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Institute for Applied Ecology

Development of the Closed Cycle and Waste Management Policy Towards a Sustainable Substance Flow and Resources Policy,
FKZ 90531411

Sub-project "Identification of Relevant Substances and Materials for a Substance Flow-Oriented Resource-Conserving Waste Management"

Abstract and summarized version

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27. June 2006, Darmstadt

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Abstract

The sub-project "Identification of Relevant Substances and Materials for a Substance Flow-Oriented Resource-Conserving Waste Management" (short title: Sustainable Materials Management – Important Potentials in Germany) represents an intermediate step in the BMU project "Development of the Closed Cycle and Waste Management Policy towards a Sustainable Substance Flow and Resources Policy" (FKZ 90531411). This Öko-Institut and IFEU-Institut sub-project will provide the Federal Environment Ministry with vital information and data relating to future focal points for closed cycle and waste management policy. This policy is dedicated to intensified utilisation of potentials for resource conservation at all levels of the production and consumption of goods. This target of resource conservation across all material flow sectors is consistent with the corresponding targets of the Federal Government's sustainability strategy (doubling both raw material productivity and energy productivity) and the EU' s resources as well as waste prevention and recycling strategies. In addition, due to the considerably increased costs of both raw materials and energy carriers, the topic of resource conservation and material efficiency is also a central issue for both industry and the consumer.

In order to answer the questions addressing the largest potentials for decreasing environmental impacts for the material flows and thereby defining the priorities of future environmental policy, a pragmatic and therefore time-efficient methodology was used. Only existing statistical data were utilised and compiled for prequalification purposes, together with existing data relating to the environmental impacts (including upstream chains) caused by the goods produced (sector perspective) or consumed (consumer perspective) in Germany. In this way it was possible to identify 10 particularly relevant produced goods and 12 particularly relevant consumer goods and to place them in the context of 6 principal material flow systems. After prequalification, and following a more detailed investigation of these six material flow systems, considerable potentials for reducing environmental impacts (conserving resources and saving energy, reducing waste flows, forcing secondary material cycles, reducing polluting gases and greenhouse gas emissions, etc.) were identified and the principal options for action with regard to utilising these potentials demonstrated (*cf.* Table 4.1 in the summarized version)

As a consequence of the potentials and options for action identified here, further investigation requirements were found out, together with important data gaps, which should be closed in the foreseeable future. The results of the sub-project confirm that considerable potentials for resource conservation can still be utilised for development of the closed cycle and waste management policy towards a sustainable substance flow and resource policy in the coming years and decades – regardless of previous successes in closed cycle and waste management policy in Germany.

Summarized version

1. Introduction

In 2002 the Federal Government approved a national sustainability strategy[1], underlined by 21 very demanding sustainability targets. Important environmental objectives were defined as components of this strategy. In the context of this project, primary targets chiefly include doubling (until 2020) both energy productivity (ratio of gross domestic product to primary energy consumption), based on 1990 figures, and raw material productivity (ratio of gross domestic product to the use of raw materials), based on 1994 figures. These targets demand significant optimisation of energy and raw material management. Progress has been made towards these long-term targets. The past successes of the closed cycle and waste management policy have played an important role here.[2]

The German Federal Ministry for the Environment, Nature Conservation and Reactor Safety (*Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit* - BMU) has voiced a number of expectations from the project "Identification of Relevant Substances and Materials for a Substance Flow-Oriented Resource-Conserving Waste Management"[3] commissioned in 2005. These include information on any relevant potential for saving energy and raw materials as well as to further reduce the emissions of pollutants to the environment. This will support optimum bundling of further activities (e.g. promotion of innovative technologies) to achieve the defined sustainability targets.[4] Some important questions addressed by the project include:

- Where do we find the greatest additional potentials?[5]
- How relevant is material storage in the technosphere with regard to conserving resources?

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[1] Perspectives for Germany – Our Strategy for Sustainable Development, Federal Government, April 2002. (*Perspektiven für Deutschland – Unsere Strategie für eine nachhaltige Entwicklung, Bundesregierung*)

[2] Perspectives for Germany – Our Strategy for Sustainable Development, Federal Government, Progress Report 2004. (*Perspektiven für Deutschland – Unsere Strategie für eine nachhaltige Entwicklung, Bundesregierung, Fortschrittsbericht 2004*)

[3] Sub-project forming part of the UFOPLAN project "Development of the Closed Cycle and Waste Management Policy towards a Sustainable Substance Flow and Resources Policy" (FKZ: 905 31 411), Öko-Institut e.V. in cooperation with the IFEU-Institut on behalf of the BMU 2005.

[4] The regular publication of Environmental Economic Accounting (EEA) by the German Federal Statistical Office documents, among other things, the trends displayed by environmental indicators which are quantifying the sustainability strategy.

[5] The project concentrates primarily on the supply side, i.e. any possible additional potentials achieved by means of any conceivable influencing of demand patterns (consumption patterns, sufficiency issues) do not form a central object of the study.

- Where does the greatest need for action remain, i.e. which potentials promise the greatest effects?
- What are the next priorities?

In this way, the closed cycle and waste management policy can be developed further to form a sustainable substance flow and resources policy. The project concentrates on the national level; however, in this context attention is drawn to the EU resources strategy and the EU strategy on waste prevention and recycling, as well as the activities of the OECD concerning "Sustainable Materials Management". The primary aims of the BMU project are:

- Establishing priorities: identification of relevant substances and materials.
- Looking to the future: trends and scenarios, development of substance and material storage[6].
- Calibration: previous addressing by the closed cycle and waste management policy.
- Policy advice: identification of the greatest potentials with regard to the Federal Government's sustainability strategy (raw material productivity, energy productivity).
- Important by-product: uncovering relevant data gaps.

2. Methodology and prequalification

Investigating the material flows of an entire national economy is a complex task that allows a number of approaches. The methodology developed for this project allows efficient identification of the principal potentials for resource conservation and for minimising environmental impacts. In principle, a scientific approach to the analysis of material flows depends on the point of view. A resources perspective, a sector perspective and a consumer perspective can be differentiated.

Under a resources perspective, the emphasis is placed only on quantification of the resource requirements of a country such as Germany or its national economy. Reliable data are available in Germany from the Federal Statistical Office, among others.[7] Merely listing the volume of all important raw materials tells us little about how efficiently these raw materials are utilised, the products they are used for and what their eventual fate may be. The resources perspective approach alone is therefore not practical.

The methodical concentration is consequently placed on a combination of the sector and consumer perspectives. The sector perspective is represented by an analysis of

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[6] Information on trends and scenarios as well as on previous addressing of these issues by the closed cycle and waste management policy can be found in the unabridged version of the final report.

[7] Cf. Federal Statistical Office EEA publications.

the material flows and associated environmental impacts with regard to the goods produced in principal sectors of the German economy. With the consumer perspective, on the other hand, the material flows associated with private consumer goods in Germany are investigated. This dual approach is especially important for an industrial nation like Germany with its multitudinous export and import interrelationships. The sector perspective also comprises process- and production-related wastes (pre-consumer waste), whilst the consumer perspective includes those wastes ensuing from products after their use phase is complete (post-consumer waste). In addition, it is important to note that different options for action may be expected for the production sector than for dealing with consumer goods in the post-use phase.

A prequalification process was performed for important produced goods based on annual manufactured volume and value criteria. An initial filter was applied at the boundary representing more than 700,000 t/a or more than 1.3 billion euros gross added value/a. This produced a short-list containing 200 products.[8] Consistent statistical data are available for both the volume and the value criteria. This is an interesting criterion because gross added value/a of a product and the complex upstream chains often associated with high gross added value express the economic importance for Germany of that product. For example, high gross added value can be used to express numerous pre-processing stages, numerous semi-finished products and building elements, as well as high energy and material use both in pre-processing or final stages. This criterion therefore provides a good contrast to the volume criterion.[9]

Following further narrowing steps 34 production sectors were identified. The most important product from each sector was selected for detailed investigation (e.g. the product Portland cement for the cement/lime/gypsum sector).

