in recent years.

Sustainable development includes conserving natural resources. According to the management rules of the Enquete Commission "Man and the Environment", this is defined as the careful handling of raw materials and the reduction of emissions so as to ensure the viability of our environment, for example in climate protection.

The achievements of waste management can be illustrated in a **comparison of the waste management situation in 1990, the first year after German reunification, with the present day and a forecast of the measures already initiated for 2005.** To this end, we analysed the **development of waste quantities**, and used a materials flow model to emulate and calculate all movements in **municipal waste** for the respective years with the corresponding technical installations. **A balance was drawn for nine indicators representing the conservation of natural resources and environmental impacts.**

The results:

- The sum total of waste from households (domestic and bulky waste, and waste for recycling as a subset of municipal waste) has remained constant over the years. With economic growth at 15 % (1992-2001), this suggests a **severing of the link between waste quantity and economic growth.** Within the overall quantity, there are furthermore signs of a significant shift in waste quantities, away from disposal in favour of the separate collection and recovery of such waste. Disregarding the sorting and treatment residues of separately collected waste for recycling, this translates into **an increase in the material recycling ratio from 12 % in 1990 to more than 46 % in 2001. If the recycling of domestic and bulky waste is also included, overall, a material and energy recovery ratio of 53 % of waste from households was achieved in 2001.**
- **Emissions of climate relevant gases were significantly reduced.** When the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements is implemented in full in 2005, **waste from households alone will produce a saving of 30 million tonnes of CO₂ equivalent from waste impacts in the year 2005 compared with 1990 levels.** This is statistically equivalent to the anticipated impacts of around 2.5 million German citizens. By 2001, 25 million tonnes of CO₂ equivalent had already been saved from household waste compared with 1990.

- The **resource savings are also considerable**. Among fossil fuels, measured in terms of energy content, from 1990 to 2001 the savings effect in waste management from household waste alone increased from 30 petajoules to over 100 petajoules per annum. This saving of primary raw materials is statistically equivalent to the amount consumed by around 700,000 residents in Germany. The savings effect for iron ore is over 1,000,000 tonnes per annum, and for phosphate ore over 26,000 tonnes, which is statistically equivalent to 1.2 million and 3 million resident reference values respectively.
- Other areas where environmental pressures have been relieved include **acidification, the over-fertilization of watercourses, and impairments to human health caused by particulate matter**. Acidification was reduced by almost 60,000 tonnes of acid equivalent per annum, over-fertilization of watercourses by 23,000 tonnes of nutrient equivalent, and emissions of particulate matter by approximately 40,000 tonnes of particulate matter equivalent. This is statistically equivalent to the volumes produced by 1.5 million, 4 million and 1.3 million residents respectively. Only in the case of the **over-fertilization of soils** have the calculated environmental impacts stagnated since the early Nineties, at around 2,000 tonnes of nutrient equivalent (corresponding to approximately 400,000 resident reference values).
- **Emissions of carcinogenic substances** from waste incineration plants – particularly dioxins and furans – have been reduced to less than one thousandth of 1990 levels, thanks to the stringent limits imposed by the 17th Federal Immission Control Ordinance, and as such are now virtually negligible.

These results indicate that waste management has made a significant contribution towards strengthening sustainable development and improving the environmental situation, as a result of the measures taken between 1990 and the present day.

1 Waste management and sustainable development

1.1 ... on the context

Meeting human needs is inextricably linked with the extraction and processing of resources, substances and materials which generate some kind of benefit. At the end of their intended use, these products and materials become available once again in the form of waste, and may be reused as raw materials. Hence, the handling of resources is an essential component of any strategy for sustainable development.

In keeping with the objective of sustainable development, in 1994 the 12th German *Bundestag* <Lower House of Parliament> formulated fundamental rules for the handling of substances in the Enquete Commission "Protection of Man and the Environment" [Enquete Commission 1994]. These so-called management rules were transferred into the Federal Government's sustainable development model [*Perspektiven für Deutschland; Unsere Strategie für eine nachhaltige Entwicklung*; page 40; Die Bundesregierung 2002].

- In the long term, renewable natural resources (such as wood or fish stocks) must only be used within the scope of their capacity for regeneration.
- In the long term, non-renewable natural resources (such as minerals or fossil fuels) must only be used to the extent that their functions are capable of being replaced by other materials or other energy carriers.
- In the long term, the release of substances or energy must not exceed the ability of the ecosystems - such as the climate, forests and oceans - to adapt.

Therefore, the aforementioned management rules on the handling of material flows within the context of sustainable development prescribe the careful handling of resources, as well as the minimisation of pollutants released into the environment. In the field of waste management, these principles are enshrined in the "Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal (KrW-/AbfG)" of September 1994.

This states that:

§ 1 Purpose of the Act:

The purpose of this Act is to promote closed substance cycle waste management in order to conserve natural resources and to ensure environmentally compatible disposal of waste.

In the interests of sustainable development, the Closed Substance Cycle and Waste Management Act defines the mandate in its basic principles:

§ 4 Basic principles of closed substance cycle waste management

(1) Waste

1. must, firstly, be avoided; this must be accomplished especially by reducing its amount and noxiousness
2. must, secondly,
 - a) be subjected to substance recycling, or
 - b) be used to obtain energy (energy recovery).

Since its adoption, the implementation of this mandate has been concretised in a series of ordinances, administrative provisions and voluntary commitments by the players involved. In particular, these include:

- The technical instructions on waste and municipal solid waste
- The Ordinance on Environmentally Compatible Storage of Waste from Human Settlements
- 17th Ordinance on the Implementation of the Federal Immission Control Act <BImSchV> on waste incineration plants, and the 30th BImSchV on biological waste treatment facilities
- Packaging Ordinance, Battery Ordinance, End-of-Life Vehicle Act and Ordinance
- Voluntary commitments, including those on the material recycling of paper and construction waste
- Commercial Waste Ordinance
- Biological Waste Ordinance, Sewage Sludge Ordinance
- Waste Wood Ordinance
- Landfill Ordinance

The specification of peripheral conditions in these legal standards since the early Nineties has created a basis for the steering of waste flows in keeping with the principles of sustainable development. This intention is underscored by the renaming of waste management to closed substance cycle waste management.

After years of translating many of these projects into practice, it was time to examine the contribution already made by waste management towards sustainable development in Germany in this context. It is also possible to assess the future contribution of measures already adopted but not yet implemented in full.

1.2 ... on the quantity of waste

As the starting point for the study, we consider the situation prior to the implementation of most of the aforementioned waste management measures. The first year of German reunification, 1990, offers a good starting point in this respect [StBA 1990]. We have compared this starting point with the current situation, and evaluated the statistical data for the year 2001 [StBA 2004] as the most recent available Federal statistical survey of waste flows in Germany.

We follow this with an outlook to the future. In a scenario for 2005, full implementation of the Ordinance on Environmentally Compatible Storage of Waste from Human

Settlements is used as a basis. This states that from 1 June 2005 onwards, only the storage of pretreated municipal waste will be admissible.

Forecasts of waste quantities and available capacities for waste disposal are available for 2005 [LAGA 2004] and provide an excellent basis for estimates. The **following table contains the principal figures for municipal wastes**:

Table 1 Overview of the quantity of municipal wastes for the years 1990, 2001 and a forecast for 2005

Quantity of waste [Amount in tonnes]	1990 StBA	2001 BMU (StBA) ¹⁾	2005 ²⁾
Domestic waste (grey bin)	30,460,853	16,466,000	
Bulky waste collected separately	3,426,692	2,676,000	
Grey bin with bulky waste			16,310,470
Sum total, domestic and bulky waste	33,887,545	19,142,000	16,310,470
Biowaste and garden & park waste	1,982,306	7,992,000	<i>7,992,000</i>
Used paper	1,604,758	7,550,000	<i>7,550,000</i>
Used glass	1,314,393	3,152,000	<i>3,152,000</i>
Leightweight packaging	0	1,870,000	<i>1,870,000</i>
Sum total, waste for recycling	4,901,457	20,564,000	20,564,000
Sum total, waste from households	38,789,002	39,706,000	36,874,470
Domestic-type commercial waste	15,238,458	8,109,000	4,160,940
Sum total, municipal waste	54,027,460	47,815,000	41,035,410

1) Quantities for used glass, used paper and lightweight packaging are total quantities excluding sorting residues and impurities requiring disposal

2) Assumptions for the scenario 2005:

Grey bin with bulky waste and domestic-type commercial waste - data according to [LAGA 2004]

Waste for recycling taken from 2001 (figures and figures calculated from this in italics)

Whereas the quantities of waste from households are well documented in the statistics of the Federal Government and *Bundesländer* <Federal states>, the equivalent data on domestic-type commercial waste contains a number of holes and uncertainties. We can assume that the apparent decline in volumes of domestic-type commercial waste indicated by Table 1 (penultimate line) from 1990 to 2001 and continuing to 2005 is primarily attributable to inadequate documentation, rather than an actual decline in these waste volumes. In view of the major data uncertainties in the segment of domestic-type commercial waste, this will be disregarded below. As such, the following comments are confined to the well-documented waste from households.

Table 1 impressively documents the waste management's evolution during the course of the Nineties from a disposal industry to a closed substance cycle management. Whereas in 1990, just under 5 million tonnes out of a total of 38.8 million tonnes of waste from households were collected separately and recycled, by the year 2001, this figure had more than quadrupled, with only a slight increase in the overall quantity of waste.

According to [LAGA 2004], in the year 2005 the quantity of domestic and bulky waste is expected to be almost 6 % lower compared with 2001. These generally recognised forecasts on waste quantities for 2005 are based on the waste balances of the Federal *Länder*. No similar forecasts exist for the Federal statistics. Given the differing survey techniques used for the Federal statistics and for the waste balances of the Federal *Länder*, the quantity data for domestic and bulky waste for the years 2001 and 2005 shown in Table 1 does not lend itself to a direct comparison. The figures reflect an

apparently higher reduction in waste quantities than is actually anticipated. However, the change in the number base from 2001 to 2005 does not have a significant influence on the results obtained in this study.

With regard to waste for recycling, we have assumed that quantities remain unchanged between the years 2001 and 2005. The location of separately collected waste for recycling is also assumed to be the same for the scenarios 2001 and 2005. However, there is a slight increase in the overall recycling ratio in the 2005 scenario compared with 2001, since it is anticipated that more waste wood from the bulky waste fraction will be subjected to recycling in the year 2005.

The **total quantity of waste from households** (domestic and bulky waste and waste for recycling as a subset of municipal waste) has remained constant **over the years**. Whether avoidance measures have compensated for the anticipated increase rates in the household waste sector in the early Nineties, or whether there has simply been neither an increase nor avoidance, cannot be determined purely on the basis of numerical analysis.

