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Improvement of Raw Material Productivity and Resource Conservation

Subproject 1: Evaluation of Potentials, Proposals for Measures and Dialogue about Resource Conservation
(Summary)

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Umwelt Bundes Amt
Für Mensch und Umwelt

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Summary

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This abbreviated version of the final report has been generated within the scope of the research project “Improvement of Resource Productivity and Conservation” funded by the German Federal Environment Agency. The project has been carried out under the direction of the Wuppertal Institute jointly with the Institute for Futures Studies and Technology Assessment in Berlin (IZT) and the UNEP/Wuppertal Institute Collaborating Centre on Sustainable Consumption and Production (CSCP).

It reflects the results of the future dialogue from 2007 to 2008 and provides insight regarding current potentials, chances, and impediments for an improvement of raw material and resource productivity in the sectors of emphasis “construction and habitation”, “steel”, and “copper”. Background research, expert interviews, and workshops have been part of the official dialogue process with stakeholders from economy, politics, and sciences. Moreover, selected options for measures with examples for efficient approaches are presented.

Objective of the future dialogue was the bundling of concrete and practice-oriented contributions concerning an improvement of raw material productivity and resource consumption as well as the development of options for measures to increase resource productivity. These have to be tied up to existing political initiatives as the European Resource Strategy and the “Ecological Industry Policy” of the German Federal Ministry for Environment (BMU).

Further information with regard to the project is available for download at www.ressourcenproduktivitaet.de.

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1 Introduction

The resource consumption of modern industrial societies is characterised by manifold new challenges. It can be considered as an assured state of the discussion that numerous negative environmental effects are connected with the amount of resource consumption. Against this background, the Federal Republic of Germany set itself the target to double resource productivity (in terms of raw material productivity) till the year 2020 relating to the year 1994 in the framework of its sustainability strategy.

This new field of action in resource policy is characterised by a threefold challenge:

- Energy and resources become more expensive because an increased demand – mainly by the population rich, newly industrialised countries like China, India and Brazil – faces the limited supply. This tense situation will remain like this in medium term, since resource requirements will continue to grow in these countries.
- In the long run the raw material supply is finite. Ever bigger efforts have to be made in order to explore and to tap new repositories. Furthermore, with rising prices of raw materials even low-value deposits get exploited in politically instable regions and sensitive ecosystems, which is associated with higher environmental pressure.
- The consumption of fossil fuels contributes substantially to climate change. Every raw material consumption involves life-cycle-wide environmental pressures, which to diminish is regarded as imperative.

Environmental pressures due to raw material use, resource conservation and more efficient use of resources are accordingly basic fields of activity of today's environmental policy. The economic development has to be decoupled more widely from resource use than hitherto and resource use has to be cut down considerably absolutely. New foci are a more efficient utilization of raw materials, resource conservative production procedures, an ecologic product design, the closure of material life cycle, and a more resource conservative fulfilment of needs by means of a change in consumption patterns.

Raw materials are cost drivers, particularly in raw material intensive production processes. At the latest since the recent rise in prices on international commodities markets it is an own best interest of enterprises to reduce these costs and to obtain therewith competitive advantages. Therefore, the increase of resource productivity is in almost all sectors a long pursued strategic business objective. In the past in some sectors specific improvements could be obtained by optimizing processes, closing internal material life cycles, substituting materials, or implementing cutting-edge technologies. Altogether, the potentials for an increase of resource productivity are not nearly exhausted yet, though. In the past years, emphasis of optimization lied in enhancement of production processes. Potentials, however, exist in all of the chain of a material flow from exploration through extraction, transport, beneficiation, production, and utilization up to the reutilization in the closed cycle or another product system.

Here it is more difficult to identify those responsible and the decision makers which benefit from and thus have an interest in an improvement of productivity. Therefore, attention shall be turned to these steps in material flows, their points of intersection with the production process and their mechanisms. Likewise it is focused on hot-spots of resource consumption. It is important to identify the stakeholders, to grasp their motivations and to integrate them in the process of discussion. Particularly system innovations depend on coalitions between stakeholders.

These challenges ask for innovations and new economic and political concepts and alliances. The German and European politics are setting the course and breaking new ground searching for innovative solutions. “The intelligent utilization of energy, resources and materials is a key issue of the 21st century.” This is one of the core phrases from the founding document of the network “Ressourceneffizienz” (resource efficiency) of the German Federal Environment Ministry (BMU/Roland Berger Strategy Consultants 2007). In this context the German Federal Government has defined two objectives of action for the year 2020 in its national sustainability strategy: the doubling of raw material productivity (in relation to 1994) as well as the doubling of energy productivity (in relation 1990). The necessity of a resource conservation which exceeds these efforts results from international economic linkages and is associated politically to a series of discourses – particularly to the question of ecological distributive justice – since the conferences in Rio (1992) and Johannesburg (2002).

Likewise the European Commission has set the framework for a sustainable utilization of natural resources already in the year 2005 (Commission of the European Communities 2005). Each country of the EU shall present a national action plan for the enhancement of resource productivity. The absolute reduction of raw material consumption including the therewith associated reduction of use of environment – and this as possible worldwide – becomes a goal of governmental and supragovernmental action. Thus, the task of policy is to provide appropriate orientations, incentives and general conditions so that all civil and market stakeholder recognise their chances and contribute their possible share to resource conservation.

Suchlike political statements and precepts are important not only regarding to resource disposability and conservation but also regarding their potential to create win-win-options for a secure raw material supply, a strengthening of competitiveness, environmental protection, and additional jobs (cf. BMU/IG Metall/WI 2006).

1.1 Objectives of the project

The objective of this project was a concrete contribution to the amelioration of raw material productivity and resource conservation in Germany. In order to initiate future coalitions for system innovations potentials of strategic importance have been analyzed and stakeholders have been identified so as to develop options for action in selected foci during the project progression. For selected topics of resource policy a platform for dialogue has been created whereat workshop dialogs were central elements of the implementation-oriented plan.

The discussion of these topics opened out in concrete measures which aimed at an avoidance of pseudo-solutions, for these would create problems again elsewhere. In order to make new strategies fit for the future a consideration of economic, ecological and social risks was necessary. To get this off the ground different stakeholders of society, economy, science and politics came to an understanding on objectives and first measures within the framework of this project.

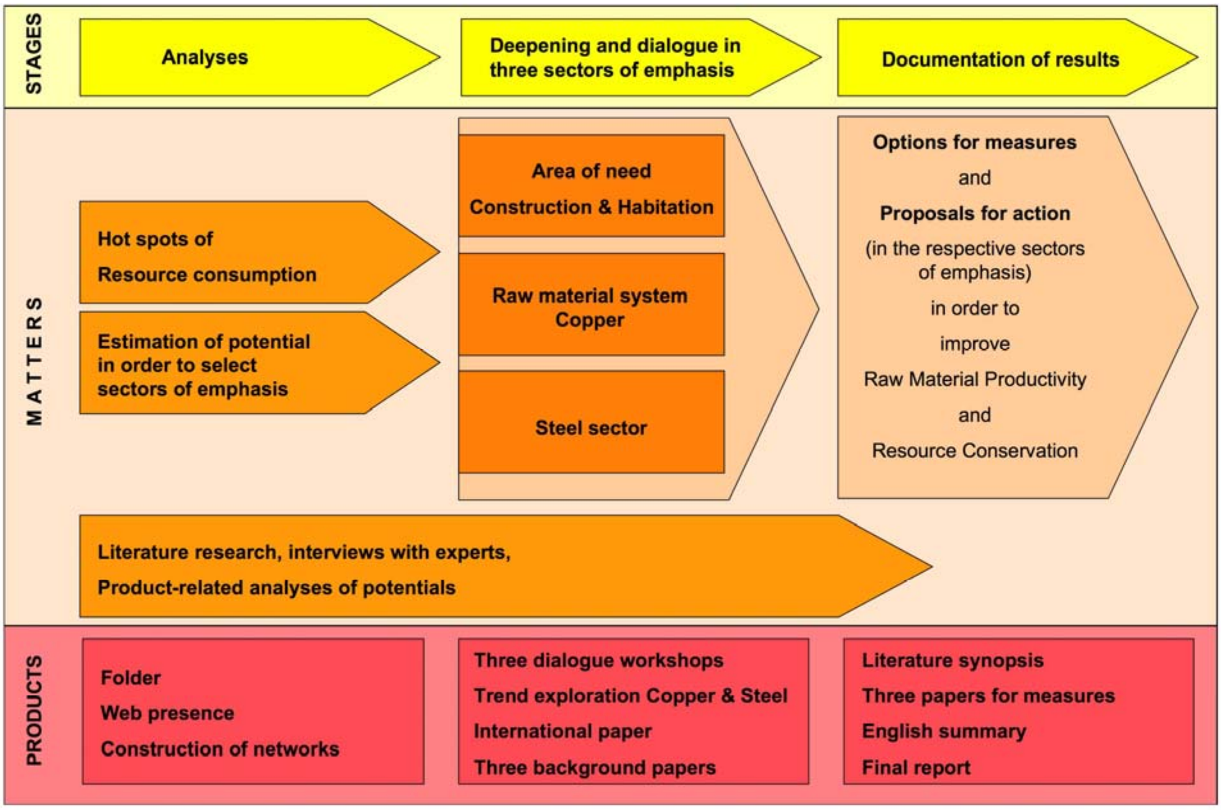
In the three selected **sector**s **of emphasis** “**raw material system copper**”, “**steel sector**”, and “**area of need construction and habitation**” the entire value creation chain has been examined in order to locate hot spots of resource consumption. Drawing upon this, concrete measures and areas of innovation for the enhancement of raw material productivity and resource conservation in Germany have been suggested. The objectives of the project were realised by means of a hot spot and potential analysis. Based on results of literature review and own research suggestions for measures for prioritary raw material systems, sectors and areas of need have been developed for all relevant stakeholders involved.