Prequalification of consumer goods was also based on Federal Statistical Office data. Nineteen consumer goods were selected from a total of 108 items on the basis of annual manufactured volume. Together, they comprise more than 90% of consumed annual tonnage of all consumer goods[10]. In the next step, the following

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[8] Data based on Federal Statistical Office production statistics.

[9] Gravel, for example, displays high relevance from a volume perspective. The gross added value per tonne, in contrast, is quite low. The opposite is generally true for many electronic products.

[10] The consumer goods data comprise the total domestic consumption, i.e. they also include imported consumer goods. Data source: Jenseit, W. et al.: (Environmental Consumption by Private Households, Öko-Institut e.V., GWS mbH, on behalf of the Federal Statistical Office 2005 (*Umweltnutzung privater Haushalte, Öko-Institut e.V., GWS mbH, i. A. des Statistischen Bundesamts 2005*).

seven environmental criteria[11] were applied both to the 34 selected produced goods and the 19 consumer goods:

- emission of greenhouse gases,
- emission of acidifiers,
- primary energy consumption (total),
- primary energy consumption (fossil energy carriers only),
- mineral resources (gravel, lime, clay, etc.),
- metallic resources (ores),
- biotic resources.

On the one hand, these criteria were selected because they include numerous important environmental protection resources (e.g. the climate) and, on the other hand, because sufficiently reliable data are available from numerous sources (material flow analyses, LCA, data from various associations, etc.). In order to formulate further focal points, the specific data vis-à-vis these criteria (e.g. tonnes of greenhouse gas emissions per tonne of steel) were determined in an intensive research phase and multiplied by the annual tonnage. In this way it was possible to compile an impact profile for each of the 34 produced goods and 19 consumer goods. In an overall evaluation of the seven criteria[12], very strong differences in relevance could be distinguished between the goods (for both each individual criterion and for the criteria as a whole). These differences were in the region of a factor of 10 and often more.

For the purpose of this project, ten particularly relevant produced goods and 12 particularly relevant consumer goods were then identified from the interim results and selected for detailed investigation.

Particularly relevant produced goods in terms of the project objectives include:

- pig iron/steel and vehicles (cars, etc.),
- petroleum products and plastics,
- mineral resources, cement, concrete,
- meat and dairy products,
- paper.

Particularly relevant consumer goods include:

- cars,
- fuel oil, natural gas and motor fuels,
- residential buildings,
- bread, products containing sugar, and drinks (fruit juices, etc.),

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[11] The data for both produced goods and consumer goods are invariably determined including the upstream chains and identified for evaluation.

[12] The criteria were adopted as equal for the purpose of prequalification.

- meat and dairy products,
- paper products (newspapers, etc.) and furniture.

By far the greatest proportion of these goods can be assigned to the three central needs areas, on both the consumer and the production sides:

- food (agriculture and foods processing),
- housing (extraction and processing of mineral resources, steel, etc.) and
- mobility (fuels processing, vehicle manufacture).

By adopting the methods described here[13] all produced goods selected, their corresponding sectors and the particularly relevant consumer goods selected can be assigned to the following six material flow systems:

1. iron ore-steel-vehicle manufacture-car consumption,
2. crude oil/natural gas-petroleum processing-fuel consumption (lateral industry: plastics),
3. mineral resources-cement-concrete-residential buildings,
4. biomass-plant processing-bread consumption,
5. biomass-animal feeds-livestock farming-meat consumption,
6. biomass-forestry-paper-furniture consumption.

The subsequent detailed analysis was performed in the context of these six material flow systems, broadly described by Figures 1-6[14]. Further important environmental aspects (e.g. high contaminant loads from heavy metals) were taken into consideration for this purpose. These also included primarily such aspects as development perspectives (increasing or decreasing future significance), ecological and technical potentials, the existence of recent innovations and the existing density of regulations.

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[13] Both the Öko-Institut and the Ifeu-Institut expressly emphasise that a simpler and more pragmatic route was consciously taken using the selected prequalification methodology in order to quickly and efficiently select particularly important produced and consumer goods for further processing. These are without a doubt of vital importance from a resources and material flow point of view. This does not imply the irrelevance of the production or consumption of further goods with regard to environmental impacts, irrespective of successful prequalification.

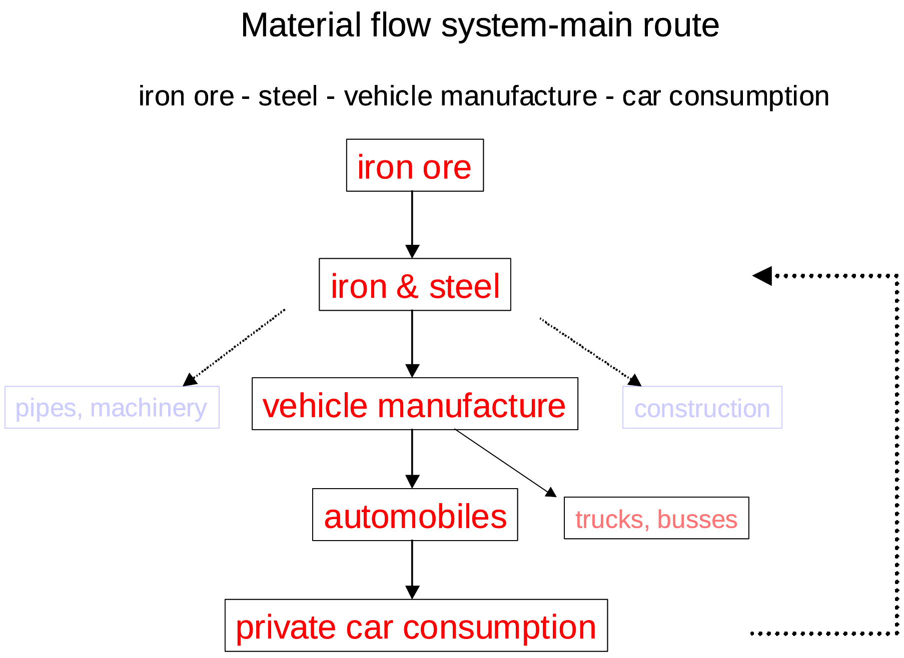
[14] The figures are not intended to represent the material flow systems in all their details. For example, representation of the import/export flows, residual substances and emissions was dispensed with in favour of clarity. Please see the unabridged version of the final report for a more detailed description of the material flow systems.

3. Results

3.1 Iron ore-steel-vehicle manufacture-car consumption material flow system

The iron ore-steel-vehicle manufacture-car consumption material flow system (see Figure 3.1) comprises one of the most important of Germany's primary industries, alongside the steel industry and, together with vehicle manufacturing (cars, lorries, busses), one of the most important branches economically, receiving around 30% of German steel production. The material flow system associated with the steel producing primary industry displays substantial resource conservation potentials (energy carriers such as coke, heavy oil, iron ore, etc.) for the next 20-30 years, not least considering the anticipated increase in the utilisation of scrap (electrosteel production).

Figure 3.1 Iron ore-steel-vehicle manufacture-car consumption material flow system



3.1.1 The steel industry

According to experts, the technical **potential**[15] for primary energy savings in the German steel industry remains considerable despite substantial reductions in the last few decades. According to a number of scenarios, the savings potential varies between around 17% (minus 128 PJ/a, lower scenario) and 27% (minus 204 PJ/a,

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[15] All potentials given in this paper should be regarded as technical potentials.

upper scenario) until 2030 compared to the initial value of 753 PJ in 2000.[16] For this it is assumed that the specific primary energy use per tonne of oxygen steel can be reduced by around 12.6% and by around 20.4% per tonne of electrosteel. The considerably greater technical saving potential represented by the upper scenario results from an assumed percentage of 45% electrosteel in 2030 compared to 33% in the case of the lower scenario (as at 2000: 28.7%). Only approximately one quarter of the specific primary energy expenditure is required to produce electrosteel. In this context it should be noted that the existing extended voluntary commitment of the German steel industry aims to reduce the specific CO_2 emissions by around 22% for the period 1990 to 2012 with respect to the entire crude steel production. This target will be achieved by a mixture of process engineering innovations and increased use of secondary raw materials.