With economic growth at 15 % (gross domestic product between 1992 and 2001 measured in terms of 1995 prices), we can identify a **severing of the link between economic growth and waste quantity** for waste from households.

According to the figures in Table 1, this produces an **increase in the separate collection ratio from around 13 % in 1990 to around 52 % in 2001**. After deducting the sorting and treatment residues, this produces an **increase in the material recycling ratio of waste for recycling from 12 % in 1990 to more than 46 % in 2001**. Including material and energy recovery of domestic and bulky waste, **overall, a recycling ratio of 53 % was achieved for waste from households in 2001**.

1.3 ... on the location of waste

Facts and figures on waste quantities are one thing. However, in order to calculate the contribution of waste management to sustainable development, it is far more important to know where this waste ends up.

The following tables provide information on the location of waste from households as seen in the years 1990 and 2001, and also as forecasted for 2005.

Table 2 lists all waste quantities subjected to recycling and/or to pre- and intermediate treatment. One particularly noticeable aspect in this respect is the sharp increase in the quantities of separately collected waste subjected to recycling. What is more, the growing significance of mechanical-biological treatment plants (MBT) from 2001 to 2005 is also apparent.

Table 2 Location of waste from households in sorting and recycling plants and mechanical-biological treatment (MBT) plants

Waste for material treatment / recycling [Amount in tonnes]	1990 StBA	2001 BMU (StBA)	2005 *)
Separately collected waste for sorting/recycling	2,919,151	12,893,516	12,893,516
Organic waste for biological recycling	1,005,790	7,604,000	7,604,000
Domestic and bulky waste for recycling	107,205	1,252,164	1,685,833
Domestic and bulky waste for MBT	0	847,836	5,034,400

*) Assumptions for the scenario 2005: Location of waste for recycling taken from 2001

Note: Unlike Table 1, the separately collected waste for sorting/recycling for 2001 includes sorting residues and impurities requiring disposal after sorting

The quantity of waste from households subjected to thermal treatment or recovery has also risen sharply from 1990 to 2001, as illustrated by Table 3. In addition, thermal procedures also accept sorting and processing residues from material recycling and mechanical-biological treatment.

Table 3 Location of waste from households in plants for thermal recovery and treatment (SF = secondary fuels)

Waste for thermal treatment / recovery [Amount in tonnes]	1990 StBA	2001 BMU (StBA)	2005 *)
Sorting residues and SF in cement kiln / power plant	72,281	1,006,863	1,785,564
Waste from households directly to incinerator	5,981,581	9,042,000	10,976,237
Sorting residues from treatment/recovery to incinerator	142,124	877,191	1,382,715

*) Assumptions for the scenario 2005: Location of waste for recycling taken from 2001

The landfill is always the last stage in a disposal chain. The waste quantities that end up on the landfill, either directly or from other disposal routes, are summarised in Table 4. The decline in waste from households that is landfilled directly is particularly noticeable here. From 1 June 2005, it will be inadmissible to dump waste that has not been pretreated. For this reason, this waste flow is no longer listed in the 2005 scenario, which should be interpreted as a forecast of the waste management situation after 1 June 2005. On the other hand, residues from thermal and mechanical-biological treatment will continue to be landfilled in future.

Table 4 Location of waste from households for landfilling

Waste for landfilling [Amount in tonnes]	1990 StBA	2001 BMU (StBA)	2005 *)
Waste from households directly to landfill	28,775,275	8,386,000	0
Sorting residues from recycling to landfill	73,744	397,160	63,285
Incineration residues to landfill	202,619	332,903	424,314
MBT residues to MBT-landfill	0	445,114	2,643,060

*) In the 2005 scenario, only inert waste and hazardous waste will be landfilled

The figures on the quantity of household waste on the one hand, and its location on the other, leads to a complex materials flow model. The following diagrams are intended to illustrate some of the diverse relationships between different waste flows using lightweight packaging materials (Figure 1) and domestic waste (grey bin, Figure 2) as examples.

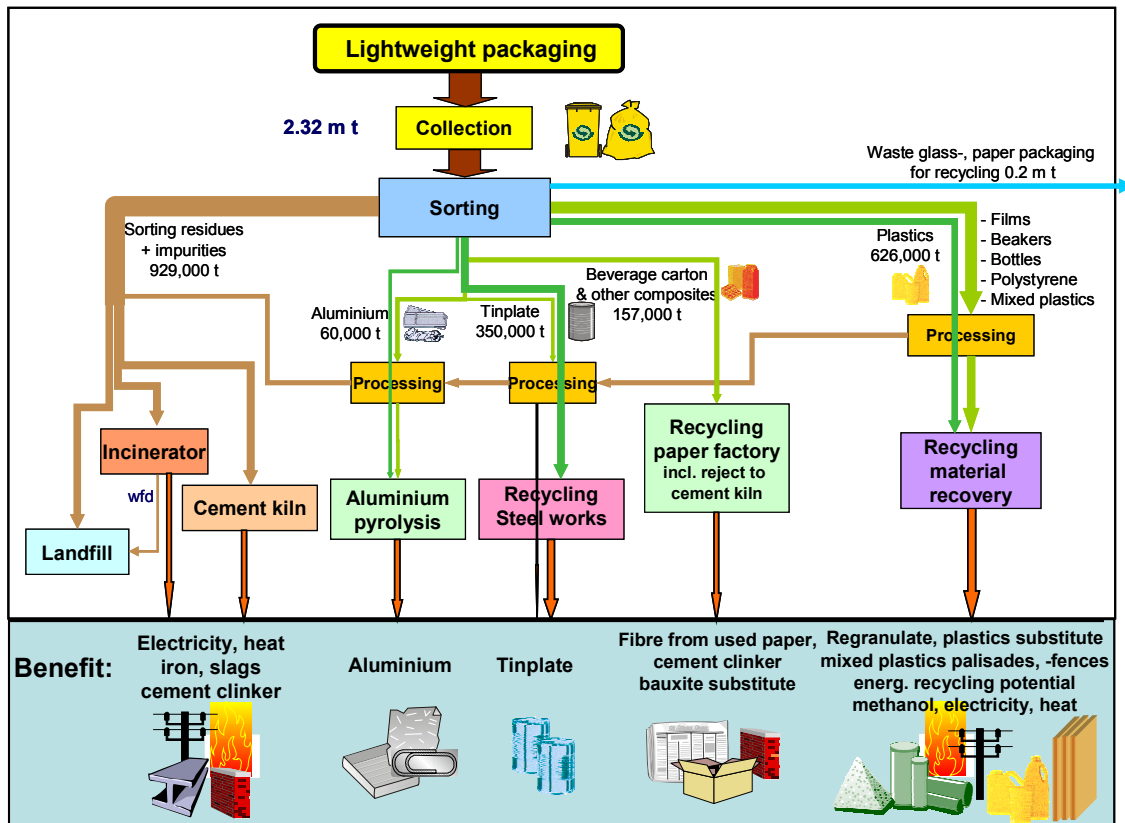


Figure 1 Diagram of modelled substance flows for “household waste 2001” using the example of lightweight packaging

The complexity of the material flows is derived from the various separately collected waste fractions, the respective waste recycling and disposal variants, and the options for the disposal of waste derived from waste recycling. For example, the separately collected waste for recycling may include impurities, which for their part may be processed and subjected to industrial coincineration. Furthermore, during the processing of sorted waste, further waste is generated which in turn requires disposal.

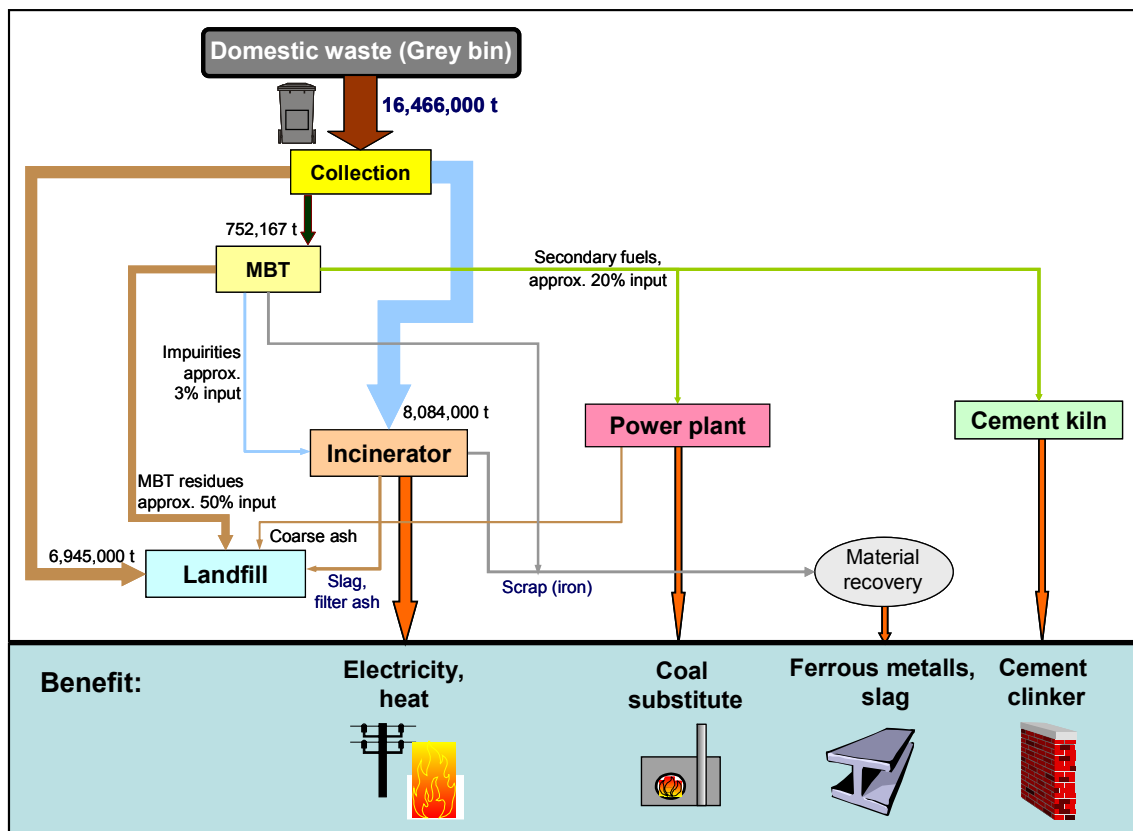


Figure 2 Diagram of modelled material flows for “household waste 2001” using domestic waste (grey bin) as an example

However, not only are material flows in waste management becoming more complex; in addition, more diverse and higher quality secondary raw materials and secondary products are also being produced. The main effect of waste management’s contribution to sustainable development may be found here, as illustrated by the following examples:

- Every not discarded paper fibre will replace a corresponding quantity of functionally identical primary fibre material.
- Plastics replace products from primary plastic or are used to manufacture products such as palisades or fences, thereby replacing concrete and wood products.
- The nutrients returned to the soil via biowaste replace a functionally equivalent quantity of mineral fertilizers, which would otherwise have to be obtained as primary material e.g. in the form of phosphate ores.
- Energy recovery e.g. in cement kilns or power plants, is used to substitute various primary energy carriers.