An adapted strategy of dialogue and communication permitted to reach specific key stakeholders in politics, economy and science as well as the interested public. Hereunto different transfer products like workshops, an internet portal, and background publications were used.

1.2 Study design

In the heterogeneous and very focus-specific setting of this R&D project with its various qualitative and quantitative requirements analyses of hot spots and potentials associated with trend exploration, different literature studies, and expert interviews constitute an appropriate combination of methods in order to achieve the project's objectives.

Figure 1: Steps of the investigation and conducted analyses



Source: Wuppertal Institute

1.2.1 Bottom-up and top-down analyses

The mass balance of a society determines the societal metabolism with the natural environment, i.e. all inputs from and outputs to nature. The possible effects of these material flows on the environment and the development of resource productivity can be described via indicators. For instance, the Federal Statistical Office of Germany calculated the indicators raw materials and energy productivity on a macroeconomic scale and described the degree of achievement of the targets according to the national sustainability strategy (doubling till 2020) (DeStatis 2003). By dint of the methods used for the determination of the sectoral resource outlay, taking into account the direct and indirect advances, deficiencies of the hitherto officially used methods are overcome. On grounds of preliminary work of the Wuppertal Institute (Behrensmeier/ Bringezu 1995; Bringezu 2000; Moll et al. 2004; Acosta Fernández 2007) has been investigated indicator-based on which economic sectors exhibit the highest materials consumption (*top-down*).

By the manner of a hot-spot analysis in chains of custody a tool has been developed which allows for a *bottom-up*-recognition of resource intensive phases (phase of raw material, processing, utilization, and disposal) within a chain of custody. Regarding the type of resource input has been made the following differentiation: abiotic and biotic raw materials as well as water and energy. This differentiation permitted to draw orienting conclusions for single chains of custody and make statements about possible core actions. Available studies served as data basis for the hot-spot analysis.

Via the methodology outlined it has been possible to depict

- the most important intermediate consumptions of each sector which result in the total resource expense. Here the quantities of the intermediate consumptions are determined by the consumer demand production.
- comparatively the total material requirement (TMR) itemised according to sectors. Hereby insight could be gained about the most consuming sectors and first starting points could be identified for tracing back this consumption intensity.

The investigation on micro- and meso-level took place with different system delimitations. The raw material system copper, the steel sector, as well as the area of need construction and habitation have been under examination. From this differentiation arose different approaches to the bottom-up analysis of these sectors. For instance, in the system wide approach for copper also international developments and linkages played a significant role. The branch-related focus on steel had a strong production-technical emphasis while the area of need construction and habitation spotlights the user perspective.

1.2.2 Analysis of relevant literature and expert discussion

In order to get an overall survey about potentials and possible strategies for an enhancement of resource productivity and conservation in the economy and in specific product fields cognitions were needed concerning (material-) technological possibilities exceeding the status quo which were discussed in science and partly already had reached pilot stage (e.g. alloys, processing and forming techniques, material substitution, new product utilization concepts, new recycling methods). This information has been gained via an analysis of literature and expert discussion. It has been used to concretise – at first independently from specific fields of action – the orientation of actions in the sectors of emphasis concerning both individual chains of custody and individual economic domains.

The emphasis of the literature selection constituted mainly statements regarding resource consumption and intensity in the entire value creation chain of a raw material. Hot-spots have been detected from the studies' underlying areas of need, branches, raw material systems, stages of life cycles and value creation chain, as well as from process steps characterised by high resource intensity. Subsequently, concerning these hot-spots, potentials for an enhancement of resource efficiency, trends and drivers, obstructions, as well as strategies and actions mentioned in the studies have been identified. This wasn't always possible due to unavailable information or a study's different emphasis. The second selection criterion has been the studies' direct as indirect reference to metal or mineral raw materials in order to flank the chosen sectors of emphasis.

1.2.3 Dialogue Workshops

Within the project a crucial significance inhered to the preparation and realization of the dialogue process. Thus, at the beginning ambitions and design of the workshop have been defined as follows: First and superior objective was to elaborate concrete suggestions for action to enhance raw material productivity and resource conservation in three selected sectors of emphasis. These suggestions should offer, as far as possible, potentials for cost cutting and innovation for all participants and the involved stakeholders, the German Federal Environment Agency (UBA) or the German Federal Environment Ministry (BMU) should be able to initiate them.

A second important objective was to win the stakeholders over to a longer-term engagement throughout the period of the three workshops and if possible beyond it. Particularly, new networks, alliances, and co-operations throughout alongside the value creation chain should be incited. Altogether the dialogue process should also contribute to an improved political management and coordination as well as reveal areas of possible synergetic effects between the sectors of emphasis.

The **range of participants** was focused on stakeholders who had expertise in the chosen sectors of emphasis. The stakeholders of an ecological restructuring and those of an "ecological industry policy", (politics, economy, NGOs, consumers) that co-influence the system indirectly were also taken into account. Furthermore, it was paid heed to an expedient complementarity of the participants' profiles of expertise. Prerequisite was the competence of an innovative decision maker strongly capable of implementation and an influential multiplier. Thematically this concerned primarily the **fields of competence** market development and growth drivers in branches and areas of need, resource conservation and environmental impact, innovation potentials, development of efficiency potentials and technological alternatives, market launch (lead markets), as well as the legal framework.

In the course of the process further key stakeholders have been identified that have a (huge) impact on the resource efficiency of the system, the branch or the area of need. These key stakeholders have been integrated – where possible – into the interview and the preparatory phase of the workshops and the final event.

1.3 Hot-Spots of resource consumption

In the following, general statements concerning resource consumption in the three sectors of emphasis are made that indicate the so-called hot-spots. Thereto, "hot-spots of resource consumption" have been identified on national level. Depending on the object of investigation, these characterise areas of need, branches, raw material systems, or as well stages of life cycle, stages of value creation chain or process steps which feature a high resource intensity (e.g. due to big ecological rucksacks). These hot-spots are not necessarily equitable with a high potential for resource conservation or a particularly high potential for cost cutting. **Potentials** constitute possibilities to increase resource efficiency (e.g. via technological optimisation) on basis of hot-spots. **Trends** of an increasing resource consumption and their **driving forces** run contrariwise to the increase of resource efficiency (e.g. increased consumption and utilization, economic factors like a growing demand etc).

For the **sector of emphasis construction and habitation** particularly the extraction of raw materials, production of building materials and the phase of utilization could be identified alongside the building life cycle as specially resource intensive phases. Central hot-spot for new development and renovation is the planning stage in which can be influenced on material intensity of all subsequent stages of life cycle by means of a strategic choice of material.