The steel industry also represents a relevant sector with regard to the accumulation of mass residual substances. Large residual substance flows such as blast furnace slag are utilised in huge quantities (e.g. as granulated slag in the cement and concrete industry). However, there is one class of mass residual substances, the blast furnace gas sludges (zinc, lead and cyanide containing sludges from blast furnace flue gas scrubbing), for example, that is currently stored chiefly in the open on company owned landfills (approximately 350,000 t of blast furnace gas sludges accumulate annually in the whole of Germany). Recycling processes for these contaminated wastes already operate in the market (reclaiming the iron, lead and zinc components) and are utilised according to the local conditions (availability of landfill space, etc.). The condition specified in the Landfill Directive and in national legislation (Technical Directive on Waste and the Landfill Ordinance (*Technische Anleitung Abfall and Deponieverordnung*)) emphasise that by 2009 at the latest (necessary reapproval of landfill sites) recycling routes must be investigated and utilised.

Further substantial reductions in the use of raw materials and energy can therefore be identified as the **options for action** in the German steel industry. An increase in available scrap on the one hand, and a medium- to long-term increase in existing production capacities for electrosteel, on the other, represents principle components here. In addition, sufficient recycling capacity must be made available for relevant residual substances, such as blast furnace gas sludges, in order to put an end to landfilling these contaminated wastes in the future.

3.1.2 Vehicle manufacturing

Vehicle manufacturing is one of the most important branches of industry in Germany, not only from an economical and social perspective, but also from an environmental point of view. The proportion of German industry's total energy

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[16] The reduction potential corresponds to approx. 10–15 Mt/a CO_2 equivalent, representing around 1.0 to 1.5% of the total German emissions in 2002.

consumption utilised in vehicle manufacturing in 1998 was 24.1%. The fact that German road vehicle manufacturing utilises around 30% of steel consumption and around 33% of aluminium consumption, underlines the paramount importance of this branch of the economy, including for many upstream industries. The specific vehicle weight is highly relevant from an environmental point of view. **Potentials** exist for the reduction of vehicle weight with regard to both the reduction of raw materials and energy utilisation in the upstream chains and for fuel consumption, and thus the emission of carbon dioxide during vehicle operation. However, in the last 25 years the average unladen weight of a new vehicle has nevertheless increased from 900 kg to 1,120 kg (due to improved comfort and safety packages and more powerful engines). Simultaneously, however, the proportion by weight of relatively lightweight materials such as plastics or aluminium has increased. Experts estimate the maximum technically achievable saving potential in terms of vehicle weight at around 40% (minus approx. 3.4 Mt of material for production of 5.8 million cars). This is accompanied by a maximum reduction in primary energy consumption of around 40% (minus 318 PJ).[17] Here, components manufactured from specifically lighter materials, such as magnesium or certain plastics, play a fundamental role. Nevertheless, it may be necessary in individual cases to judge whether very high expenditure in the production phase may not cause a negative effect overall.

The continued research, development and implementation of vehicle designs that contribute to a considerable reduction in vehicle weights must be emphasised as **options for action** of paramount importance to the vehicles sector.

3.1.3 Treatment of automotive-related wastes

Due to the extremely tight regulation density resulting from the European End of Life Vehicles Directive and its national implementation, the utilisation of old car bodies is already well developed as far as the after-use phase is concerned. The degree of recycling is currently being increased further by the establishment of post-shredder technologies (processes for separating the light shredder constituent into a diversity of sub-constituents and subsequent specific recycling). These are intended to ensure adherence to the demanding recycling quotas imposed by the European Directive. In addition, future recycling of scrap vehicles will be supported by the prescribed minimisation of the use of heavy metals in vehicle design, thereby minimising incompatible substances.

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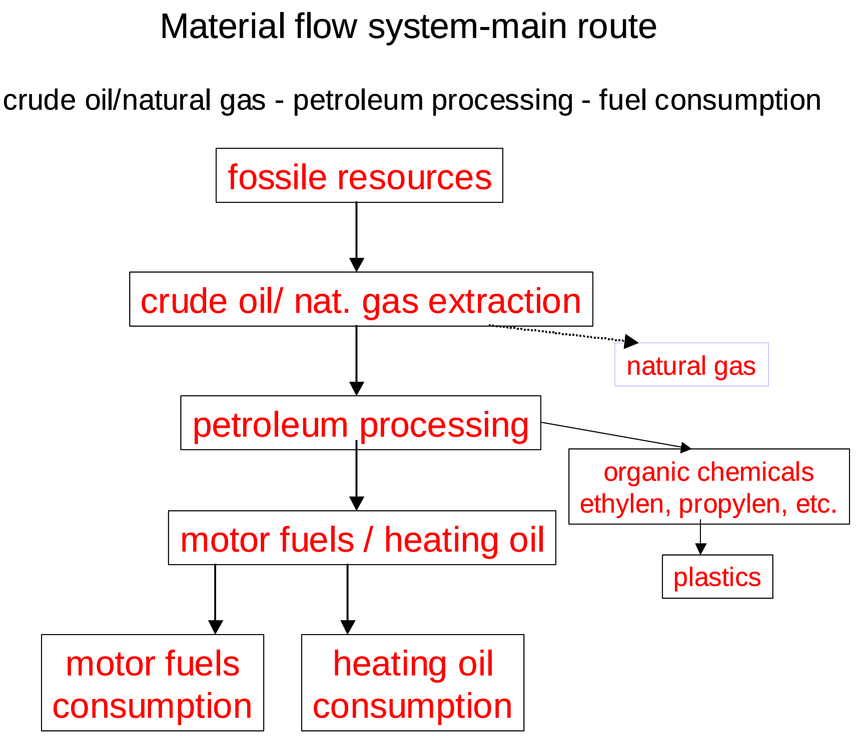
[17] The reduction potential corresponds approximately to 18 Mt/a CO_2 equivalent, i.e. 1.8% of the total German emissions for 2002 (without additional substantial savings from reduced fuel consumption).

3.2 Crude oil/natural gas-petroleum processing-fuel consumption material flow system

The crude oil/natural gas-petroleum processing-fuel consumption material flow system (see Figure 3.2) comprises two key sectors of the German economy, including petroleum processing and the important lateral industry of plastics manufacturing.

Figure 3.2 Crude oil/natural gas-petroleum processing-fuel consumption material flow system



3.2.1 The petroleum industry

At 320 PJ/a, the petroleum industry accounts for slightly more than 2% of Germany's total energy consumption (consumption and processing losses, not product feedstock). A proportion of between 2 and 3% of greenhouse gas emissions is assumed, and even nearly 9% for SO_2 emissions.

Many of the core elements of the plant engineering base in Germany's refineries originate from the nineteen-sixties. Individual components have been successively renewed, allowing some optimisation. Nevertheless, the technically achievable **potentials** for increasing efficiency and reducing emissions are not exhausted by far. The greatest potential for saving energy and thus reducing CO_2 emissions lies in the process heating and boiler systems. Together, they account for around 70% of total refinery energy consumption. Older plants display thermal efficiencies ranging between 80 and 85%. Using new technologies with optimised heat control, values up to 93% are possible. This is already implemented on a few new plants. Relative to the total industrial plants in Germany, a reduction in total energy consumption (minus 16–32 PJ/a)[18] of roughly 5 to 10 percentage points can be technically achieved in this way. Further reductions can be accomplished by coupled generation of electricity and steam, for example. Consequently, the **option for action** here consists of increasing the energy efficiency through re-engineering of older plants towards the standards of modern refineries.