Waste management is therefore evolving into materials flow management.

In order to be able to determine the contribution of waste management to sustainable development, it is necessary to

- **trace the material flows of all wastes**
- **consider every process in the material flow chain, be it collection, sorting, processing, transportation etc., and the associated input.**
- **examine and incorporate the effects of waste recycling on the saving of primary raw materials.**

1.4 ... on the calculation model

An analysis of the contribution of waste management to sustainable development in Germany can only be achieved by considering the material flows caused by it. Material flows and the resource requirements that trigger them, as well as emissions into the environment, are emulated and calculated using the materials flow software UMBERTO (www.umberto.de).

UMBERTO allows us to model material and energy conversion in each process occurring in waste management and materials flow management in the required level of detail. This not only includes processes such as collection, transportation, sorting, processing, incineration, co-incineration and landfilling, but also the primary processes of materials production which are replaced by secondary products. Each process is emulated in such a way that the program calculates its respective resource requirements and emissions to the environment.

Processes such as waste incineration are well-known and may be implemented accordingly. However, some emissions are dependent upon the specific composition of the waste. For example, in the case of carbon dioxide emissions from waste incineration plants, the proportion of carbon – classified according to fossil and non-fossil carbon – must be determined depending on the waste being incinerated. Furthermore, allowance is made for development of the technical status of the processes over the years in question.

Finally, the individual processes are linked together via arrows on a graphical interface in accordance with the information on waste quantity and waste location at each point of the network. The respective waste quantities are incorporated into the network, and produce the material flows model (cf. Figure 3). The network of processes is not confined to one level, but is hierarchically structured.

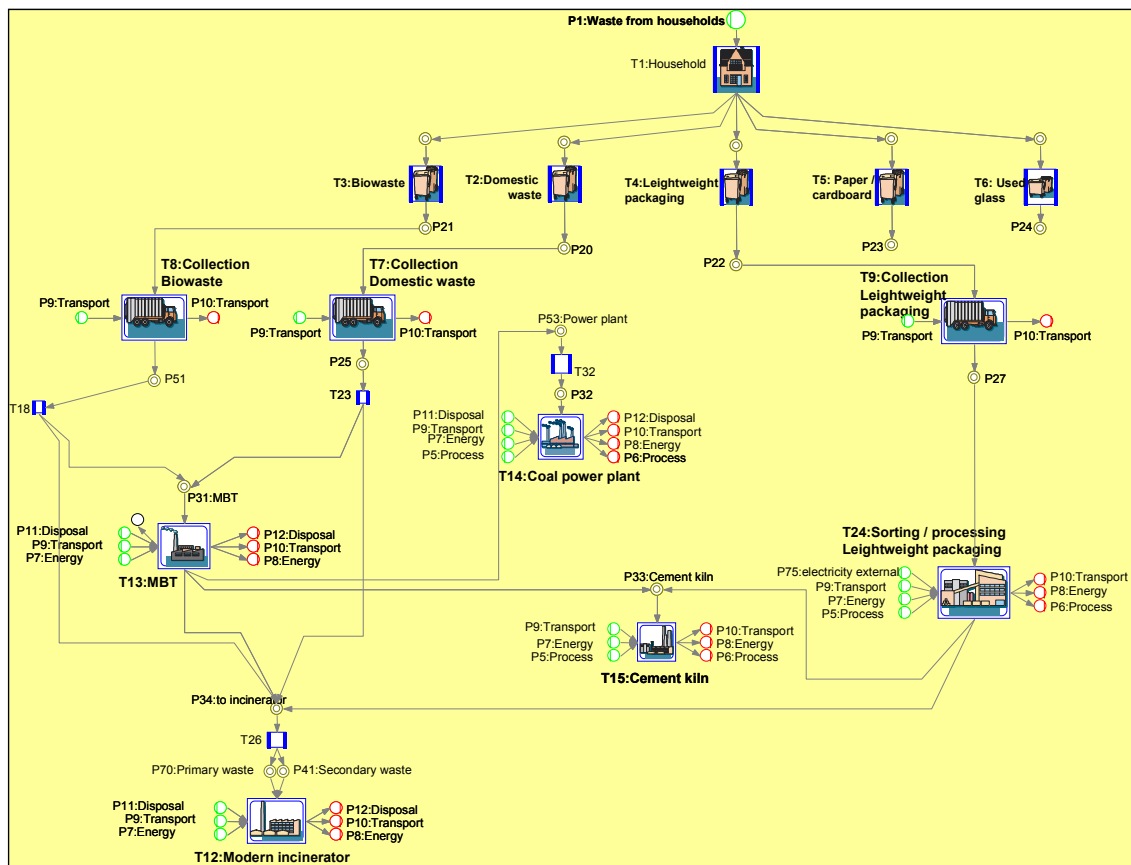


Figure 3 Excerpt from the materials flow model for waste from households, prepared with the UMBERTO software

For the materials flow model as a whole and for any given sub-systems, input and output balances of material consumption and emissions to the environment may be generated automatically, examined for any given number of parameters, and graphically depicted.

2 Resource conservation and environmental impacts

- Topics and indicators

In order to be able to determine the contribution of waste management to sustainable development in Germany, it needs to be defined and somehow made “measurable”. We have already mentioned that the very wide-ranging definition of sustainable development should be confined to the handling of resources as outlined in paragraph 1 of the Closed Substance Cycle and Waste Management Act.

Natural resources are defined as:

All components of nature which provide a direct benefit for humans, such as fossil fuels, renewable, replenishable raw materials, and genetic resources. Natural resources also include services performed indirectly by nature for humans, such as the absorption of emissions (sink functions) and the maintenance of ecological/biogeochemical systems [UBA Nachhaltige Entwicklung in Deutschland; 2002]

Using this comprehensive definition of resources, we have selected some important key indicators.

Finite fossil fuels and finite mineral resources are used as indicators for the narrower approach to resources. Regarding the sink functions of the environment, we have selected the following areas of adverse environmental impacts: global warming potential, acidification, over-fertilization of soils and watercourses, and impairment of human health.

The selected topics evaluated and the corresponding indicators are outlined below:

1. Fossil energy resources

Fossil energy resources continue to play a major role in the production methods of our industrial society. They are considered a finite resource, albeit with varying reserve quantities depending on the energy resource (petroleum, natural gas, coal).

In order to be able to outline the handling of fossil fuels, **cumulated energy demand** is used as an **indicator**. This refers to the sum total of all energy inputs of the primary raw materials petroleum, natural gas and coal. The indicator is measured in the **unit of joules**.

2. Mineral resources

Alongside fossil fuels, mineral resources must also be conserved as finite raw materials in the interests of sustainable development. Future generations should have the same opportunities to access these materials. From the wide range of mineral resources, we

have selected two substances by way of examples. Firstly, **iron or iron ore**, and secondly **phosphate ore**, as a key raw material for agricultural fertilizers. The **absolute quantity in tonnes** is used as the indicator in each case.

3. Global warming

As well as conserving resources, climate protection is considered to be one of the most pressing environmental problems. Within the context of the Kyoto Protocol, Germany has undertaken to reduce six greenhouse gases by 21 % between 1990 and 2012. Apart from the dominant greenhouse gas carbon dioxide (CO₂), a key role is also played by methane (CH₄) and nitrogen dioxide (N₂O) in the waste management sector. As an indicator, the **impact equivalent to carbon dioxide** is used as a reference quantity. This is specified and measured in terms of **tonnes of CO₂ equivalent**.

It is important to mention that long-term deposition (for more than 100 years) of non-fossil carbon in landfills or soils leads to a reduction of the greenhouse effect. The offsetting of this so-called carbon sink is not regulated via conventions and therefore will be disregarded here.

4. Acidification

One important environmental impact which must be taken into account when considering the sink function of environmental media is the acidification of the protected environmental commodities soil and water. The acidifying effect emanates primarily from sulphur dioxide and nitrogen oxides. However, other gases such as hydrogen chloride, hydrogen fluoride, hydrogen sulphide and ammonia also contribute to the acidifying effect. The acidifying **effect of an equivalent quantity of sulphur dioxide** is used as an indicator. The indicator is measured in terms of **tonnes of SO₂ equivalent**.

5. Over-fertilization of soils and watercourses

Another superordinate environmental impact which utilizes the sink function of the environment is the over-fertilization of soils and watercourses. Nutrients or precursor substances of nutrients are released into the air and waterbodies, where they alter the natural conditions of the ecosystems. The main air emissions leading to the over-fertilization of soils are nitrogen oxides and ammonia. Phosphate and nitrogen compounds contribute to the over-fertilization (eutrophication) of waterbodies, supported by the depletion of oxygen – measured in terms of chemical oxygen demand. Differentiated according to the two exposure pathways, an **equivalent phosphate quantity is chosen** as the indicator and specified in terms of **tonnes of PO₄ equivalent**.

6. Impairment of human health from carcinogenic substances and particulate matter

The overall situation regarding the impairment of human health is difficult to evaluate. The local situations and possible contamination paths are too diverse. For this reason,

we have selected two types of stress on human health which are more likely to be evenly geographically and temporally distributed, and for which no effect thresholds are known.

Regarding the carcinogenic effect of air pollutants, **the equivalent quantity of carcinogenic substances in relation to arsenic measured in tonnes of As equivalent** (As, Cd, Cr(VI), Ni, BaP, PCB, PCDD/PCDF) is used as an indicator, whilst for particles the **absolute quantity of dust particles and secondary particles smaller than 10 micrometers (PM10) measured in tonnes of PM10 equivalent** has been chosen. Figures supplied by the European Environmental Agency are used to convert compounds such as SO₂, NO_x, NMVOC and NH₃ into secondary particles.

3 The contribution of waste management to sustainable development from 1990 to 2001, with an outlook to the year 2005

- The results

For the six selected topics with a total of nine indicators of sustainable development, the contribution of waste management for household waste is outlined below in diagrammatic form.