Urgent problem areas in the area of need construction and habitation lie in the sections **land consumption** and **material flows**. According to the Enquête-commission on the protection of men and environment, roughly 40% of the annual waste accumulation can be assigned to the construction sector. The accumulating quantities of waste lie, however, beneath the quantity tied up annually in buildings (cf. Deutscher Bundestag 1997 in: Wallbaum/Kummer 2006, p. 19). “Out of the averaged 51 t of natural resources (Bringezu 2004, p. 78) that uses every Central European each year ca. 30% result from how people construct and reside even today.” (Wallbaum/Kummer 2006, p. 19).

Further hot-spots lie in the sections choice of material, energy consumption, land consumption, building material waste, as well as material and raw materials in the building inventory. The highest material consumption accrues during the stage of raw material extraction and production of building materials as well as during the building utilization phase. “Buildings are long-lasting. For instance, two third of the houses habituated in the year 2030 are constructed today, only 1% new buildings are added annually (Fachinformationszentrum Karlsruhe 2002, p.1).” (Wallbaum/Kummer 2006, p. 20) “As an “educated guess” it can be stated that material replacements during the utilization phase entail additional direct as indirect material expenses which account for approximately 50% of the bare brickwork’s resource expenses.” (Wallbaum/Kummer 2006, p. 31)

The hot-spots of the **raw material system copper** lie primarily in the mining of copper ores due to too high environmental pressures. Approximately 98% of quantitative material flows during mining arise in form of overburden and waste that can be added on to resource consumptions as ecological rucksacks and that way can be made visible. Especially regarding the raw material copper the relevance of these ecological rucksacks becomes clear: Copper and copper products alone account for 2,3% of all metal raw materials, semi-finished and finished products in Germany’s material flow analysis for the year 2000 (imported copper concentrate, cathode copper, copper products, as well as copper and copper products fabricated in Germany). Including the secondary precursor material necessary for the German production the share of copper and its products in all metal raw materials, semi-finished and finished products, whether made in Germany or imported, rises to 29% and thus is more important the branches iron and steel as well as aluminium and their products.

Moreover, it has to be mentioned the rising demand for copper in the newly industrialised countries that leads to a generally rising resource consumption. The average ore grade of mined copper decreased to less than 1% in the last years which can be caused, for one thing, by depleting copper deposits but, for another thing, as well by the introduction of new technologies like the SX/EW-process (solvent extraction/electrowinning) that allows for a cost-effective mining even in case of a significantly lower ore grade. In mining copper approximately 100-350 t of overburden and 50-250 t of tail accumulate per metric ton of copper (mining and processing) (cf. Erdmann et al. 2006). Moreover, 30-100 GJ energy and 200-900 m^3 water are consumed and 300 kg SO_2-emissions are generated. In addition, in mining but as well in processing and recycling copper dissipative losses to the environment occur. Furthermore, water, land, and air pollution, transport of the raw materials to the consumer countries, as well as pollutions occurring during the utilization phase of copper products have to be taken into account.

From the growing demand for copper in the newly industrialised countries originate additional ecological challenges. For instance, China’s brisk foreign investments in Africa and Asia erode humanitarian and ecological standards. The rising demand on a high price level causes an expansion of mining in new areas and a development of low-value deposits. Depending on mining method and technology adoption the environmental pollution augments. For example, in small mines in Chile production is resumed due to the price increase. Frequently, environmental standards are not observed and the exploration takes place in ecologically sensitive areas. At the same time, there are massive problems with energy and water supply. Binding indicators and objectives are required in order to ameliorate the environmental situation (cf. Giurco 2005, as well as Schüller 2006; BGR 2007).

Hot-spots of the steel sector: On a quantity basis, iron and steel are the dominant metallic material. That also applies to the environmental impacts related to the overall production (van der Voet 2003) and the resource consumption. The absolute production outputs are, however, a direct consequence of the intensive use of steel. This intensive use of steel, in turn, is associated with the good availability of the raw materials and the versatile applicability of the material. Relating to the production output, the resource consumption is relatively low compared toe other metals (Ritthoff 2005). In the production of primary aluminium and primary copper are used roughly 5 and 50 times, respectively, as much of raw materials (s. table 1).

Table 1: Use of abiotic materials in the production of selected metals

	t/t
Pig iron	7,34
Aluminium (primary)	36,51
Copper (primary)	348,47

Source: Wuppertal Institute

Resource consumption of the steel industry is mainly determined by the used iron ores and energy consumption. Here it has to be distinguished between steel produced by means of blast furnaces and such produced by electric arc furnaces. Whereas in the former iron ore and energy carrier have an approximately equally sized shared in resource consumption, in the latter the energy carrier dominate clearly since the used materials are secondary ones (Herzog et al. 2003).

Resource efficiency of steel production has been increased significantly already via many optimization steps. On the basis of the use of higher-value ores in combination with a complete abdication of an extraction of iron ore in Germany the German steel industry could achieve already significant increases in resource efficiency. The effect of this is a duplex one: On the one hand, a cutback in used quantities of iron ore occurs, on the other hand, energy consumption is reduced (Ritthoff 2006). Furthermore, for example, the total output from inserted iron resources improved from approximately 60% in 1960 up to 90% in 2005 (Ameling 2007).

The deployment of high-value ores is a crucial cause of the enhancement of resource and energy efficiency in the steel industry. Between 1960 and 2003 the specific deployment of raw materials could be reduced that way in total by 44% per metric ton of crude steel. Regarding reducer consumption, blast furnaces in Germany operate at the procedural minimum (Lüngen 2004; Still 2005).

Big progress concerning the efficiency of the production process could be achieved beyond the deployed energy carrier and raw materials, as well. This becomes clear by the example of fireproof (fp) materials in the steel and iron production (among other things in blast furnaces and converters). The abrasion of fp-materials is associated, on the one hand, with considerable costs as well as resource and energy consumptions, on the other hand, also with stoppages in production due to the renewal of installations. By means of a further enhancement and the targeted deployment of fp-materials the steel industry's consumption could be halved over the last 30 years (Ritthoff 2005).

2 Area of need construction and habitation

2.1 Trends and impediments

Trends in the area of need construction and habitation can turn out regionally differently and can require adapted measures. The elevated land consumption, the socio-demographic change, the differentiation of lifestyles, and the increase in dry mortarless construction are stated as general trends.

The share of single-family houses in newly constructed residential buildings in Germany is going to rise till the year 2025 to 95% against 75-80% in the year 2001 (Wallbaum/Herzog 2001). Thereby the increasing demand for living space results from the growing number of privately owned homes which tend to consume more land per capita than rented flats, the increase in single-person households, and a consequence of demographic change: the increasing share of the elderly in the overall population which, however, require more living space per capita than younger people (GdW 2006, p. 19).

Germany's demographic development undergoes a change: From 1990 to 2000 population grew still by about two millions, as early as till the year 2010 a slight decline has to be expected that is going to develop more rapidly. For the period between 2005 and 2050 a decline in population by ca. 10% to than roughly 74 millions inhabitants is forecasted. The Federal Statistical Office of Germany (DeStatis) denotes the long-term population development till the year 2050 as contraction and ageing process at the same time (2006).

It can be noted a change of client needs and a differentiation of lifestyles in society. This developments change the penchant for certain forms of habitation and construction. Also the forms of cohabitation became more diverse in the last decades. This trend is characterised by an increase in "non-conventional" living arrangements (patchwork families, single mother/father, etc.) besides the "normal family", in single households, and in households with elderly members.

Findings of a study of the Club for Timber and Dry mortarless construction (VHT) concerning the innovation potential of various construction methods (brickwork, steel and dry mortarless construction): "The most innovations until the year 2012 are going to originate from the dry mortarless construction whose most important component is the building material gypsum – almost half of used material is gypsum. Additionally: While the deployment of brickwork and reinforced concrete (ferroconcrete) on the construction sites diminishes, the dry mortarless construction is gaining ground. The size of the European market is believed to increase by about 30 percent until 2012." (Tichelmann 2005, p. 2)

As general **impediments** to resource efficiency in the area of need construction and habitation can be mentioned the following:

- **Consumers/home-builders:** Paucities of information concerning the profitability and applicability of innovations (e.g. enhanced building technique) (cf. ADL/WI/ISI 2005, p. 61);
- **Knowledge of occupants:** Especially regarding technologies which require a change in the building occupant's behaviour an intensified attendance is necessary (e.g. by means of monitoring programmes or road shows at regular intervals) (Field report of the architect Michael Müller concerning the passive house and students' hall of residence "Neue Burse" in Wuppertal);
- **Architecture firms/construction firms:** Shortage of qualified staff for planning, project management and execution (cf. ADL/WI/ISI 2005, p. 61);

- **Construction firms/producers of building material:** Lacking funds for investments in machinery and equipment (e.g. in the production of building materials) (cf. ADL/WI/ISI 2005, p. 61);
- **Sustainable building planning:** Lacking technical, organizational solutions and concepts (e.g. for resource conserving, life cycle oriented planning concepts) (cf. ADL/WI/ISI 2005, p. 61).