The potential for reductions is currently far higher for SO_2 emissions. Complete renewal of refinery plant would not be absolutely necessary for this; instead, retrofitting of the appropriate flue gas scrubbing systems or further reductions of heavy fuel oils as a refinery fuel would suffice. While the large coal-fired power stations were able to exhibit substantial reductions during the nineties due to national implementation of the 13th German Federal Immission Protection Ordinance (*BImSchV*), the refinery heating systems, being either older systems, systems often of smaller capacity (below 50 MW or 50 to 300 MW) or special systems (catalytic cracker, Claus plant), are generally not affected by stricter thresholds. In some cases SO_2 emissions could be reduced by up to 90% by adopting an end of pipe solution, common in power stations. If this is extrapolated for the complete industrial plant base a reduction of around 50% (minus approx. 25,000 t/a) could be realised. This amounts to around 5% of the total SO_2 emissions for Germany. This objective can be further supported by reducing the use of sulphur-rich heavy fuel oil as a fuel. Beside the installation of flue gas scrubbing systems described here, it follows that an additional **option for action** lies in the optimised selection of the fuel used.

3.2.2 The plastics industry

With a production volume of 17.5 Mt in 2004 (7.8% of the world market) and a current annual rate of increase of 4.2%, the German plastics industry also plays a vital role in terms of economic sectors. In addition, increasing production volume is assumed in future. Simultaneously, as a buyer of naphtha, the plastics industry is one of the mineral oil industry's most important customers. Large ecological potentials exist on the production side of the plastics sector primarily in the upstream mineral oil processing industry (see above). With regard to the actual plastics products, the immediate and future development of further substantial recycling potentials (up to 80% of occurring volume; preliminary estimate of the Öko-Institut) represents one of the central challenges. In 2003, the recycled proportion (mechanical recycling, feedstock recycling and energy recovery) of plastics was a mere 58.4% relative to the generated volume. It should be emphasised here that in

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[18] This corresponds to approx. 1.2 to 2.4 Mt/a CO_2 equivalent.

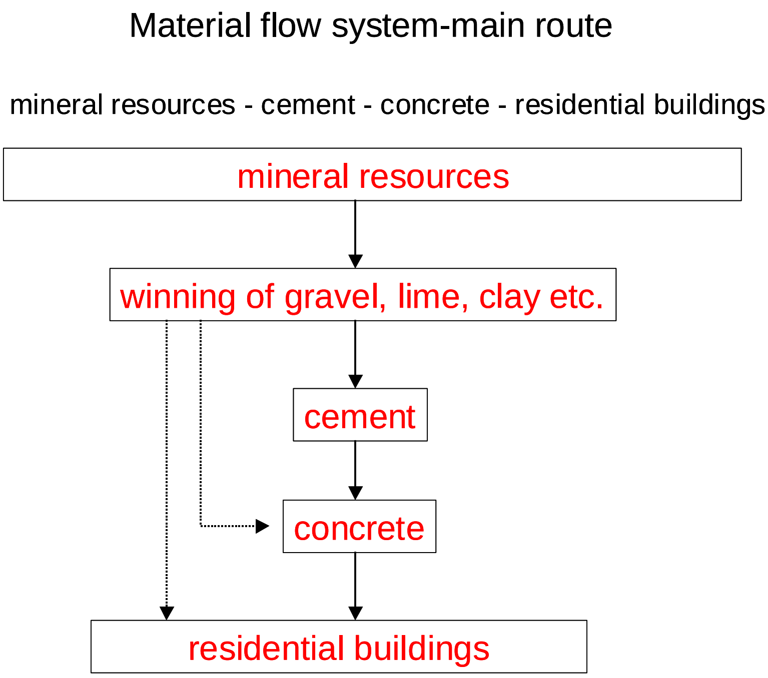
2003 the 8.9 Mt consumed domestically considerably exceeded the total domestic plastic waste of around 4 Mt in the same year. This means that also plastics are stored in the technosphere (in buildings, vehicles, furniture, electronics products, etc.) and that a considerable increase in volume must therefore be expected in the future. Consequently, an increase in the recycling quota to 80% relative to today's waste volume will easily lead to 1 Mt/a of additional recycled plastics; however, in a long-term projection until 2020 (long-term substantial storage development, which in turn must one day lead to a considerable increase in waste volume), this means a **potential** of up to 5 Mt/a of additional recycling volume.

This points to the central **option for action** in this sector for future years; considerably increasing the recycling volume for plastics in real terms. The recycling course pursued here (mechanical recycling or energy recovery) depends on the individual plastics, their fields of application, the logistics in place or subsequently put into practice and not least on suitable customers. The mobilisation and recycling of plastics from mid- to long-life applications with the greatest ecological benefits (see below, e.g. residential buildings) is a future-oriented task and is also supported by a series of critical legislative regulations (prohibition of disposal of the respective untreated waste since June 2005) and their consequences (enhanced attractiveness of material segregation and recycling by making disposal more expensive). The perceptive treatment of problem substances occurring in some of the volume of waste plastics (e.g. heavy metals), and their environmentally compatible segregation and discharge from the material cycles, are of particular importance for optimal recycling success.

3.3 Mineral resources-cement-concrete-residential buildings material flow system

On the production side, the mineral resources-cement-concrete-residential buildings material flow system (see Figure 3.3) comprises as its core element the important primary production of cement and the principal customer directly associated with this, the concrete industry. On the demand side, the residential buildings sector continues to assume a leading role despite the now familiar decrease in new building activity since the mid nineteen-nineties. The residential buildings sector remains highly relevant for the products of other industrial sectors such as the plastics industry, the glass industry, the brick industry, etc.

Figure 3.3 Mineral resources-cement-concrete-residential buildings material flow system



3.3.1 The cement industry

In 2004 the German cement industry achieved cement sales (including clinker export) of 33.4 Mt for a resource input (lime, marl, chalk, etc.) of 51.7 Mt. Approximately 6.5 Mt of this consisted of secondary resources (granulated sand, FGD gypsum, fly ash, etc.). The production of every tonne of cement in Germany in the same year was associated with around 0.675 t of CO_2, of which 60% were resource-related emissions. The specific fuel input for German cement production has been reduced by more than half since the nineteen-fifties. Further reductions are still possible with further plant refurbishment, but probably to a more moderate extent because of the thermodynamic limits of the "clinker firing" process. The secondary fuel input has increased more than fourfold in the last ten years to 42.2%. The secondary fuel spectrum provides interesting perspectives for the cement industry due to the use of residual substances originating from renewable raw materials. Waste wood is already used today in the cement industry. The voluntary commitment of the German cement industry (9th Nov. 2000) envisages a reduction in energy-related (fuel- and electricity-related) specific CO_2 emissions of 28% for the period 2008-2012 relative to 1990 (if fully realised this corresponds to an assumed emission reduction **potential** of approx. 2 Mt/a). In addition, a emissions trading scheme has been installed since 01.01.2005: this affects all companies in Germany producing cement clinker. Beside the reduction of energy input and of CO_2 emissions, further reduction potential exists within the German cement industry primarily in the reduction of nitrous oxide emissions (retrofitting of old systems:

cautious estimate of industry-wide reduction potential: approx. 10–20%, i.e. minus approx. 4,000 to 8,000 t/a[19] compared to 2004) and a reduction in the output of trace elements such as mercury. The **options for action** in the cement industry therefore lie in a further increase in the energy efficiency of existing industrial plants and additional forcing of the use of secondary fuels, as well as retrofitting a number of old systems with SNCR technology.