Explanation of the diagrams:

All waste management activities – from collection, to sorting, transportation and processing through to production of a secondary material or waste disposal – are linked to resource consumption and environmental impacts. These are represented by an **upward-pointing bar**. The sections highlighted in colour represent the contributions of the individual sub-systems and processes to recycling and treatment.

The material and energy recovery of waste leads to the saving of resources and the relief of environmental pressures at a different point in the economic cycle. This savings effect is represented by a **downward-pointing bar**. Consequently, the downward-pointing bars represent credits relating to each substituted material or to the energy substitution of the recycling process. The colour coding indicates which contribution originates from which material or energy credit.

Resource and environmental **impacts** from waste management activities (upward-pointing) and resource and environmental **relief** from the primary activities saved (downward-pointing) may be offset against one another. The sum total produces a **net result** showing whether the contributions of waste management tend to impact (net bar pointing downwards) or relieve the environment (net bar pointing downwards) overall. The net bar is a monochromatic pillar adjacent to the waste management and credit bars; because it is derived from a differential, it cannot be expediently broken down into sectors.

All diagrams show:

- The situation in 1990 prior to the entry into force of most waste management measures
- The situation in 2001 with the latest up-to-date waste figures available in the form of a national balance sheet
- The potential situation for 2005 after implementation of the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements

3.1 Fossil resources

The waste management measures stepped up since 1990 have led to a clear increase in the use of fossil energy resources. Particularly with the recycling of paper and board, lightweight packaging and biowaste, there has been an increase in the consumption of fossil resources.

On the other hand, the implementation of waste management measures has also effected a clear increase in environmental relief. The greatest contributions to the savings of fossil energy resources originate from the more widespread material recycling of paper, cardboard and lightweight packaging, as well as the increased capacities of incineration plants. Industrial coincineration, primarily in power stations and cement kilns, represents an increasingly important contribution, and is expected to rise further, according to forecasts for 2005.

The savings of fossil fuels have risen at a much sharper rate than expenditure, due to increased material and energy recovery. This produces a higher resource saving for 2001 versus 1990 of around 70 PJ. (1 PJ = 1 petajoule = 10^{15} joule) The requirements of the Closed Substance Cycle and Waste Management Act for resource-conserving production methods have therefore been impressively verified.

Thanks to the more widespread use of thermal recovery following mechanical-biological pretreatment or direct use in incineration plants, this trend will also **continue for the year 2005, even for the measures already initiated. A further 30 PJ saving of fossil fuels is anticipated** (assuming an unchanged volume and location of waste for recycling).

With regard to waste from households, the saving of fossil fuels from waste management will therefore be around 100 PJ higher under the 2005 scenario compared with 1990. This is statistically equivalent to the consumption of a large city with 700,000 inhabitants, or just under 1 % of the consumption of fossil fuels in Germany in 2001.

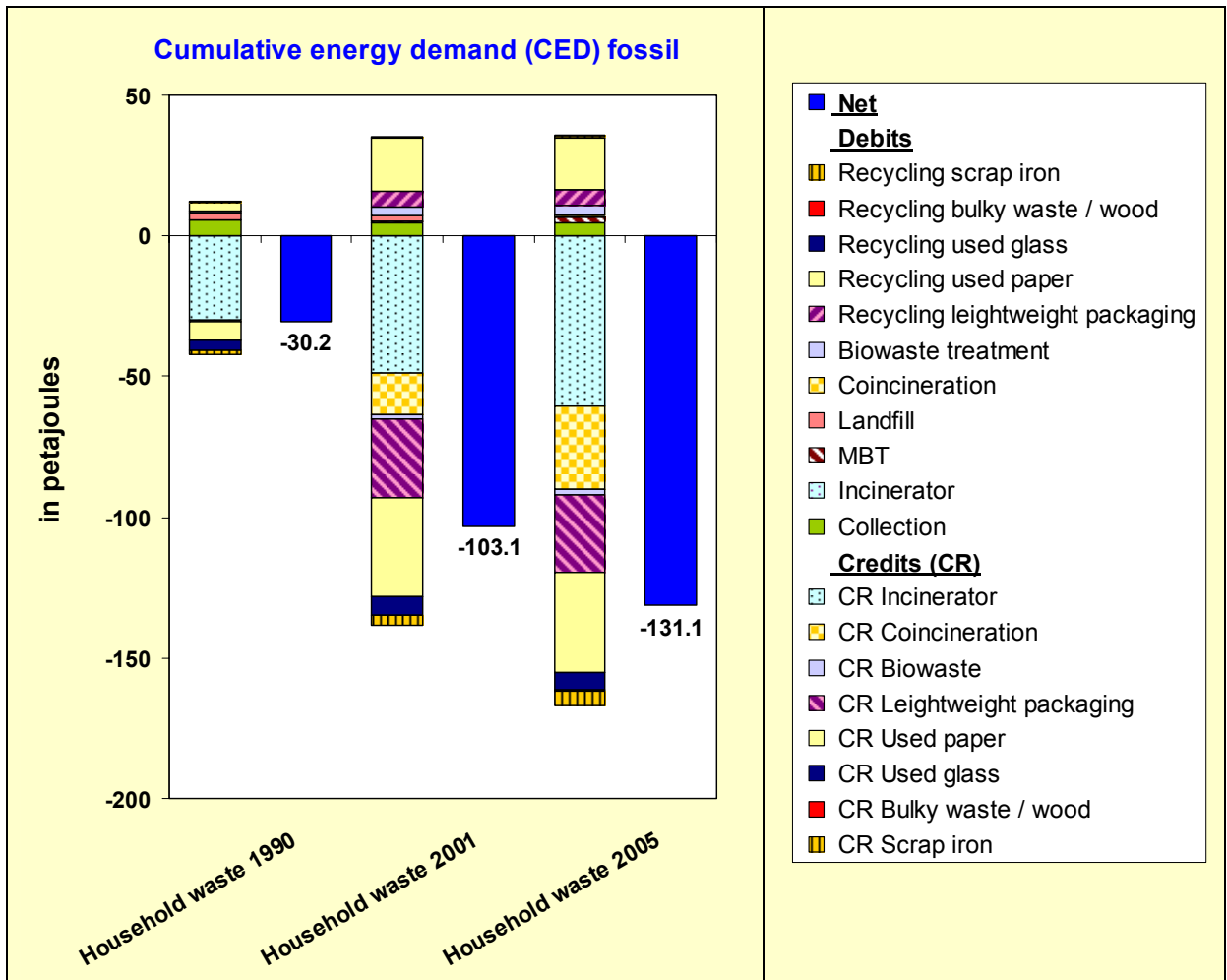


Figure 4 Results for the exploitation of fossil resources

3.2 Mineral resources

The conservation of natural resources (§ 1 of the Closed Substance Cycle and Waste Management Act <KrW-/AbfG>), as one of the main objectives of waste management, includes mineral resources as well as energy resources. **Iron or iron ore** and **phosphate ore** have been selected here as typical examples from the diverse range of mineral resources.

Iron and iron ore

The savings of iron and iron ore from the household waste segment has increased significantly from around 240,000 tonnes in 1990 to more than 1.1 million tonnes in 2001. This is mainly attributable to tin cans collected via lightweight packaging, large quantities of which still ended up on landfill sites in 1990. Expanded incineration capacities likewise lead to a higher rate of reuse, via scrap recovery in the slag. With the more widespread use of waste incineration plants in the scenario for 2005, coupled with the fact that iron segregation is fairly effective, the proportion of iron and steel recovery will rise further.

Phosphate ore

Phosphate ore is primarily used as a mineral fertilizer in agriculture and landscape gardening. In agriculture, gardening and landscaping, phosphate may be substituted via the use of compost and digestate. Although the phosphate content in compost is not very high, the use of compost nevertheless leads to a saving of raw phosphate.

The significant increase in the recycling of biowaste from 1990 to 2001 has therefore also led to significantly increased resource savings for phosphate ore. Whereas in 1990, savings were limited to around 2,000 tonnes of phosphate ore, in 2001 this figure had already risen to more than 26,000 t. As no change in the separate collection and recycling of biowaste was assumed for the 2005 scenario, this quantity remained constant.

Almost five times as much iron and iron ore was recovered from household waste in 2001 as in 1990.

In 2001, biowaste recycling led to a twelve times higher rate of return of the nutrient phosphate to the biological cycle than in 1990, and hence to a corresponding saving of phosphate ore.

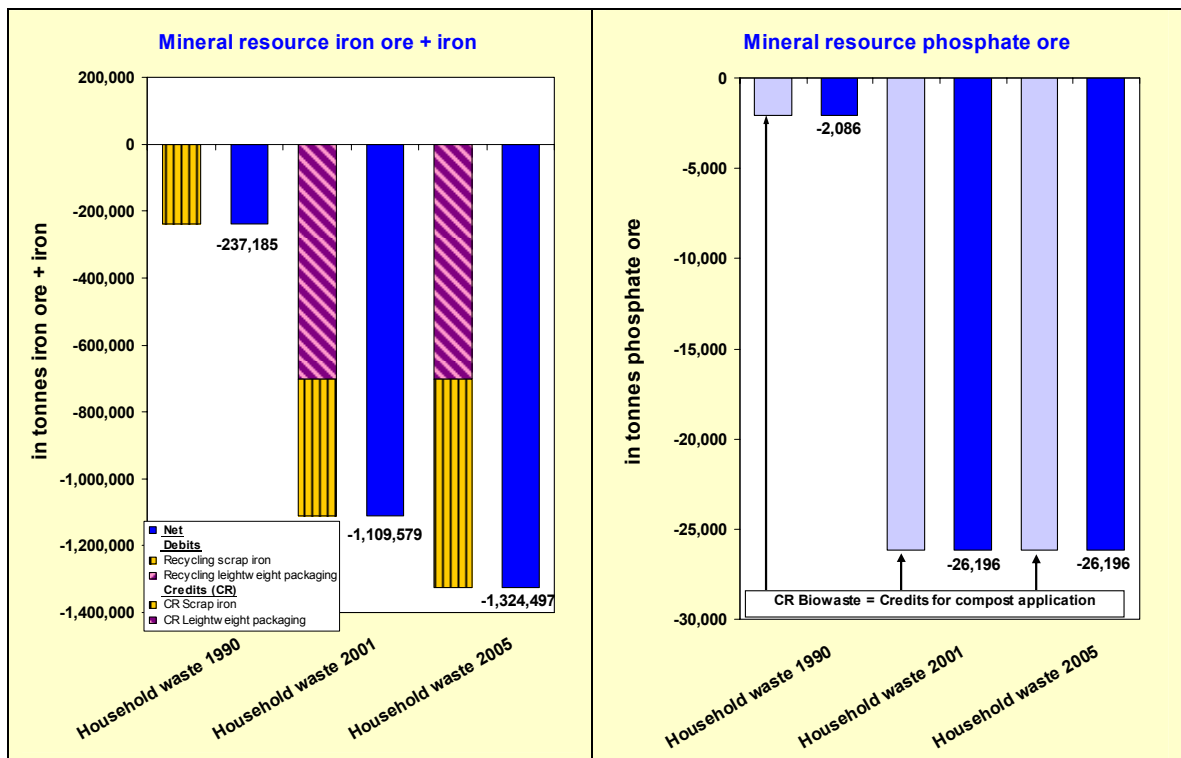


Figure 5 Results for the exploitation of mineral resources for iron/iron ore and phosphate ore.