2.2 Potentials to increase resource efficiency and conservation

The area of need construction and habitation represents a huge challenge to a sustainable development (Enquête-Commission 1998). Roughly 30% of our environmental consumption (as measured by material extraction in kg) per capita and year are required for the way that we construct and reside even today (Bringezu 2004). Building stock and circumjacent infrastructure (e.g. streets, squares) occupy a big part of resources (land, energy and raw materials) (Deutscher Bundestag 1998). About one third of all directly and indirectly generated material flows per German citizen arise from the area of need "construction and habitation" (Wallbaum/Kummer 2006, p. 163). Therewith, "construction and habitation" is by far the most material-intensive area of need (Bringezu/Behrensmeier 1998; Behrensmeier/Bringezu 1995, p. 27). The total material consumption of roughly 52 t per German citizen each year (Bringezu 2004, p. 81) correspond approximately the mass of 17 compact cars per capita and year alone in the area of need "construction and habitation" (assumption: 1000 kg/compact car).

In order to comply with the climate protection objectives as agreed on in the Kyoto Protocol, above all, the renovation of the building stock can contribute significantly. The saving potentials are huge: While a major part of future requirements for residential buildings could be met by existing buildings, many home-builders dream further on of single family detached houses in the green. Much too rarely it becomes clear that similar living comfort, energy- and resource-optimised, could be created also in urban environment and with better infrastructure connection.

Different potentials for savings of resources could be identified for each stage of building life alongside the building life cycle. The study "sustainable construction" forecasts in a sustainability scenario that until 2025 up to one third of the annual raw material utilization could be economised via the application of a measure mix. "The annual utilization of mineral resources for 'construction and habitation' [..] reduce by about one third." (UBA, 2004, 13) – i.e. minus 89 m t/a, that is from 269 m t to 180 m t, in the sustainability scenario.

Many of the stated indicators for saving potentials equally point in this direction. Emphases are primarily on the possibilities of a foresighted and aspects of resource productivity considering planning stage, on the prolongation of building life spans, and on the energy saving during the utilization stage. Optimizations in the stage of construction material procurement – e.g. via the intensified usage of recycling material (building materials and materials from municipal waste) – can contribute significantly to sustainability in the necessity field „construction and habitation", as well.

Some identified potentials alongside the stages of building life cycle are listed in the following:

Stage of extraction and production of building materials

Sustainable building materials:

- Development of innovative and resource efficiently producible and disposable building materials
- Substitution of renewable resources for conventional building materials
- Enhancement of material and energy efficiency in the extraction/production of conventional materials
- Resource efficient energy generation, particularly electricity (in order to discharge the production and the building utilization phase) (cf. Wallbaum/Kummer 2006, p. 37)

Building material recylcing:

- Enhanced building material recycling on a high-quality level (cf. Wallbaum/Kumer 2006, p. 37)
- Usage of building wastes as a resource (cf. Wallbaum/Kummer 2006, p. 37)
- Promotion and strengthening the establishment of concrete recycling in premium applications (surcharge for new concrete) – Estimated potential: Raw material savings up to 10% from approx. 2010 on (up to 16 m t/a) (Öko-Institut 2006, p. 23)

Planning stage

Cutback of mineral resource needs:
Reduction potential of approx. 50% (i.e. 80 m t/ha) buildings between 2000 and 2025 by means of an elongation of building life span (extensive renovations, merging of residences, abatement of vacancies, confinement of new building volume to needs, laboured selective deconstruction of unused buildings (Öko-Institut 2006, p. 23).

Life cycle observations/resource efficiency checks for new development and renovation:
Life cycle oriented analyses or check lists accompanying the planning concerning quantitative resource consumptions of parts of a building (e.g. typical wall superstructures) in combination with common renewal cycles. (Potential cannot be quantified meaningfully at present) (cf. Wallbaum/Kummer 2006, p. 37).

New building and renovation execution phase

Renovation, maintenance and further use of the building stock:
By means of a conversion and further use of existing buildings 50 to 80% of material can be saved (cf. Wallbaum/Kummer 2006, p. 34, 39). “Referring to the renovation and new development rates of the past, the savings achievable by resource efficiency analyses accompanying the planning can be estimated at approx. 58.85 m t in new development and 117.7 m t in old building.” – That means to reduce 5,000 kg of abiotic materials against 1,500 kg/ m^2 in the utilization phase (idem, p. 39).

Energy savings/energetic building renovation:
“The possibilities for energy savings in the building stock concerning frontage and building renovation are not used sufficiently up to now (status from 2002). As shows the renovation of a big housing estate in Ludwigshafen, with today’s new insulating materials and window

systems for thermal insulation currently an average reduction of 180 kWh per square meter and year in specific heat requirement is possible.” (Bundesregierung 2002, p. 167)

Reduction of structural damages by means of quality control:
“Every year in Germany avoidable structural damages amounting to about 3.35 bn Euro arise due to errors in planning and execution. Frequently this is caused by building as rapidly and cheap as in any way possible. In some cases defects are not realised or consciously ignored by craftsmen and construction firms and it is continued to work until hence emerge apparent damages.” (MDR 2004)

<u>Utilization phase (incl. Conversion/maintenance phase)</u>

Cutback of energy requirement for heating and hot-water preparation:
By innovations in building services and by switching to renewable or less climate affecting energy carriers (cf. Wallbaum/Kummer 2006, p. 37); “If all accommodation units were heated by natural gas assuming unchanging heating requirement of 150 kWh/m^2*a [referring to Germany], this would correspond to a theoretic saving potential of 267 m t of abiotic materials (i.e. a reduction of today’s environmental consumption by factor 6).” (Wallbaum/Kummer 2006, p. 39)

Energy saving via building automation and forward-looking building services:
Sensor systems that regulate heating and lighting depending on whether someone is in the room: “By a consequently implemented concept of building automation with integrated room automation, it can be saved up to 65% of lighting energy and up to 35% of energy for heating and cooling. On the consolidated balance sheet, the requirement of primary energy – and thus the energy costs, as well – can be reduced up to 50%.
The financing costs for such a system lie usually significantly under the estimated savings on energy costs. A model calculation showed that in the case of an additional investment of 700 Euros per room, the financing costs amounting to 90 Euros are confronted annually with 150 Euros of cost savings – a yield in the two-digit range.” (Becker/ Knoll 2007))

<u>Deconstruction</u>
Regarding the separation of building material fractions, a high-quality recycling should be enabled.

<u>Further potentials</u>

Carbon dioxide emissions in the field of action construction and habitation:
The annual emissions of roughly 227 m t CO_2 could be reduced by about 52% until 2025 (UBA 2004, p. 15) pursuant to the sustainability scenario 2025 (cf. UBA 2004, p. 14).

Reduction of land consumption:
The additional annual land consumption for habitation could be reduced by up to 85% until 2025 (compared to the year 2000) (UBA 2004, p. 12f). “Get off from new development on the ‘greenfield’ and strengthen settlement cores. That way, the additional land we consume can be reduced by more than eighty percent within two decades.”

Export of the technique for sustainable construction:
Approximately two third of the global activities in building construction is executed in developing countries. Half of all urban residential buildings in China were built not until the 1990ies. Here exist high potentials for resource savings due to locally low standards: “Due to insufficiently strict construction standards or a construction practice not sufficiently geared to the standards, new buildings in many new industrialised and developing countries require up to

two third more of energy for heating and air conditioning than would economically appropriate." (Rat für Nachhaltige Entwicklung 2004, p. 6)

2.3 Options for actions – regulative, promoting, marketing, and information instruments

Consecutively, some regulative, promoting, marketing, and information instruments are presented as measures for an enhancement of resource efficiency that have been discussed with stakeholders in the project.