3.3.2 Concrete production

Raw materials and energy are already being saved in noticeable amounts by the widespread use of granulated slag and anthracite fly ash in concrete production. Further **potentials** for conserving raw materials are expected from the use of high-quality recycled concrete as a replacement for gravel in the production of new concrete. Based on the estimated maximum possible volume of 16 Mt given in the literature for 2010, this represents a saving potential in absolute terms of around 10%, assuming today's concrete production figures. The **options for action** in this case principally involve the promotion and improved advancement of concrete recycling for high-quality applications (aggregates for new concrete). This option is supported by the optimisation of selective demolition of both residential and non-residential buildings in order to ensure the availability of the superior qualities required for high-quality concrete recycling (minimisation of incompatible substances such as gypsum, etc.).

3.3.3 Residential Buildings

The importance of the residential buildings sector (new, stock and demolition) for developing the closed cycle and waste management policy further towards a sustainable substance flow and resources policy is regarded as very high. Regardless of the fact that merely heating this housing stock causes a substantial proportion of the national greenhouse gas emissions (180 Mt CO_2 including upstream chains, approx. 97% domestic emissions), the residential buildings sector is of immense importance from an ecological perspective in terms of resource use, the emission of greenhouse gases and a number of other criteria. In 2000 alone, new building activity and residential buildings maintenance/modernisation accounted for 33 Mt of CO_2 (primarily from manufacturing cement/concrete, bricks, sand-lime bricks, foamed concrete and steel). 150 Mt of mineral resources were used in residential buildings (excluding infrastructure such as roads). In contrast to this, calculations by the Öko-Institut performed in 2000 showed that around 33 Mt of building waste accrued (only 5 Mt of this from demolition, 28 Mt due to maintenance,

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[19] The reduction potential corresponds to approx. 0.25 to 0.5% of total German emissions.

etc.).[20] This clearly demonstrates that the material input for the residential buildings sector currently exceeds output by a factor of almost 5. Scenarios (reference developments) up to 2025 indicate an increase in the residential buildings stock material store of almost 20% from 10.5 Bt (billion tonnes) (2000) to 12.6 Bt (2025). The residential buildings stock will increase by around 5.5 million units during this period.

In the residential buildings sector the greatest potentials are primarily given by sustained upgrading of the building stock. Substantial reduction potentials may be realised up to 2025 by means of ambitious, technically feasible energy efficiency rehabilitation measures and a number of other important instruments:

- reduction of CO_2 emissions by 52% (approx. 110 Mt/a)[21] by 2025,
- reduction in the use of mineral resources from 150 Mt to around 70 Mt (approx. reduction of 80 Mt, i.e. 50%) by 2025 (buildings only),
- reduction in land consumption by 2025 from 31 ha/d to 5 ha/d[22] despite a distinct increase in living area,
- minimisation of the release of problematic substances (e.g. heavy metals, mineral fibres) during conversions and demolition.

One important mid- to long-term **option for action** is the forced energy efficiency rehabilitation of large sections of the housing stock. Concomitant with this, the extension of building lifetimes by extensive refurbishment, pooling of apartments, lowering of unoccupied apartments and thus limitation in new building volume to meet requirements (cf. Tab 4.1) is of major importance in terms of mineral resources conservation. In addition, the forced exploitation of inner development potentials (e.g. derelict land) and suitable increases in density are important options for action for reducing land utilisation. Another important option for action is represented by the utilisation of the constantly growing building stock material store by targeted and selective demolition. In future, this will allow large additional material fractions (concrete, steel, plastics, waste wood, etc.) to be input as secondary materials in production processes. Greater transparency for problematic and hazardous substances (heavy metals, asbestos, etc.) is important here. These must be segregated during demolition and removed from the material cycles both for risk minimisation and resource conservation reasons. The problems involved with insulating materials containing artificial mineral fibres (KMF) with a high carcinogenity index, i.e. insulating materials that do not conform to the KI 40-KMF standard, in widespread use until 2000, are highly relevant in this context. In the

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[20] Building waste from new building activities was not included in this calculation. In building practice – in particular in small-scale housing – building material waste accrued in new building is partially disposed of together with other site waste.

[21] This reduction potential corresponds to approx. 13% of total German emissions.

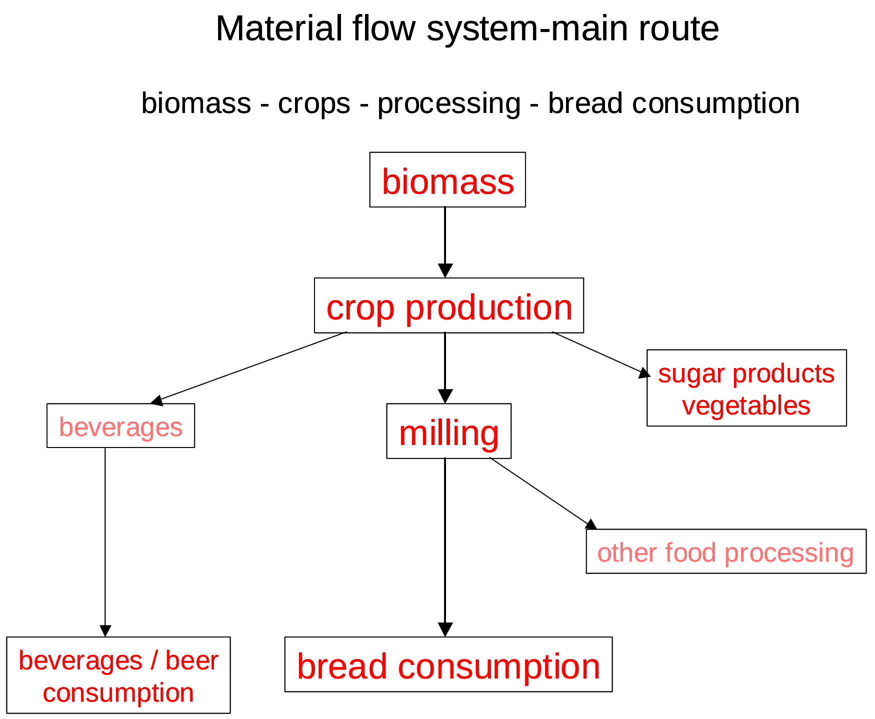
[22] This corresponds to a reduction from 113 km² per year to 18.25 km² per year.

next few decades these may represent a high risk potential where unsuitable methods (wrecking ball, etc.) are employed for building demolition.[23]

3.4 Biomass-plant processing-bread consumption and biomass-animal feed-livestock farming-meat consumption material flow systems

The biomass-plant processing-bread consumption (see Figure 3.4) and biomass-animal feeds-livestock farming-meat consumption (see Figure 3.5) material flow systems are dealt with jointly here because they overlap to a great extent both in their potentials and in their options for action.