Explanation on system boundaries:

The consumption of raw materials and the environmental pressures caused by investment goods (e.g. steel in plant engineering) have been disregarded, both for the waste system and for the purpose of credits. They are minimal in relation to the figures for waste treatment and therefore negligible in the initial approximation.

3.3 Global warming potential

Between 1990 and the present day, waste management has made a substantial contribution toward reducing climate-affecting gases. A further reduction is anticipated for 2005.

Whereas in the year 1990, more than 25 million tonnes of CO₂ equivalent (net) originated from disposed household waste, a reduction by almost the same amount by the year 2001 meant that this segment of waste management no longer constituted an additional pressure for the global warming potential, at least. In other words, the relief afforded by waste management measures almost outweighs the impact.

Emissions of methane gas from landfills constitute the predominant contribution of waste management to the global warming potential. A reduction in the waste from households stored on landfills, coupled with improvements in the technical facilities such as landfill covers and the collection of landfill gas, have contributed to a significant reduction in these pressures.

From 2005 onwards, the contribution will be further significantly reduced thanks to the implementation of the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements, since the new Ordinance prohibits the storage of untreated waste. We anticipate a further net reduction of 5 million tonnes of CO₂ equivalent for the quantity of waste disposed of from households under the 2005 scenario, which in turn will lead to net relief of approximately 4.5 million tonnes by waste management.

As well as reducing methane emissions from landfills, the increased incineration capacities will admittedly lead to an increase in carbon dioxide emissions, but this will be offset by a corresponding increase in credits from the substitution of fossil fuels. In particular, industrial co-incineration indicates high levels of efficiency and hence a high degree of substitution. Material recycling also contributes, but is considered secondary to the reduction of landfill gas emissions.

Of the quantity of waste from households disposed of in Germany each year, no additional pressures are now incurred for the climate. Under the 2005 scenario, due to the implementation of the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements, the global warming potential will actually be relieved by some 4.5 million tonnes of CO₂ equivalent. Overall, therefore, a reduction in greenhouse gases of around 30 million tonnes of CO₂ equivalent compared to 1990 levels is anticipated for 2005, due to greenhouse gas emissions caused by waste disposal.

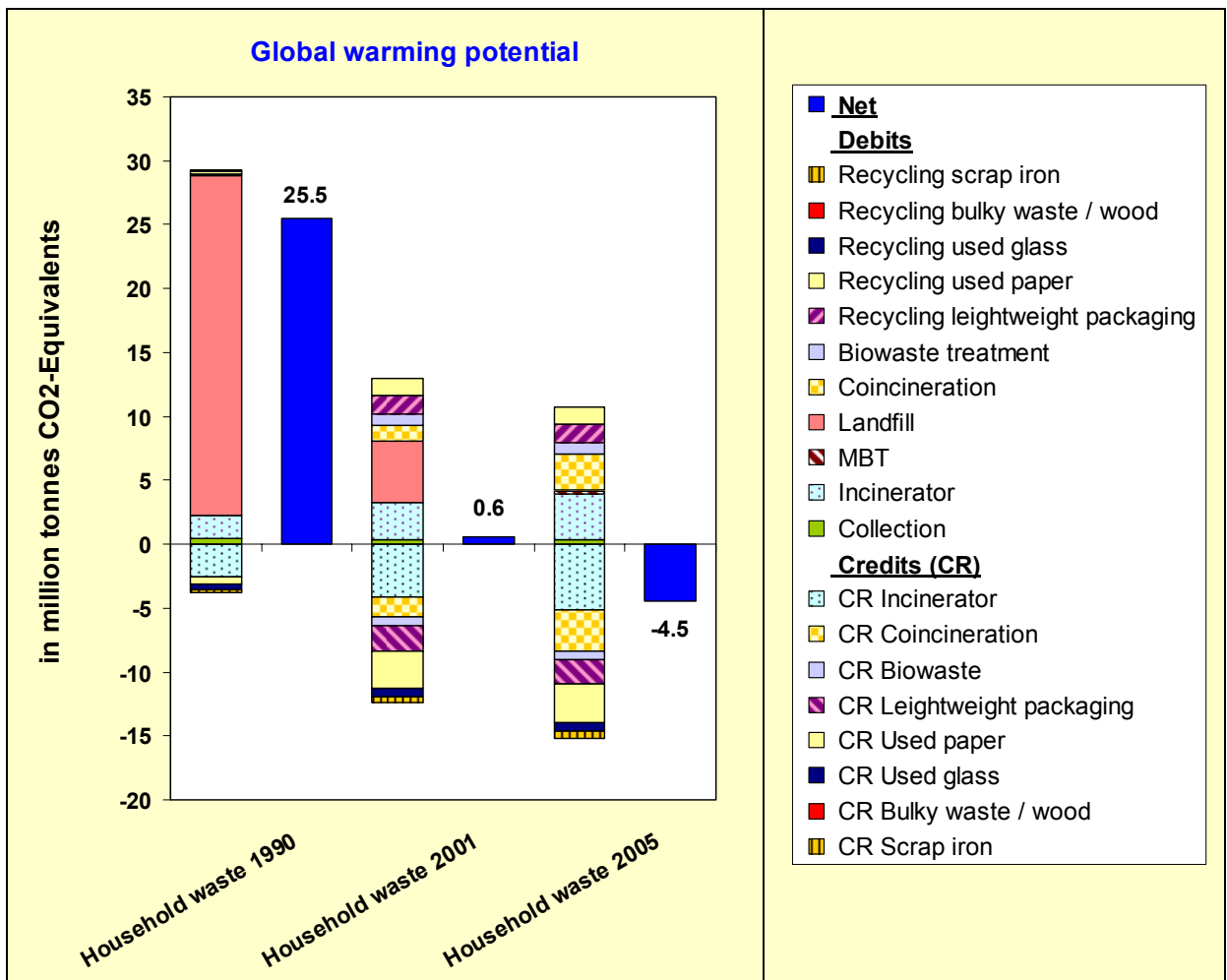


Figure 6 Results for the impact category “global warming potential”

Explanation on “landfill” in the legend

Emissions of landfill gases from a stored quantity of waste develop over a period of many years (approximately 100 years). In this calculation, all emissions from a landfill arising in future are related to the year in which the waste was stored. As such, this produces a different figure than that given in the report on climate gas emissions per annum, for which all waste stored in the past which is still producing gas today must be taken into account.

3.4 Acidification

In the year 1990, the waste industry contributed over 60,000 tonnes of SO₂ equivalent to acidification. As there was little relief to offset this, the net impact was almost 55,000 tonnes of SO₂ equivalent. The considerable improvement in emission standards for acidifying gases under the Waste Incineration Ordinance (17th BImSchV) achieved a significant reduction in this form of environmental impact up until the year 2001. Contrary to this, there has been a sharp increase in emissions of ammonia from open biological waste treatment facilities, which ultimately dominated impacts in the year 2001.

Apart from a reduction in acidifying emissions, however, in the year 2001 credits from substituted primary materials manufacturing helped to avoid emissions and in fact achieved a net relief of around 4,000 tonnes of SO₂ equivalent. The credits are dominated by the material recycling of paper and cardboard and lightweight packaging. A minor contribution is also given by iron scrap and biowaste recovery. Higher credits are also derived from energy recovery, since the incineration of waste generally leads to lower emissions than with fossil fuels, due to lower sulphur contents.

The forecast for the year 2005 shows little change in the area of acidification, since the impacts and relief from material recycling are the same, and only an expansion of incineration in waste incineration plants with good flue gas purification would create higher credits from energy generation.

Ammonia emissions from open biological waste treatment plants limit the success achieved from the more stringent emission standards for incineration plants, so that the environmental relief is limited to around 4,000 tonnes of SO₂ equivalent per annum. However, the improvement from 1990 to the present day has been considerable, with a reduction of almost 60,000 tonnes of SO₂ equivalent.