2.3.1 Regulative instruments

Law of tenancy
Approximately 61% of inhabited accommodation units in Germany are rented, so that a decisive share of the up to now not rehabilitated stock is affected by the user-investor-dilemma (desicca 2007). That is, energetic renovations of buildings usually represent on the one hand investment costs for the building owners/land lords and on the other hand energy savings regarding the ancillary costs – mainly for the tenant. Higher investment costs for the owners (investor) confront lower operating expenses for the tenant (user). Is an existing building rented, the incentive for investments in energetic renovation is determined by the possibility to allocate the investment costs and thus, in the long run, profit from the investment by oneself.

The current law of tenancy assures that both sides, landlords and tenants, profit from the long-term cost savings by energetic renovation. In the German Civil Code (BGB), § 559 regulates the "rent increase after renovation". According to that, landlords are allowed to increase rent by up to 11% already nowadays if a general and permanent amelioration of housing conditions or sustainable savings regarding energy or water are achieved by virtue of modernisation measures. In practice, however, a feasible calculation method facilitating an allocation of energetic savings is lacking.

In individual cases, the rent increases have to be justified by concrete enhancements and thus, a rent increase of 11% succeeds only rarely without extensive effort (www.ressourcenproduktivitaet.de).

Also an increase of rent to the locally usual reference rent, according to § 558 BGB, only uncommonly helps to include the thermotechnical renovation state of habitations, since this increase frequently is effected on basis of local rent indices that usually do not reflect specifications regarding the energy requirement of the residential building stock. Here, the legal definition of "rent index" from § 558c BGB (rent index) and/or § 558 BGB (qualified rent index) could be adjusted, so that the thermotechnical standard has to be included into the locally usual reference rent.

Tax law
In income tax law, costs for modernisation and renovation expenses in rented buildings can be set off against tax (with respect to renovation concerning buildings occupied by the owner himself, this applies, however, only to labour costs and not generally to all modernisation expenses). If these costs arise within the first three years after the acquirement of an object and less value added tax surmount 15% of acquisition costs, they are written off – equally as the acquisition costs – over 50 years (see § 6 of German income tax law (EStG) for "valuation"). In order to avoid these long depreciation periods, many owners protract (costly) maintenance and modernisation measures and carry them out only years later – or never. By

means of an adjustment of the income tax law (EStG), maintenance and modernisation measures that are ecologically reasonable, as e.g. thermal insulation, could no longer be ranked among the original cost close to acquisition. That way, it would be possible to write them off in a shorter period. Thereby, it would be more attractive economically to implement maintenance and modernisation measures promptly after the acquisition of a building.

Promoting instruments

Already today, there are various possibilities to get funding for investments in material and energy efficient construction. For instance, among others, the Reconstruction Loan Corporation (KfW) offers a range of programmes that increase incentives for energetic renovation and energy efficient construction. Alone in the year 2006, 2,300 m kWh of energy could be saved by these programmes (CO2-online GmbH/Frauenhofer IBP 2007, p. 10).

A financial grant via loans and subsidies, however, usually does not provide the impetus to take renovation measures. The financial promotions are “taken along” after having already decided renovation (www.ressourcenproduktivitaet.de). Thus, it seems expedient that in the future, on the part of the KfW, also advice concerning energetic renovation and material efficiency is subsidised. Currently, numerous stakeholders offer advice on energy and material efficiency. Furthermore, hints and advices concerning energetic renovation are offered (e.g. by the Federal Office of Economics and Export Control (BAFA), German Energy Agency, the Tenants’ Union (Mieterbund), consumer advice centres, Federal Working Committee for Old Building Renovation (BAKA e.V.)) increasingly via the most different channels (e.g. web portals).

2.3.2 Marketing and information instruments

Ecological rent index

Today’s conventional rent indices are provided by the city or community. They contain only rarely references to the energetic standard of the offered habitations, since they lack the appropriate data basis that is necessary to compile an ecological rent index. Contemporaneously, however, nationwide uniformly criteria officially required are lacking, as well.

A universally valid selection of criteria and matters for an ecological rent index would secure uniform information content and would enable the comparability of different cities. The city Darmstadt and also the “heating index” within the BMU-Campaign “Climate seeks for protection” (www.klima-sucht-schutz.de) provide examples for the successful application of an ecological rent index.

Within the scope of a reform of the law of tenancy, the legal definition of the term “rent index” (Mietspiegel) could be broadened to ecological criteria. But also without such a reform, a comprehensive offering would be thinkable. Stakeholders important to approach the objective of a further dissemination of ecological rent indices are e.g. representatives of local rent index commissions. Moreover, lobbies of tenants and owners could advocate the compilation of ecological rent indices according to standardised criteria.

Extension of the energy certificate for buildings towards a resource certificate

Up to now, only little is known to public regarding the life-cycle-wide resource consumption for buildings. Existing knowledge concerning resource consumption for single types of buildings is limited to case studies within the scope of scientific accompanying research on construction projects. Today, to private constructors with few buildings, it is possible only to a certain extent even with high efforts, to take into consideration life-cycle-wide aspects of resource efficiency (material, land, energy). Thus, considerations with respect to ecological construction and renovation frequently are limited to the issue of energy.

The energy certificate for buildings can be issued according to size and age as consumption-oriented or requirement-oriented certificate (see EU Directive 2002/91/EC and the German Energy Efficiency Ordinance (EnEV)). Energy consumption certificates rather reflect the pattern of use of the occupants, since the consumption value is calculated as an average of the actual consumed energy of the preceding three years. By contrast, energy requirement certificates convey a more comprehensive image of the building's state and facilitate statements with respect to the building's energy efficiency. Thereby, the requirement certificates represent an approach to take into consideration at least the energy requirement of a building in the utilization phase including the upstream chains of energy supply (generation, transport, etc.).

In the long run, this instrument could be advanced towards a resource certificate that displays, besides the energy requirement, also the life-cycle-wide material requirement of a building in its various phases of life by material as well as the life-cycle-wide material intensity. That way, an information basis and wealth of experience could emerge that enables a directed consideration of issues of resource productivity (material, energy, land) as early as in the planning stage. In order to develop a resource certificate, besides stakeholders from research, primarily experiences from construction industry are in demand.

Marketing and information demands

In comparison to new development, construction and habitation in building stock is perceived frequently as more difficult and/or risky, as well as unprofitable. This applies to many architects as well as some target groups among consumers.

Decisions on habitation are taken frequently with strong emotions instead of a comparison of facts. Thereby, predominant ideals not always correspond to the subsequently encountered reality of life (see e.g. Project for protection of free space of the Association for Environmental and nature protection (BUND), www.freiraumschutz.nrw.de). Although it is known for a long time that especially families that move to the outskirts frequently afterwards miss the infrastructure of city centre, the ideal of a single family detached house is still predominant.

As prove experiences within the programme klima:aktiv in Austria, a broadly applied marketing and information campaign could contribute to the dissemination of existing knowledge regarding the construction and habitation in building stock and to advert to the advantages of habitation in the modernised and energetically optimised building stock. A comparable platform which, in addition to energy efficiency, takes life-cycle-wide aspects of material efficiency into account, as well, does not exist so far. This could be launched at federal level for example by the Federal Chamber of Architects or a newly to create umbrella organisation of existing material and energy efficiency networks. A campaign uniform nationwide could bundle and assist the commitment to material and energy efficient construction already existing in many federal states. Besides building owners and tenants, the target groups construction firms, professional housing providers, trade and repair businesses, architects, consumers (amongst whom also pupils and even children in kindergarten).

A nationwide marketing and information campaign could, amongst other things, be aimed at an amelioration of the image of construction and habitation in building stock, dissemination of supply with advice and information adapted to the needs of important target groups, resource conservation (use of building stock aids to save material and energy flows), prevention of a further suburbanisation and an enhanced attractiveness of city centres, diffusion of new forms and types of buildings, as well as safeguarding of jobs.

Resource conservation and promoting of urban habitation
Polls show that also families frequently prefer to live in the city provided that secured playgrounds, like walled yards, football areas and other offerings of infrastructure, are available. Under such conditions, only older childless couples exhibited a preference for living in the hinterland (InWIS 2007). A marketing and information campaign could be combined with existing projects and actions and directly address the needs of different target groups. Simultaneously, such a campaign could be used to further sharpen the consciousness for the subject matter of resources and to offer target-group-oriented information with respect to resource saving patterns of use.