Figure 3.4 Biomass-plant processing-bread consumption material flow system



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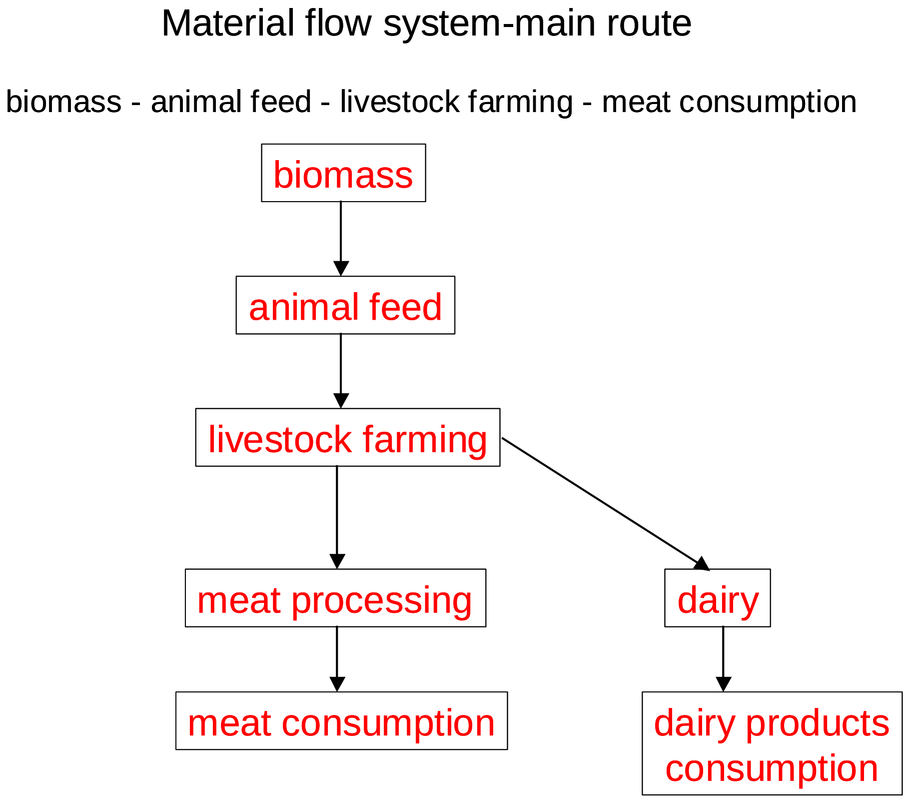
[23] These problems are heightened by the fact that the illegal installation of non-approved insulating materials cannot be completely ruled out, even post-2000. Moreover, in the case of demolition and refurbishment work the installation date (generally long ago) of the insulating materials is unknown or, at best, uncertain.

Figure 3.5 Biomass-animal feed-livestock farming-meat consumption material flow system



On the production side, both, vegetable and meat foodstuffs production, as well as the production of dairy products from livestock farming, are associated with a high degree of greenhouse gas emissions and nutrient input (nitrogen, phosphor in ground- and flowing waters). The livestock farming chain is principally characterised by the emission of large quantities of ammonia (95% of German ammonia emissions originate from agriculture and here primarily from pig and poultry farming) and not energy-related greenhouse gases such as methane and nitrous oxide (laughing gas). The methane emissions from livestock farming (95% from cattle) sank noticeably between 1990 and 2002 from 1.63 million tonnes (Mt) to 1.28 Mt and further methane emissions associated with the use of commercial fertilisers sank from 1.61 Mt (1990) to 1.31 Mt (2002). Nitrous oxide emissions fell from 14.4 Mt to 9.8 Mt during the same period. The causes for this can be sought not least in the considerably improved productivity of dairy cattle.

The yield per hectare, that is the agricultural productivity, also continues to increase at an annual rate of 1-2%. Assuming the level of production remains unchanged, this represents a considerable release of agricultural land over the next few years. Additional areas will continue to be freed-up due to the decline in the importance of grassland farming. In all, a land release of up to 30% (approx. 5.73 Mha) by 2030 may be assumed. On the one hand this provides new space for nature conservation, but also allows the cultivation of renewable raw materials for energy and feedstock purposes. On the other hand, due to increasing imports of feed such as soy, it must be assumed that additional nitrogen in excess of that from commercial fertilisers will enter the environmental media (soil, water, etc.).

Slight improvements have been noted recently with regard to excess nitrogen per hectare (105 kg/ha in 2002 in contrast to 114 kg/ha for the period 1996-2000); however, considerable effort is still required to achieve the Federal Government's target of 80 kg/ha by 2010. In absolute numbers, the **reduction potential** required until 2010 is around 650,000 t nitrogen per year. With regard to ammonia emissions, experts estimate a reduction potential of 20–30% (approx. 90,000–140,000 t/a)[24].

One **option for action** is represented by the reduction of fertiliser use in order to reduce excess nitrogen. Optimised application of liquid animal manure (timing and type of application of liquid animal manure to the soil) and improved technical measures (e.g. combination washers/biofilters) can reduce the considerable ammonia emissions that result from factory farming. In addition, important options for action in terms of environmental and nature conservation remain with regard to freeing-up land accompanying the necessary restructuring process.

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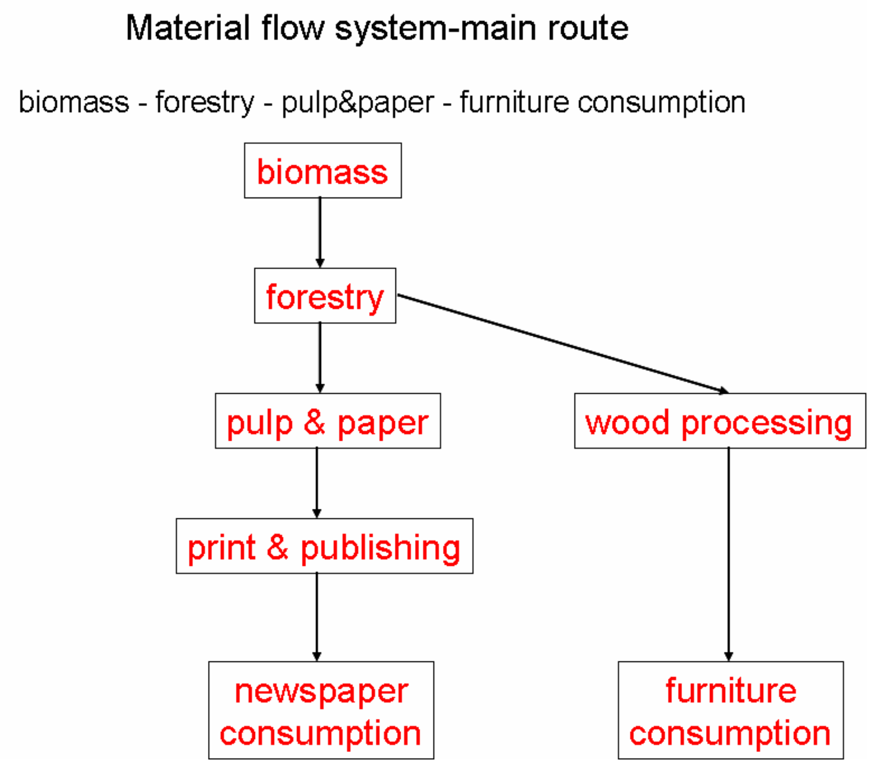
[24] The reduction potential corresponds to 15 to 24% of the total national ammonia emissions.

3.5 Biomass-forestry-paper-furniture consumption material flow system

The biomass-forestry-paper-furniture consumption material flow system (see Figure 3.6) addresses paper and pulp production as well as furniture consumption.

Figure 3.6 Biomass-forestry-paper-furniture consumption material flow system



3.5.1 Paper production

No meaningful reduction potentials are discernable for paper and pulp production in Germany and northern Europe in terms of important environmental parameters. This does not apply to paper and pulp production outside of Europe. Because no direct options exist for intervention, this can only be influenced by consumer behaviour. The production and use of products made from waste paper is possible with considerably lower energy consumption and associated emissions. However, due to the high recycling ratio on the one hand and the desired product quality (e.g. tear strength, whiteness) on the other, the replacement of paper containing wood by waste paper has now reached a certain limit and can only be increased further if accepted by commercial customers and consumers.

With an input of approx. 12 Mt of waste paper in contrast to cumulative production and consumption figures of 18 Mt and 18.5 Mt respectively for all paper types (2002 figures), particular attention must be paid to retaining these high quotas. Any use of water-soluble printing inks and other feedstock and consumables in the paper chain could impair recycling capability and thus reduce waste paper utilisation. Or increased interest in the whiteness of a paper may suppress the use of waste paper or lead to increased bleaching of products containing waste paper, which in turn is associated with increased environmental impacts. On top of this there are a number of individual topics such as the emission of chelating agents or other very specific pollutants in wastewater from paper production, which should be addressed within the scope of a substance flow policy. However, these cannot be easily quantitatively and qualitatively evaluated and require more detailed investigation in each case.