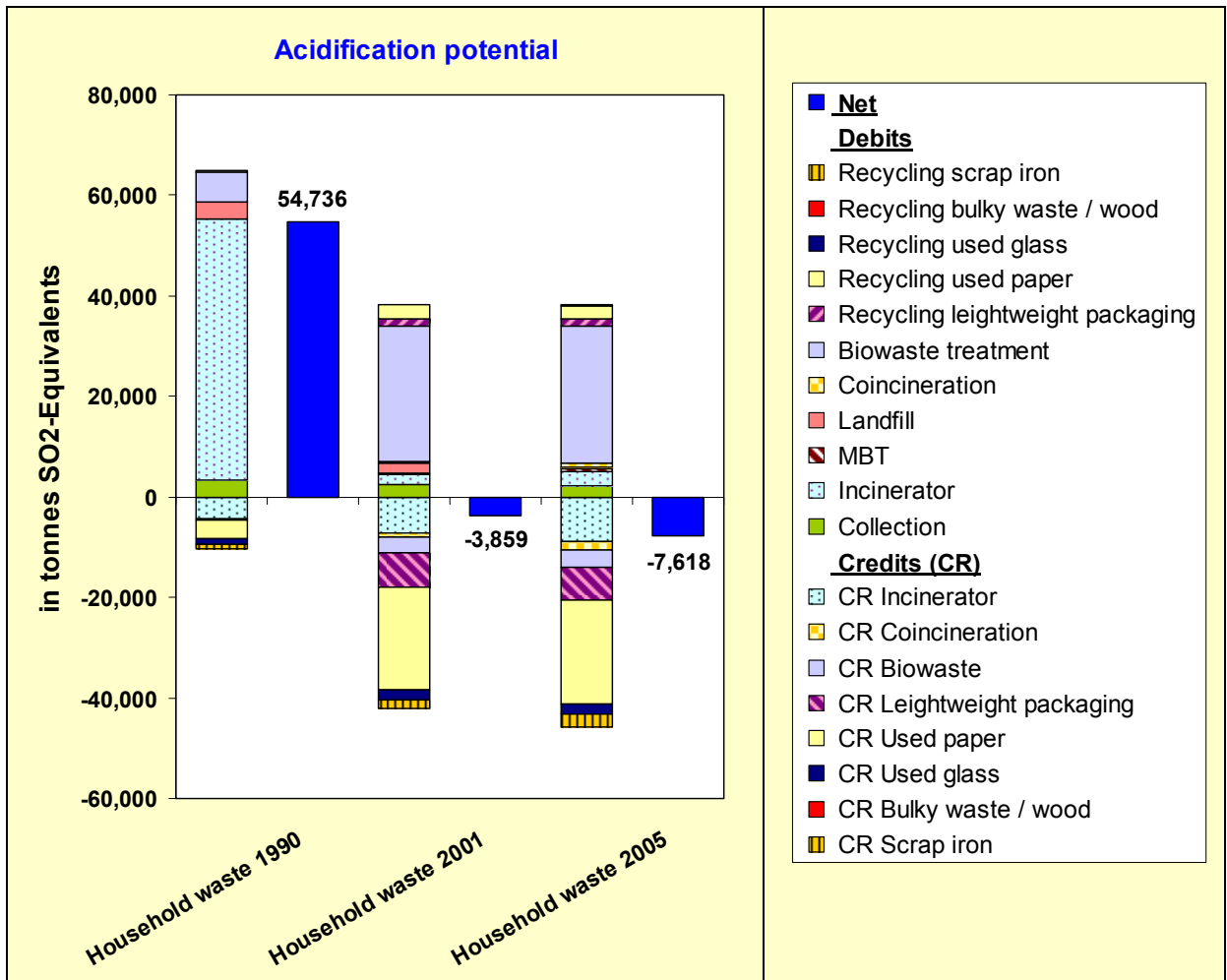


Figure 7 Results for the impact category “acidification”

3.5 Over-fertilization of soils and watercourses

Soil conservation

The over-fertilization of soils – determined via the emissions of eutrophying compounds into the air – has hardly changed at all in the period from 1990 to 2001. The measures of the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements will also have little effect on this form of environmental pollution for the year 2005. The net impact from this impact category is around 2,000 tonnes of PO₄ equivalent.

In 1990, predominant emissions were nitrogen oxides from incineration plants, ammonia emissions from composting of biowaste and from landfilling of waste and finally nitrogen oxides from the collection of waste from households. These impacts were not accompanied by any mentionable credits on the opposite.

The quadruplication of biowaste treatment between 1990 and the present day lead to a considerable increase of ammonia emissions in this sector. At present approximately 85 % of the separate collected biowaste is composted, some half in open treatment plants. Also the application of produced compost, especially fresh compost, is combined with further ammonia emissions. The implementation of flue gas purification for nitrogen oxides in incineration plants minimized impacts from waste incineration despite risen incineration capacities, however, without being able to compensate the augmentation due to the biowaste treatment.

In the first line the credits from the increased material recycling of paper and cardboard and lightweight packaging prevented an explicit rise of the net impacts from 1990 to 2001 in the end. Especially the energy intensive primary production of paper and therewith associated nitrogen emissions from the production of certain paper grades made a contribution. The same applies for the recovery of plastics of the lightweight packaging, even though to some less degree.

It has not been possible to reduce the over-fertilization of soils caused by waste management measures, particularly due to the treatment of organic waste in open applications, which is increasingly collected and recycled separately.

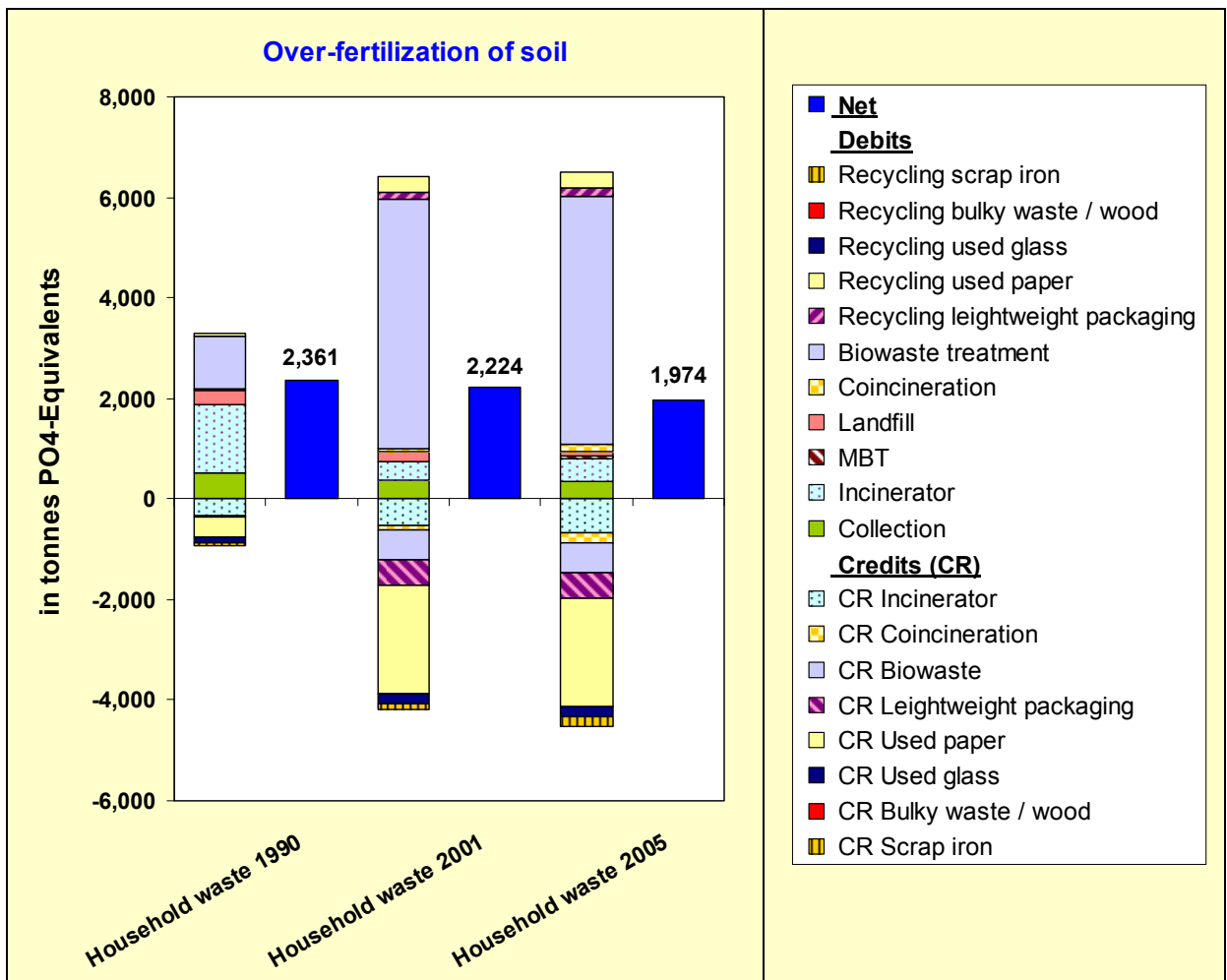


Figure 8 Results for the impact category “over-fertilization of soils”

Water protection

Apart from the exposure pathway of over-fertilization of soils, the contamination of watercourses by fertilizing and oxygen-depleting substances (aquatic eutrophication) is determined almost solely by landfilling and waste paper recycling. The reduction in watercourse contamination from approximately 17,000 tonnes of PO₄ equivalent in 1990 to a net relief of around 6,000 tonnes of PO₄ equivalent in 2001 is primarily attributable to the reduction in the quantity of household waste that is landfilled, coupled with improved landfill technology (collection and treatment of leachate). The relief of watercourses from primary fibre production via paper and cardboard recycling has produced a net relief overall. When the storage of non-pretreated waste is prohibited from 2005 onwards, there will be a further slight reduction in eutrophying watercourse pollution.

The net impact of watercourses with eutrophying and oxygen-depleting substances by waste management still ending in 1990 has been changed to a net relief, primarily thanks to improved landfilling techniques, the reduction in the quantities of waste stored, and waste paper recycling. The achieved overall reduction between 1990 and 2001 comes to nearly 23,000 tonnes PO₄ equivalent.

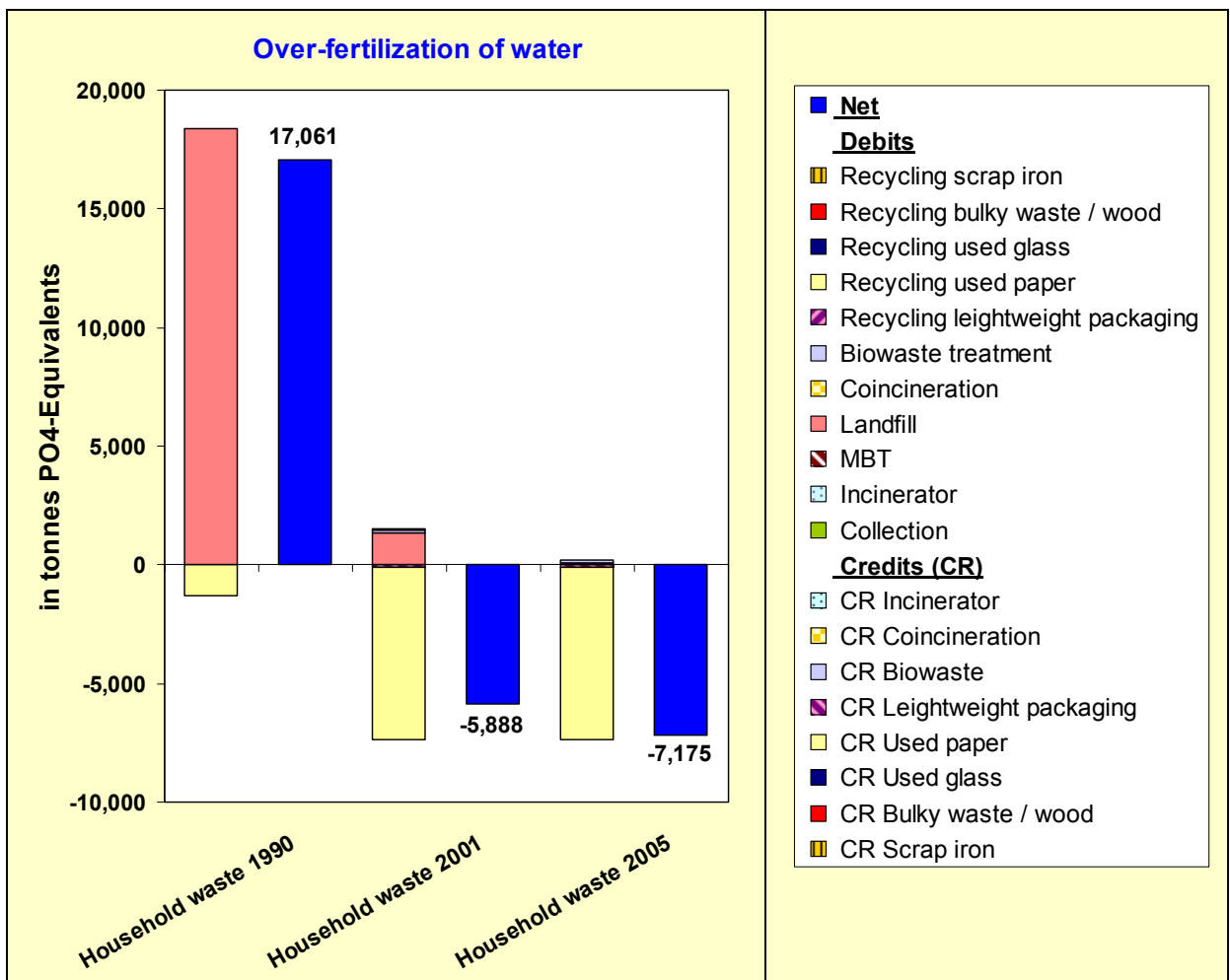


Figure 9 Results for the impact category “over-fertilization of watercourses”