2.4 Further options for action and recommendations

Education and qualification offensive
The efficiency of the utilisation of building materials is decisively determined by those who deploy them, i.e. architects and workmen. The potentials can be used optimally especially if all those involved exhibit a high expert knowledge as well as the courage to confront “inefficient” trends with innovative strategies. The technical quality of workings carried out does not play a major role for material efficiency. Therefore, significant potentials for resource efficiency lie in the advancement of know-how of workmen and in quality assurance. The special knowledge of those involved in the construction process is an important factor of success for customer satisfaction, resource efficiency, and order situation. Specialisation in renovation (also for workmen) leads to a higher success rate. Thereby, defects in the constructions can be prevented.

Here, it is expedient to launch a qualification offensive for architects, planners, and also workmen. By further education measures with cross-business and trade-specific contents, the addressed target groups can extend fitting exactly their expert and consultancy competences, and thus are enabled to gear the own products and services to the various “target groups”.

Information and consultancy
The situation of information regarding the ecological and energetic characteristics of living space complicates the inclusion of ecological and resource efficient criteria to the selection for both, tenants and owners. Consequently, a growing demand for consultants is observable, since these can advise the consumer independently and capably. Here, instruments as labels and seals of quality can support. Moreover, certificates for buildings or an ecological rent index are already promising and developable approaches, and the purely energy focused consultancy could be extended and supported by consultancy services around the complex of issues of resource efficiency. Also to users, first labels are available to take resource efficiency into account at an early stage, e.g. in form of the FSC-label (Forest Stewardship Council) and the advancements of the EPD (Environmental Product Declaration). With respect to energy demand during the utilization phase, it exists a extremely high dependency of resource productivity on patterns of use. Insofar, high efficiency potentials lie in the dissemination of knowledge concerning a resource efficient use of modern building services. It is not sufficient to construct a ultra-modern and efficient building. It is necessary, as well, to explain to users the philosophy of the building.

Enlargement of perspective
Need for action exists especially with regard to a targeted promotion of renovation of existing buildings, redensification, and activation of fallow land. E.g. the promotion of an intensified

inner-development of the settlement areas during concurrent revitalisation of settlement cores, particularly in core cities (reduction of outmigration from cities) are ranking among this.

Also the encouragement of an increased mix of utilization can support an intensified use of existing buildings, e.g. by means of new forms of high-density construction for habitation and business use as well as additional taxation of the use of new areas. The context of the building itself and the further levels in the context of city planning have to be examined conjointly. For individual construction projects, an extensive planning is necessary that includes aspects of resource efficiency also with regard to city planning. Here, the long-term objective of an "appreciation of quarters" is an important factor by means of which also the use of building stock could be advanced.

Beyond the building and renovation planning, the field of project development should be promoted. Then it becomes possible to take considerations of resource efficiency and aspects of city planning into account. With regard to resource efficiency, the short and simple formula is: Good planning = resource efficiency.

Redesigning and extending funding programmes

Many funding programmes in the sector construction and habitation aim primarily on new development. In order to encourage necessary investments, the funding programmes of the KfW should be extended towards resource efficiency. Here, besides the instrument of loans reduced in interests, also temporally limited direct subsidies and fiscal facilities to write off could be deployed.

Amelioration of the image of construction in existing buildings

The presently bad image of "construction in existing buildings" restrains a broad implementation. The use of old buildings holds an increased cost risk compared to new buildings. The final price is therefore hard to calculate. A relatively secure estimation of the cost of the modification is given only after intensive planning which increases financial risks mainly in the pre-financing. An unerring and reliable amelioration of the image of existing buildings' renovation is however necessary in order to make the use of old buildings more attractive to a broad target group, e.g. young families.

Co-operations

The area of need construction and habitation is characterised by a strong reciprocal interlinkage of the different stakeholders. During the construction process, different trades are working together. Thereby, however, significant possibilities for optimisation appear. The co-operation of different stakeholders is of big importance and is necessary in order to achieve the targets for resource efficiency. In this context, the collaboration of planning and trade with the builders as well as of the professional housing providers with the tenants is important and needs to be enhanced. Furthermore, it is to be aimed on an optimised collaboration in construction within the value creation chain. In the middle and long run, chances of a laboured policy for an increase of resource efficiency are big, although the challenges to be faced are not to be underestimated. The necessary increase in resource efficiency therefore will not be reached as a sure-fire success, but can be achieved only via a combination of precepts, incentives and support.

By its high contributions to environmental burden, the area of need construction and habitation offers giant potentials for resource conservation and thus becomes an important field of action for strategic approaches towards an increase in resource efficiency. These, however, are realised solely if the societal general conditions actually enable and promote an efficient handling of natural resources.

3 Raw material system copper

3.1 Trends and impediments

In the sector of emphasis copper, trends and drivers generally are characterised by increasing resource consumption in newly industrialised countries. Between 2001 and 2006, the demand for copper escalated globally from 14.9 to 17.1 m t by the growth in the People's Republic of China (PRC) and other newly industrialised countries. Main drivers are the development of infrastructure and the electrification. The PRC represents almost two third of the increase. It used over 3.8 m t copper and thus supersedes the USA (2.3 m t) as most important consumer (IKB 2007, p. 8f).

RWI/ISI/BGR (2006) estimate an increase in global copper use of about 72% or 2.7% p.a. until 2025 (base year 2005). At the same time, the potentials for substitution are limited since copper is indispensable in electrical engineering as an important conductor material. The high demand could not be supplied in short-term by existing mining capacity. Consequently, between 2003 and 2006, price increased from 1,500 to around 8,000 USD per metric ton (BGR/RWI/ISI 2006, p. 71).

The high demand for copper from newly industrialised countries will continue since a close relation exists between an increasing level of wealth and demand for copper for copper. Thereby, also general trends resulting from modern industrialised countries' dynamics of innovation play a role: e.g. the increasing crosslinking of industries and technical installations, the augmenting demands towards telecommunication in business and spare time, the decentralisation of energy industry, but also the high security and comfort standards in today's automotive engineering. In these fields of growth, the enhancement of resource productivity can contribute to curb the demand for copper.

Against the background of the worldwide development of demand, an increasing importance is attached to the extension of secondary production in Germany and Europe. But, even if in 2025 the global recycling rate for copper lay for example at 35% instead of 13%, the demand for primary copper still would augment by about 30% with an increase in consumption of 72% (RWI/ISI/BGR 2006).

In the **field of action automotive engineering**, different trends and drivers are detected:

- The development of vehicle population and the thereto related inflows and outflows (including the lifespan that influences these parameters): Though the number of driving licenses is augmenting due to ageing of society and increasing individual mobility by car, social and demographic factors (income, reduction of population), however, contemporaneously limit the future increase of new registrations.
- The equipment of vehicles and the thereto related material strategies in automotive industry (particularly areas of application of copper deployment): High standards for safety and comfort in today's automotive engineering, especially via niche vehicles with complex electronic and strong accumulators (cross-country vehicles, convertibles with electric top, etc.) lead to further increases in the demand for copper (ca. 1.5 to 2.5% of total weight).
- Emergences of saturation on the German market: The automotive industry tries to boost its value creation by an expansion in the big growth markets in East Asia (e.g. China).

In the automotive engineering, the following **impediments to implementation** run against an enhancement of resource productivity and conservation:

- Some requisites in the construction of automobiles lead to conflicts of objectives in practice (e.g. costs, environmental protection, and recyclability). These should be overcome by integrated cost-benefit analyses within the scope of life cycle assessment (LCA).
- Interface between second-hand car market and waste regime: Impediments that impede an exhaustive development of recycling potentials in the sector of end-of-life vehicles. The waste regime with its high environmental standards is increasingly getting into a situation of rivalry with different submarkets as the second-hand car trade, the trade with demounted single components, and the trade with scraps. Out of annually more than 3.2 m deleted vehicles (KBA 2007a) only half a million is still salvaged in Germany (BVSE 2006).