In the paper production sector the origin of the actual wood raw material plays a primary role. The quantity of paper used in Germany roughly corresponds to 50 Mt of fresh wood mass. This makes the paper industry an important user of wood raw material. The type of management employed in German forests and, more importantly, in the forests where the wood used in German paper originates, is an environmentally relevant topic which can only be quantified with some difficulty. Here, attention should be paid to wood from certified forests, e.g. using the FSC label (although there are also FSC labels for wood originating from plantations). Increasing the proportion of wood from certified sources represents an important **potential** (conservation of biodiversity, etc.) for the future.[25]

Collectively, the **options for action** in the paper sector involve mainly the consumer side, for both commercial customers and the end user, at least at the present time[26]. A targeted demand policy would be in a position to considerably strengthen the recognised positive environmental developments such as near-natural wood management, high waste paper input and low-emission production. It is possible to further develop the German *Blue Angel* environmental label, which plays a vital role in maintaining the use of recycled fibres, in accordance with the above data concerning fresh fibres. By taking the requirements of the FSC label with regard to fresh fibres into consideration, the *Blue Angel* would play an important role for paper from both primary and secondary fibres.[27]

3.5.2 Furniture consumption

The furniture consumption sector is only of intermediate importance in terms of the material flows and associated environmental impacts.

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[25] Problems were encountered here in the sawing mills: Paper production makes extensive use of sawing waste, which allegedly cannot yet be separated into FSC or other certification systems. FSC has therefore revised its Chain of Custody.

[26] Sales of recycled paper (e.g. in the hygiene industry, but also for school exercise books) can be further enhanced in this manner.

[27] Details and the opportunity for clear communication of an appropriate enhancement to the Blue Angel first require detailed and careful coordination with the specialists involved at the UBA.

Currently, 9.6 Mm^3 of finished wood (corresponds to 6.5 Mt of air-dried wood) are used for furniture production in Germany. By weight, 66.4% remains stored in wooden furniture products, the remaining 33.6% are residual substances. Further materials such as metals also occur. The EU annual waste figures include 4.6 Mt of wood, 0.9 Mt of metal, 0.45 Mt of plastics and a further 0.3 Mt of PUR foams forming the principal fractions from waste furniture.

The figures allow an estimate of the annual increase in the store of furniture of approx. 4.8 Mt for the housing and office building sector in Germany alone. This estimate agrees well with the living area in Germany. This continues to increase and in the end represents (together with associated areas) the receptacle for furniture in the technosphere.

This also indicates an increasing mid- to long-term **potential** represented by the "old furniture" material store in the context of a sustainable resources conservation policy. The **option for action** available must be sought in improved material segregation and subsequent recycling (recycling or energy recovery of waste wood, metal and plastics recycling, etc.) of waste furniture. Some regional administrations already segregate bulky waste (and thus waste furniture) to a large extent as a result of the legislative framework (Technical Directive on Waste, etc.) and the high disposal costs. As no complete overview of the effects of these local activities is available, it is not currently possible to precisely quantify the accessible potential. In order to allow even better recycling of the secondary resources potential from waste furniture, which will continue to increase in the future, widespread segregation nevertheless represents an option for action.

4. Overview of potentials and options for action

Table 4.1 summarises the important potentials and options for action. The information is described in more detail and derived in Chapter 3 and in the unabridged version of the final report. Further data, details and referenced sources can be found there. It should be noted that due to a lack of sources some of the figures for potentials listed in Table 4.1 represent technical estimates by the Öko-Institut or the IFEU-Institut (cf. the respective notes and sources given in the unabridged report). The potentials described serve primarily to give an idea of the magnitude of the potentials and the respective focus (e.g. sulphur dioxide emissions). These are, on the one hand, generally only purely technical potentials, i.e. they generally represent maximum target values for the period in question. On the other hand, validation of some of the estimated potentials and the options for action require more detailed investigations of the selected foci (see Chapter 5).

Table 4.1 Overview of potentials and options for action

Sector	Potential	Option for action
Steel production	**Reduction in primary energy consumption: 17 or 27% respectively (128 or 204 PJ/a corresponds to approx. 10–15 Mt/a CO_2 equivalent) between 2000 and 2030,** lower and upper scenarios respectively (increase in proportion of electrosteel from 28.7% to 33% or 45%)	Energy savings arising from innovations in electrosteel and oxygen steel production, additional increase in the proportion of electrosteel production by forcing scrap collecting and recycling (dismantling of buildings, etc.)
Steel production	**Avoidance of landfill for up to 350,000 t/a of blast furnace gas sludge**, in particular, recycling of iron, lead and zinc components.	Creation of suitable and sufficient recycling capacities for blast furnace gas sludges.
Vehicle manufacturing	**Reduction of vehicle weight: up to 40% (approx. 3.4 Mt/a**); **thereby reducing primary energy consumption: up to 40% (318 PJ/a corresponds to approx. 18 Mt/a CO_2 equivalent),** additional savings of considerable amounts of fuels.	Advanced R&D of lightweight components and vehicle designs as well as appropriate implementation.
Mineral oil industry	**Reduction in total energy consumption: approx. 5–10% (16–32 PJ/a corresponds to approx. 1.2–2.4 Mt/a CO_2 equivalent)**	Comprehensive refurbishment of the numerous old plants.
Mineral oil industry	**Reduction of sulphur dioxide emissions: approx. 50% (approx. 25,000 t/a)**	Systems refurbishment based on power station desulphurisation.
Plastics industry	**Increase in recycling of plastic waste from 58.4% to 80% (at least 1 Mt/a, dynamically increasing in the long-term to additional 5 Mt/a)**, base year 2003: long-term until 2020, incl. energy recovery.	Increase in recycling quotas, in particular from intermediate- to long-life products (vehicles, electronics, construction applications): landfill minimisation, improved collection, etc.
Cement industry	**Reduction in specific CO_2 emissions: 28% (approx. 2 Mt/a)** between 1990 and 2008-2012 in accordance with voluntary commitment.	Implementation of the voluntary commitment by further optimisation of energy efficiency (grinding technology, etc.) and increased use of secondary fuels of biogenic origin.
Cement industry	**Reduction of NOx emissions: 10–20% (approx. 4,000–8,000 t/a)** in the mid-term compared to 2004	Equipping the remaining old systems with SNCR technology (selective non-catalytic reduction)

Concrete production	**Raw material conservation: up to 10% (up to 16 Mt/a)** from around 2010	Promotion and stronger establishment of concrete recycling in high-quality applications (aggregates for new concrete)
Residential buildings	**Reduction in CO_2 emissions: approx. 52% (approx. 110 Mt/a)** between 2000 and 2025	Forced remediation of the often suboptimal housing stock in terms of energy efficiency (principal option)
Residential buildings	**Reduction in the requirement for mineral resources: approx. 50% (approx. 80 Mt/a)** between 2000 and 2025.	Extension of building lifetime by comprehensive refurbishment, pooling of apartments, lowering of unoccupied apartments and thus a restriction of new building volume to meet requirements, forced selective demolition of unused buildings.
Residential buildings	**Reduction in land utilisation: from 31 ha/d to 5 ha/d,** net housing and development land.	Forced exploitation of inner development potentials (e.g. derelict land), suitable density increases.
Residential buildings	**Minimisation of the release of problematic substances (e.g. heavy metals, mineral fibres) during conversions and demolition.**	Forcing and qualitative improvement in selective demolition and separate collection and recycling, removal of problematic and incompatible substances from the material cycles and their safe and hazardless disposal.
Agriculture, livestock farming	**Reduction in excess nitrogen: by 30% (approx. 650,000 t/a; from 114 to 80 kg/ha)** by 2010 based on 1996-2000.	Reduction in fertiliser use and optimisation of its application.
Livestock farming	**Reduction in ammonia emissions: 20–30% (approx. 90,000 to 140,000 t/a)**	Optimisation of liquid animal manure application management (primarily time and method of application).
Paper production	**Substantial increase in the use of wood from certified forests and (consumer side) increasing use of environmentally friendly paper,** important contribution to biodiversity.	Increased use of wood from near-natural cultivation (FSC certificate) and further development and propagation of the Blue Angel for paper.
Furniture consumption	**Optimised recycling and energy recovery of waste furniture** resource potential grows in future due to store build-up in the technosphere (precise information and data require detailed investigations).	Forced segregation primarily of metals (recycling) and wood (recycling or energy recovery in high efficiency systems) from bulky waste.