3.6 Impairment of human health

Cancerous risk

The reduction in impairments to human health, measured using the indicator of atmospheric emissions of carcinogenic substances, shows an impressive development. The clear improvement in emission standards from waste incineration plants as a result of the 17th BImSchV and resulting from this, the reduction in carcinogenic atmospheric pollutants such as dioxins and furans, as well as heavy metals and other pollutants, has produced a significant relief.

The reduction from 188 tonnes arsenic equivalent impact to a net relief of 3 tonnes arsenic equivalent needs no further comment.

In particular, the risk of cancer was drastically reduced due to the tightening of emission standards for waste incineration plants.

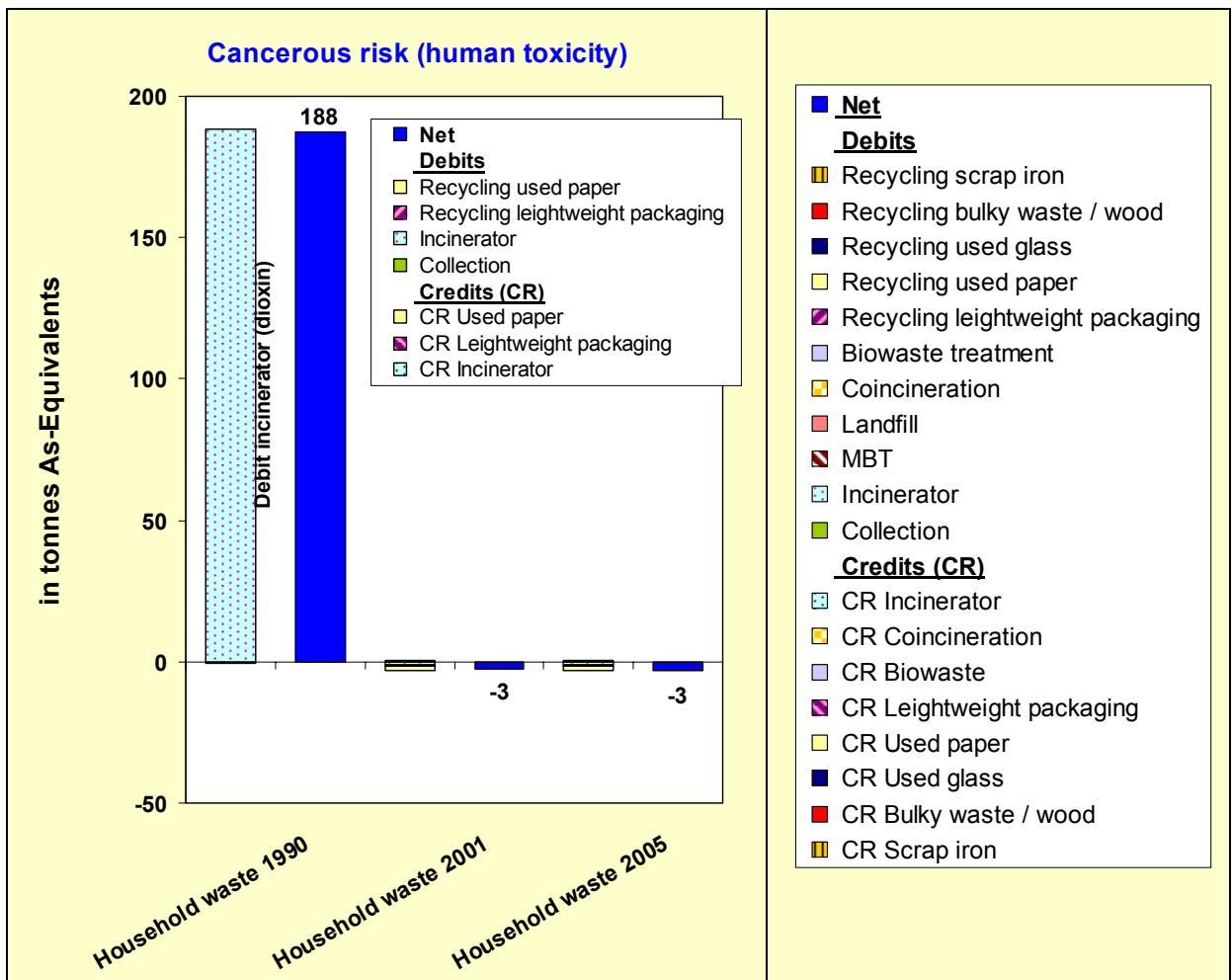


Figure 10 Results for the impact category “cancerous risk” (human toxicity)

Risk of atmospheric contamination with particulate matter

The development of atmospheric pollution with particulate matter (PM10) has likewise shown significant improvements between 1990 and 2001. A decline in the emissions of particulate matter and its precursor substances by 41,000 tonnes of PM10 equivalent has seen a reversal from a net impact from the waste management in 1990 to a net relief of almost 25,000 tonnes of PM10 equivalent in 2001. A further reduction – albeit on a smaller scale – is anticipated from the measures for 2005.

The Waste Incineration Ordinance (17th BImSchV) has likewise played a key role in this respect, and contributed significantly to the reduction of emissions of particulate matter as well as of sulphur oxide and nitrogen oxide emissions building secondary particles in the atmosphere.

Nevertheless, secondary particles are also formed from ammonia emissions deriving from the biowaste treatment. As found with the over-fertilization of soils the quadruplication of the recovery of biowaste here also leads to an enlargement of the impacts of particulate matter. However, in 2001 the impact of particulate matter caused by waste management is one fourth below that in 1990, already without the credits taken into account.

The distinct reduction of the risk of atmospheric contamination with particulate matter is due to the relief out of the credits. Credits are predominated from material recycling of paper and cardboard, lightweight packaging and used glass. The higher emissions of particulate matter out of the production with primary materials could be substituted with the alternative production based on secondary materials combined with less emissions of particulate matter.

A further contribution to higher credits is also given from thermal processes. The energy production of incineration plants observing the strict emission standards of the 17th BImSchV substitutes a conventional energy production with primary fuels that underlies less strict emission standards. Therefore, increasing incineration capacities between 2001 and 2005 lead to a further reduction of emissions of particulate matter and to a further net relief.

Likewise with regard to emissions of particulate matter, the “net impact” still existing in 1990 has been eliminated, and transformed into a significant “net relief”.

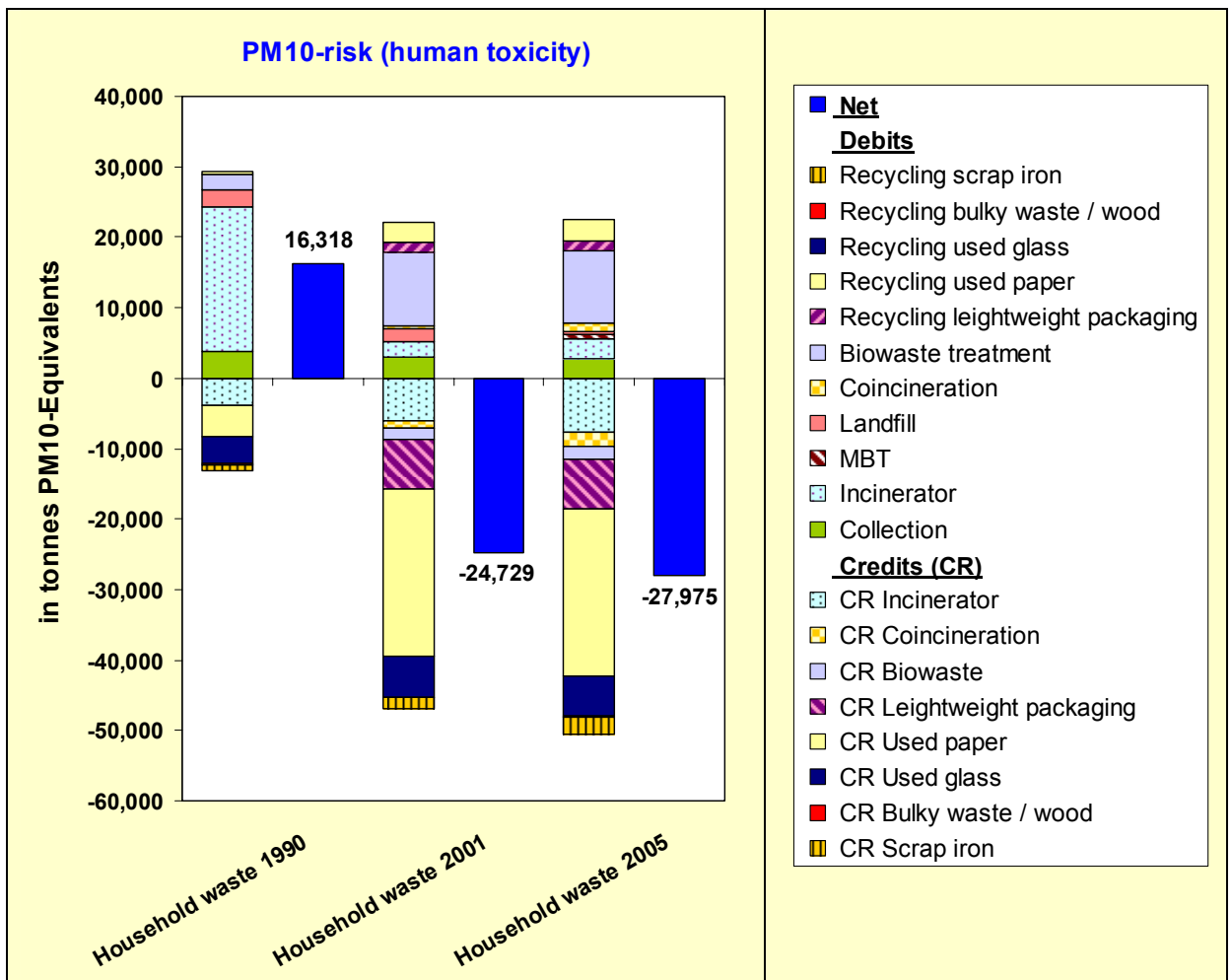


Figure 11 Results for the impact category “PM10 risk” (human toxicity)

4 The achievements of waste management in Germany

Finally, the contribution of waste management – in this case, waste from households – to a sustainable development shall be illustrated in overview format. Therefore, the so-called "net results" - meaning the differences between the impacts and reliefs caused by waste management - are summarized in table 5. Positive values mean an excess of environmental impacts, negative values refer to a surplus of the reliefs. Shown are all environmental categories for the years 1990, 2001 and 2005 that have been specified before.