In the **field of action information and communication technologies** (ICT), in the last decades, various high-performance technologies and thus trends established that base on different networks: cable- and circuit-based systems (landline, wiring harness) as well as radio systems (terrestrial as well as satellite-based mobile communication). It is characteristical that the first two resort extensively to copper as basis for circuits. Parallel to the offerings of the new media (high-speed data transmission, wireless communication, mobile navigation, download of films, etc.), the demand for high-capacity transmission paths for huge amounts of data is rising more and more. Within the scope of product development and manufacturing, the resource efficient handling of copper is not necessarily in the focus of the companies' interest since other factors are graver regarding costs or customer wishes. For instance, in miniaturising mobile phones and digitalising its functions, not resource productivity but the extension of functions and offerings of very compact and lightweight devices is to the fore.

Within the scope of the analyses of this field of action, of interviews with experts, and of workshops, four problems/**impediments** have been identified in the ICT sector:

- At the production level, criteria of resource efficiency play a role primarily if the resource prices are reflected relevant in the commodity prices. However, in this case, it is sought for possibilities to reduce costs on the part of industry, as well, e.g. by means of use of alternative materials or by resource saving construction principles. Regarding copper use in ICT appliances, a distinct conflict of objectives exists. On the hand, admittedly, copper is deployed in considerable quantities, on the other hand, though, material costs in appliances is of subordinate import in comparison to labour costs for example.
- Within the scope of the utilisation of ICT products, particularly the short time spans of utilisation due to a high technological innovation rate affect counterproductively the resource efficiency. Furthermore, the continuing decline in prices of ICT products led to a repair culture.
- The expansion of radio technologies and the use of radio circuits for data transmission have led to a multiple structure of supply in which different circuits are used similarly by now. A high relevance of examining the modalities of deployment arises especially from the use of copper in landline.
- In the ICT sector, the highest deficits – and potentials in terms of resource efficiency, as well – are observed in the recirculation of products no longer in use and in recycling. In material recycling, the materials relevant on a quantity basis are separated according to the electronics and electronic appliances law (ElektroG). These are not

necessarily, however, the most valuable materials from a perspective of resource policy.

It can be observed from the general description of the raw material system and the analysis of the relevant literature that the highest potentials for resource conservation lie in the early stages of the value creation chain. Improvements in productivity, that in consequence indirectly curb resource demand, have to be deduced subsequently in individual fields of use. At this, the different edge conditions have to be considered. Hence, it is expedient to describe the potentials implementation-oriented for individual fields of action.

An improvement of resource productivity in single fields of use would lead to positive environmental effects in both, the producer countries and the importing industrial nations. From the analysis of the relevant literature emerges that resource productivity could be increased considerably by a package of measures (efficient and targeted deployment, substitution, and recycling). Whether, however, an absolute decrease in resource consumption is associated herewith depends on the particular growth rates.

3.2 Potentials to increase resource efficiency and conservation

From an economic perspective, technological innovations improving resource productivity lead to a series of positive external effects (e.g. improvement of competitiveness) and, at the same time, environmental impacts of production and thus negative external effects are abated. Against this background, both dimensions should be examined for the design of incentive schemes to tap the potentials.

The potential “copper recycling”

Copper scraps are recyclable by up to 100%. The share of recycling is 55% in Germany (BGR/RWI/ISI 2006, p. 72) and 13% worldwide (idem, p. 258). Copper scraps are traded on an international market. For import dependent consumer countries as Germany, a high recycling share is important with regard to two aspects: cost saving and security of supply. The processing of secondary raw materials – mainly from domestic emergence – reduces the required imports and discharges the balance of trade (RWTH 2002). For instance, in the year 2005, the recycling of various metals substituted raw material imports amounting to almost 4 billion Euros and thus led to a value creation of corresponding extend. Hereof, 2.2 billion Euros originate from saved energy that would have been required for the new production of materials (Barth 2006).

From a perspective of environmental policy, copper recycling offers sizable potentials. Burdens from mining and transport are omitted (Ayres et al. 2003, p. 9). According to the Research Institute for Energy Economy (FfE 1999), the material and energy consumption of primary and secondary copper results as follows:

Table 2: Material and energy requirement for primary and secondary production of copper

	Unit	Primary methods	Secondary methods
Production of concentrated copper			
Energy	MJ/t	14-15.000	0
Dirt material	t/t	37-38	0
Production of copper			
Energy	MJ/t	41-46.000	30-32.000
Yield	%	97	n.s.
Sulphuric acid	t/t	1,8	0
Slag	t/t	1,1	0,53
Other rests	kg/t	33	90

Quelle: Research Institute for Energy Economcy (FfE) 1999; Ayres et al. 2003

Altogether, copper recycling in Germany proceeds at a high technological level. Though, high-capacity recycling concepts have not yet established in all end-user markets, especially not in those in which copper does not represent the main mass flow. Ayres et al. (2003) come to the conclusion that the recycling potentials for copper are not tapped sufficiently. Moreover, new problems are to be expected in consequence of the shift of consumption towards countries without a recycling infrastructure (as China and India). Likewise, the (still) strong economic interests of mining are inhibitory for the extension of recycling. Therefore potentials for a technology transfer regarding recycling infrastructures exist particularly in newly industrialised countries in which copper utilisation still augments.

In the **field of action vehicle electronics and construction**, potentials are stated as an efficient deployment of materials, recycling-oriented construction and development of products, improved recycling technologies, as well as enhanced statistical measurement of material flows. The enormous demand for copper in automotive industry becomes obvious by the worldwide use for vehicle electrical systems amounting to 1.5 m t/a. This represents approx. 10% of the global production of copper from mining (Steuff 2006). According to own calculations of the Wuppertal Institute, the deployment of copper in the German vehicle population is going to double during the next twenty years from currently ca. 22 kg to ca. 40 kg on average of the passenger car fleet within the German vehicle population (cf. Lucas et al. 2007). This additional use of copper predominantly is due to the numerous additional electric and electronic functions of vehicle electrical systems' architecture that – with regard to so-called add-on packages – looms ever larger in marketing. Here, three sectors can be distinguished: Increase in security, better control of the individual assemblies, and extension of comfort and entertainment functions.

The potential „more efficient material use and lightweight construction"

The selection of materials is effected on the part of manufacturers hitherto according to numerous function-oriented criteria. Driving force in the area of innovation "materials" is up to now the call for lower fuel consumption and less emissions by means of utilisation of more "lightweight" materials. In the past, increasing needs for comfort and security have led to an increase of vehicles' total weight. Lightweight construction strategies lead to a change in construction design and the herefrom derived material properties concerning also the use of copper.

Altogether, the following technological innovations exhibit a high potential to optimise the deployment of copper in automotive engineering:

- Optimisation and adjustment of the E/E architecture to reduce weight (miniaturisation, integration of functions, weight-reduced vehicle electrical systems)
- Development of new, functionally adjusted copper alloys
- Material reduction and miniaturisation of vehicle electrical systems by new conduit and contact part technologies
- Quality management (as contribution to an extension of products' lifespan)
- Substitution of aluminium for copper in high current power supply (e.g. conductors of batteries)

The potential „recycling-based construction and product development"
Until the year 2000, automotive manufacturer had taken a series of measures to support recycling-based product development (ARGE-Altauto 2000, p. 10ff). Mandatory recycling standards and directives have been developed for manufacturers. In order to improve recycling potentials, recommendations are given for the engineering of components and vehicles as well as for the use of new and secondary materials, as for example:

- Analyses of dismantling in order to evaluate the recyclability of a vehicle and its parts
- Measures aiming at an engineering optimised for recycling, as e.g. reduction of material diversity (amongst others regarding bumpers made of PP/EPDM (polypropylene/ethylene propylene diene rubber) blends and a thermal insulation at the all-aluminium undercarriage instead of a sandwich construction)
- Material identification of all synthetics over 100 g and all elastomers over 200 g
- Joining techniques suitable for repair and pre-treatment (e.g. optimised screw joints at extensive exterior assemblies and clipped on rear light inserts)
- Provision of a software for dismantling common vehicle types for recycling plants (International Dismantling Information System: IDIS software)

Existing strategies for recycling-oriented construction and production would have to be extended to the essential areas of application of copper deployment in the vehicle in order to improve the potentials for copper recycling. A product development optimised for recycling is an important prerequisite for an ecologically compatible and cost-effective salvage of the copper share of future end-of-life vehicles. A starting point for this purpose is the easy demountability of important copper-containing parts (identification of copper-containing assemblies).