5. Further investigation requirements and relevant data gaps

This project allowed particularly relevant material flows and their associated production processes, produced goods and consumer goods to be identified in a timely and efficient manner with the aid of a material flow approach. This establishment of priorities represents an important requirement for the development of the closed cycle and waste management policy towards a sustainable substance flow and resources policy in Germany. Because it was only intended to use existing data and sources in this six month project, collection of our own source data (e.g. by interviews with specialists, expert workshops, etc.) is reserved for further detailed investigations. On the one hand, the results of the project demonstrate the need for more detailed investigations with regard to the development of the important potentials illustrated here. On the other hand, a number of relevant data and information gaps were identified which should be closed in the short-term (i.e. in the next one to two years).

5.1 Investigation requirements for accessing relevant potentials

In general, the work has demonstrated that, in the context of resource conservation and energy saving, it will be possible in future to access large potentials in a number of sectors from the growing material stores in the technosphere. Generally speaking, it would be an interesting exercise to examine existing regulations, including those of a general nature, e.g. in tax legislation, to discover whether any regulations exist that create broad positive (e.g. lorry tolls) or negative effects (e.g. high burden of taxation for the factor work in contrast to the factor resources) on sustainable materials management, together with expert estimates of the extent for each case.

5.1.1 Iron ore-steel-vehicle manufacture-car consumption material flow system

Detailed investigations are important for the steel industry in terms of defining the necessary conditions for promoting a sustainable increase in energy efficiency and the conservation of resources by improving scrap utilisation (electrosteel route). This will assist in exploiting the large potential for reducing environmental impacts (*cf*. Chapter 4). Broad and detailed identification of potentials covering all – primarily intermediate- to long-life – applications (scrap vehicles, residential buildings, non-residential buildings, rail infrastructure, machines, etc.) would therefore be very important to the steel industry in order to arrive at more detailed scenarios and projections for developing the scrap potential. This information, equally vital to both publicly- and privately-owned businesses, in turn represents an essential precondition in terms of substantiating the necessary framework conditions for an optimal increase of secondary raw material utilisation in the future.

In vehicle manufacturing, the investigation of previous and expected future effects caused by the development and use of weight-saving components (fuel savings) represents a task with long-term relevance. Opposing effects (increase in vehicle weight due to larger, more powerful cars and new "extras", occasionally serving other purposes (e.g. increasing safety)), must be taken into consideration. Life-cycle analyses suited, among other things, to early recognition of counterproductive developments (e.g. use of components extremely energy-intensive in their manufacture) should be employed. In the scrap vehicles sector the results of recycling quota monitoring (spring 2006) should be evaluated at short notice and developments closely followed with regard to the progress made in recycling methods for treatment of the light shredder fraction (e.g. VWSicon).

5.1.2 Crude oil/natural gas-petroleum processing-fuel consumption material flow system

Detailed investigations are necessary for this material flow system primarily on the production processes side in terms of the technical possibilities and measures suited to considerably reducing sulphur dioxide emissions from mineral oil processing. With regard to forcing plastics recycling mainly from intermediate- (e.g. electronics) and long-life applications (structural and civil engineering, vehicles, etc.), precise knowledge of the plastics inventory in the material store is required – similar to steel. Beside information on quantities, questions regarding the inventory of problematic substances (e.g. heavy metals) and optimum selective demolition are at the forefront (*cf*. remarks on investigation requirements for residential buildings)

5.1.3 Mineral resources-cement-concrete-residential buildings material flow system

A detailed overview of current technical options and measures suited to considerably reducing dust and nitrous oxide emissions (refurbishment of old plants, etc.) are of interest to the cement industry for the purpose of defining detailed investigations.[28] An important area of research would be an explicit investigation of the current ecological condition of the German cement industry. This is against the backdrop of the BAT (Dec. 2001) and the voluntary commitment of the German cement industry, as well as in terms of the development of further potentials. Beside measures for reducing both energy consumption and CO_2 emissions (maximising the potential for secondary fuels, among other things), detailed investigations should be placed at the focal point of a status report aimed at minimising the discharge of trace elements (influence of the spectrum of fuels or secondary fuels, etc.).

In particular, an investigation of suitable measures and initiatives for significant improvements to building demolition practice is required, because the current framework is insufficient. Not least because of numerous problematic substances (e.g. asbestos, heavy metals) and incompatible substances (e.g. gypsum in concrete recycling, insulation materials manufactured from fibres, etc.) contained in the material store, which in practice make successful high-quality recycling more difficult or even hinder it completely, a means of optimal material segregation by selective demolition should be sought. This should adopt an ecological perspective, taking practical aspects (effort, costs, minimum limits, etc.) into due consideration. In terms of results, an appropriate investigation should be

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[28] The Federal Environment Agency already plans to carry out appropriate investigations with regard to the topics addressed with reference to the cement industry.

open and unbiased, comprising all imaginable categories of measures (adaptation of legal regulations, communication measures, voluntary measures such as voluntary commitments entered into by various associations, etc.) with regard to their efficiency and practicality for future access to potentials.

In addition, an investigation of existing restraints, including the specification of concrete proposals to overcome them, will prove extremely relevant in the future in terms of options for improved activation of the material store from permanently unused buildings (permanently unoccupied office buildings, factory buildings, residential blocks of flats, etc.). In this context it is important to mention the extensive complex of subsidies and the tax framework. In terms of resource conservation effects, the current counterproductive arrangement of land transfer tax can be named as an important example.

5.1.4 Biomass-plant processing-bread consumption and biomass-animal feed-livestock farming-meat consumption material flow systems

Within the agricultural sector, the primary requirement is for extensive investigations of the question of which way the land expected to be freed up within the next twenty years as a result of agricultural productivity increases can be optimally dealt with in the context of sustainability (e.g. areas given over to nature conservation, for biomass feedstock or energy applications). Additionally, it is important to investigate how, by what means and with what prospect of success the continued high agricultural ammonia emissions can be substantially reduced. These investigations should comprise a wide spectrum of possible options (e.g. technical emission reduction in factory farming, type and means of liquid animal manure application, etc.).

5.1.5 Biomass-forestry-paper-furniture consumption material flow system

An investigation of the best or most efficient practice in Germany would be suitable with regard to improved utilisation of the potentials arising from the waste furniture material store. A discussion of best practice strategies is interesting (e.g. optimal collection and recycling results for metal components, wood components, etc.) because waste furniture is generally disposed of or recovered by means of bulky waste collections or in municipal building yards and the practical details differ here from one regional administration to another. Subsequent nationwide communication of suitable information on exemplary recycling strategies for waste furniture/bulky waste is also relevant in view of insufficient regional disposal or recovery capacities (key word: interim storage).

5.2 Closing important data gaps

In conjunction with the subject of data gaps, the material store contained in non-residential buildings is highly interesting from a resources perspective (high proportions of metals, concrete, etc.). Here – in contrast to residential buildings – there is considerably less knowledge about the quantities of different materials and their possible mobilisation periods and rates. It is therefore recommended to close these important data gaps by means of a detailed investigation.

Considerable data gaps were also determined in relation to the electric and electronic products sectors and their associated resource potentials. Here, too, a substantially higher level of knowledge would be desirable in order to estimate the potentials and options for action. Due to the special complexity and dynamics within this sector (rapid changes in models and the technological properties of products, the variety of some "exotic" but important metals from a resources perspective, etc.) the investigation effort here – subject to the necessary detailed description – is considered more extensive compared to that required for closing the data gaps mentioned above with regard to non-residential buildings.