In order to calculate the contribution to environmental protection using the net results of impacts and reliefs, it is necessary to contrast these results with the total resource consumption in Germany, i. e. the total environmental impacts. The total values for Germany in 2001 in the different categories examined [Umweltdaten 2002] are also listed in table 5. For example: The total consumption of primary fossil fuels in Germany in 2001 was about 12,000 PJ in terms of energy content. The emission of climate-affecting gases was about 970 million tonnes CO₂ equivalent. In comparing the 2001 net results for each category with the respective total value for Germany, the present contribution of waste management to environmental protection in terms of disposal of household wastes in Germany becomes apparent.

To further illustrate this point, a comparison is made between these figures and the environmental impacts caused (statistically) by one average inhabitant in Germany. To this end, the total resource consumption and the total environmental impact are divided by the 82,537,000 people who were living in Germany in 2001. The result is the value of resources consumed, statistically, by each inhabitant in Germany. For example: the average inhabitant consumed about 145 GJ of energy from primary fossil fuels (petroleum, natural gas, coal) and emitted about 12 tonnes of CO₂ equivalent of climate-affecting gases. The resource consumption and the environmental impact caused by the average inhabitant are also listed in table 5.

Using these figures of resource consumption and of the impact caused by the average inhabitant, the contribution of waste management to all categories can be expressed in average inhabitant numbers.

- For example: The savings in terms of fossil fuels were 103.1 PJ. This value is equal to the raw material consumption of about 700,000 average inhabitants (700,000 multiplied by 145 GJ is about 103,000 TJ or 103 PJ). The result of "700,000 average inhabitants" stands for: "In 2001 the relief of fossil fuel consumption in waste management is as high as the resource consumption of about 700,000 inhabitants of Germany." In terms of calculation, the absolute amount of an indicator of waste management is divided by the respective per capita value (in this case: 103 PJ / 145 GJ).

Table 5 Net results of waste management development in 1990, 2001 and 2005 in absolute numbers and total load in Germany and impact per capita (2001: 82,537,000 inhabitants)

Impact category	Net results			Load in Germany 2001	
	1990	2001	2005	total	per capita
Fossil resources	-30.2 PJ	-103.1 PJ	-131.1 PJ	12,010 PJ	145.51 GJ
Mineral resources iron + iron ore	-237,185 t	-1,109,579 t	-1,324,497 t	30,845,000 t	373.71 kg
Mineral resource phosphate ore	-2,086 t	-26,196 t	-26,196 t	1,728,021 t	20.94 kg
Global warming potential [CO ₂ equivalent]	25.5 m t	0.6 m t	-4.5 m t	970.9 m t	11,763 kg
Acidification [SO ₂ equivalent]	54,736 t	-3,859 t	-7,618 t	3,348,420 t	40.57 kg
Over-fertilization of soils [PO ₄ equivalent]	2,361 t	2,224 t	1,974 t	428,714 t	5.19 kg
Over-fertilization of water [PO ₄ equivalent]	17,061 t	-5,888 t	-7,175 t	457,620 t	5.54 kg
Cancerous risk (human toxicity) [As equivalent]	188 t	-3 t	-3 t	473 t	0.006 kg
PM10-risk (human toxicity) [PM10 equivalent]	16,318 t	-24,729 t	-27,975 t	2,523,442 t	30.57 kg

The conversion to a per capita average now offers the possibility to compare the different environmental categories and to understand their respective importance. In order to guarantee a mathematically correct comparison of the achievements since 1990, the net results for 1990 and 2005 were also based on the average per capita resource consumption and the emissions effected by the average inhabitant in 2001.

The net results of these calculations, including all years and all investigated environmental sectors, expressed in terms of average inhabitant numbers, are presented in Figure 12. It is now possible to compare the quantities in an overview.

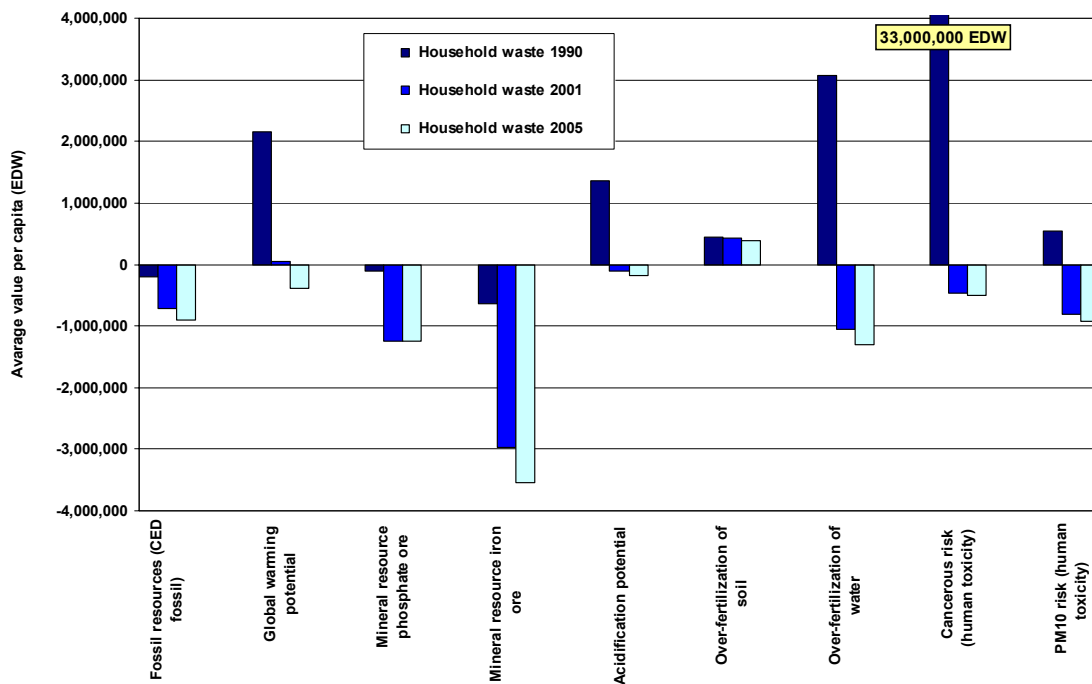


Figure 12 Net results of waste management development in 1990, 2001 and 2005 for the nine indicators analysed, expressed in terms of average inhabitant numbers.

Figure 12 allows for the conclusions summarized below:

- In 2001 waste management achieved a net relief in almost all environmental categories. This means that the reliefs surmount the impacts, in some categories to a considerable extent. This has not always been the case: In 1990, a majority of the categories examined were responsible for significant impacts on the environment.
- Depending on the category, the relief effect for 2001 is up to an equivalent of 3 million average inhabitants. This means that the environmental relief provided by waste management equals the impact statistically caused by 3 million average inhabitants. In other words: The relief effects from waste management are up to 3.5 % of the total environmental impacts in Germany.
- The implementation of the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements in June 2005 will lead to additional relief in the waste management sector.
- One exception is the category "over-fertilization of soil". In this sector, there is only a small decline in environmental impacts with numbers stagnating at 400,000 average inhabitants. The main reason for this are emissions of ammonia from treatment of bio waste in open applications. These emissions are adverse to the reduction already achieved in the release of nitrogen oxide from waste incineration.

- One category clearly stands out. The emission of carcinogenic air pollutants (especially of dioxins) produced in waste management in 1990 present an equivalent of 33 million average inhabitants. The tightening of emission standards for waste management plants – primarily waste incineration plants - has led to an environmental relief of the cancerous risk statistically equivalent to 500,000 average inhabitants in 2001 and 2005.
- In the category "global warming potential", relief effects and impacts are almost balanced in 2001. This is a considerable improvement to an equivalent of 2 million average inhabitants from 1990 to 2001. The complete implementation of the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements in 2005 will lead to a net relief in this category as well. In 2005, the balance of climate-affecting gases caused or saved by waste management will be reduced by 30 million tonnes CO₂ equivalent (2.5 million average inhabitants) from 1990. These numbers show that waste management contributes considerably to climate protection.
- The fulfilment of the requirements for the conservation of natural resources laid down in the Closed Substance Cycle and Waste Management Act is demonstrated impressively by the three examples: fossil fuels, iron ore and phosphate ore. Savings in fossil fuels add up to an equivalent of 700,000 average inhabitants already in 2001 und will be at 900,000 in 2005, owing to already instituted measures. The examples of mineral resources with a relief equivalent to nearly 3 million average inhabitants for iron ore and over 1.2 million for phosphate ore also give an impression of the relief effects that can be achieved through closed substance cycles – already just in terms of the here studied household waste.

When comparing quantities it should not be disregarded, however, that the various environmental categories also differ in quality. Global warming is a worldwide problem, which is acknowledged as hardly reversible. On a global scale, the objectives concerning this problem are far from being met. In comparison, the over-fertilization of surface waters is a local problem. Suitable measures for reduction have led to a considerable success in this sector.

Waste management has made an impressive contribution toward strengthening sustainable development and improving the environmental situation via the measures implemented between 1990 and the present day. Following a dramatic decline in the cancerous risk potential, all other indicators, apart from one, indicate a clear improvement. The trend is continuing into 2005 for those measures already adopted but not yet implemented in full.

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