The potential "improved recycling technologies regarding end-of-life vehicles"
Generally, the end-of-life vehicle recycling features a considerable potential for an improvement of resource productivity. The recycling quotas according to the end-of-life vehicle ordinance are a crucial instrument of environmental policy to increase this potential (at the least 85% of a vehicle's average weight, from 2015 on up to 95%). Also the waste storage regulation (AbfAblV) having become effective in June 2005 has caused that with respect to the beforehand mostly deposited shredder light fraction new possible uses have to be developed (80% have to be recycled materially or re-used, from 2015 on at the least 85%).

The recycling quotas can be improved as well by disassembling, if applicable treatment, and reutilisation of assemblies containing high amounts of copper. Thereby, an efficient dismantling depends essentially on a construction suitable for dismantling (among others compact type of construction, position, and joint) and the dismantling depth in the disposal companies.

In car recycling usually only big and still serviceable aggregates (electric generator, starter, and electric motor) are demounted since small aggregates, connectors, and cables can be demounted only manually which is associated with additional labour costs.

Particularly small electronic assemblies and the wiring harnesses remain part of the so-called shredder light fraction with their high copper share. The classic shredder technologies are aimed at the recovery of the main mass flow steel. The potential for the recovery of the entire non-ferrous fraction[1] can be increased if the selectivity of the magnetic segregation can be improved by a high degree of crushing.

Further potentials can be tapped by so-called post-shredder technologies. It denominates the mechanical aftertreatment of shredder residue, especially the high-heating-value shredder light fraction (SLF) (e.g. synthetics, rubber, wood, textiles, foam plastic, soil, and glass). Regarding the innovation activity in this sector, two types of process innovations can be distinguished that, in principle, are able to separate completely the remaining copper share from the SLF and thus to increase the recovery potentials (Killmann/Pretz 2006):

- Sequence flows within the crushing process proceeding with common technologies are newly organised and optimised.
- Novel technologies are developed that are implemented in the existing processes.

Presently, these technologies are not employed exhaustively since particularly the strong decrease of feedstock from the car recycling sector led to low capacity utilisation of existing facilities and thus had a negative impact on the readiness to invest (cf. Arge-Carnet 2005). Also the unequal European standards concerning the storage of SLF lead to material outflows towards foreign countries and contribute to the uncertainty. Since secondary copper makes up only approx. 2% of the total material flow of old cars, the high copper prices and the possible secondary raw material sales in this segment do not represent a sufficient incentive, whereas the recovery of scrap and heavy fraction is considered to be profitable.

The potential “Improved statistical survey of material flows”

The monitoring for a life-cycle-wide survey of material flows has to be improved primarily at the interface between second-hand car trade and old car recycling. Here, some considerable informational deficits exist (Recycling Magazin 2007). On the basis of the current statistical enquiries, the final whereabouts of a big part of the vehicles deleted from motor vehicle statistics are undefined. Mainly, the survey of those deleted vehicles that are exported is problematic (cf. Fuder 2002). In order to improve the situation concerning the availability of data with regard to an international material flow management, on the one hand, exporters of second-hand cars would have to be pledged to provide information regarding the whereabouts and the age of vehicles. On the other hand, the practice of reporting concerning the export of end-of-life vehicles and old car bodies should be changed.[2]

In the **field of action information and communication technologies**, different fields of activity are highlighted that led expect potentials for resource efficiency. Here, above all, multi-functionality, miniaturisation, the sustainable utilisation of ICT products, enhanced recycling, and the substitution of copper grids have to be mentioned.

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[1] Non-ferrous metals are metals that do not contain iron or alloys in which iron is an essential part (e.g. copper, aluminium, zinc, bronze, and brass).

[2] Companies exporting from Germany to another Member State of the EU (internal trade statistics) are obligated to report if the value of their intra-community merchandise traffic in the current or prior year exceeds 300,000 EUR. With respect to the external trade statistics (export to a „third country“, i.e. outside the EU), those shipments have to be declared that value more than 1,000 Euros or exhibit an overall weight of more than 1,000 kg.

Multi-functionality of ICT appliances is the functional and technical combination of different applications of various apparatus in a single device. Multi-functionality is found mainly in mobile phones, which include besides the telephony function also functions as camera, calendar, or SMS. Other examples are appliances with hardcopy function that can e.g. stamp, scan, copy, or fax. In principle, multi-functionality is an approach to tap potentials of resource efficiency since a single device could substitute for various others.

Miniaturisation is the downsizing of assemblies of ICT products. Miniaturisation is associated necessarily with a reduction of mass. In the early nineties, car phones still weighed approx. 800 g; mobile phones weighed still more than 200 g (Reichel 2003, p. 43); modern mobile phones weigh about 100 g (Sullivan 2006, p. 2). Miniaturisation is enabled primarily by the production of ever smaller chips with ever more functions that exhibit the same or greater processing power. Though, miniaturisation can lead to rebound effects as well, like for example the extension of utilisation of ever smaller products.

A **sustainable consumption of products** can be achieved, amongst other things, by upgrading of products – generally the replacement of parts to improve efficiency – or by designing products for a long lifespan. Upgrading is relevant mainly for the enhancement of modular computers' performance. In spite of these possibilities, the lifespan of a PC of approx. 10 years is used only to a small part (Behrendt et al. 2004, p. 45). A prolongation of lifespan or a longer utilisation of products (useful life) would be efficient possibilities for a sustainable utilisation of ICT devices. A doubling of lifespan leads mostly to a bisection of material flows originating from production.

Recycling of electrical scrap is a further important approach to tap efficiency potentials. The accumulation of electrical scrap is continuously growing. For the year 2005, the accumulation of private and commercial electrical and electronic scrap (EE scrap) is estimated to approx. 1.8 m t for Germany (Federal Environment Agency/UBA 2006). Hereof, private households represent about 1.1 m t. Further possibilities to recover copper exist in light of the considerable quantity of electrical scrap and the only medium-level recycling quota mandatory according to the Electrical and Electronic Equipment Act (EEE Act / ElktroG).

The **extension of grid technology on basis of fibre glass** is a further possibility to lower copper deployment. This is adopted in on-grid communication mainly in the long-distance sector. The demand for high transmission rates, however, leads to a laying of fibre glass cables also in cities as far as to the end customer. Though, the landline of Telekom still consists of almost 90% copper (Telekom 2006) what is, amongst others, due to the deployment of copper for house connections – the last mile. Urban mining, the recovery of copper cables during the replacement by fibre glass technology, could thus contribute also to the tapping of efficiency potentials.

Besides the network-based infrastructure, a **radio-based network technology** has been established area-wide by mobile phone service providers. Transmission techniques as UMTS are equally powerful as a simple DSL connection. New techniques as WiMAX (Worldwide Interoperability for Microwave Access) are even essentially more powerful (tns-Infratest 2006, p. 247) and can offer an alternative to the fast connection technologies ADSL (Asymmetric Digital Subscriber Line) and perhaps even VDSL (Very High Speed Digital Subscriber Line). Also for small computer networks in companies or in households, by now possibilities exist for a wireless communication via W-LAN so that the deployment of copper cabling is dispensable.

3.3 Options for measures in the field of action vehicle construction and electronics

Lightweight construction and new vehicle concepts for material saving

By virtue of the lightweight construction strategies of vehicle manufacturers, efforts can be recognised to optimise the material use within the vehicle electronics. "Seeing the development of copper costs during the past twelve months, the cognition does not lie so far that new concepts for miniaturisation have to be found. But the CO2 discussion and the new threshold values to be expected force us to reduce mass and weight significantly." (Best/Vandevelde 2007, p. 19f)

Against the background of further functional growth of on-board electronics, possible gainings in efficiency regarding the use of copper are compensated. Nevertheless, these gainings are important to curb the growth of copper demand. Within the scope of existing vehicle concepts, an absolute reduction in copper use is rather improbable. Thus that is why it should be thought about entirely new vehicle concepts that do not follow the trend towards a further broadening of electronics in vehicles.

Replacement by aluminium and fibre glass

Copper is situated in an area of conflict between the requirements of lightweight construction and a further "broadening of electronics" in vehicles. Against this background, the ratio of quantity development and tapping of efficiency potentials has to be evaluated generally with respect to the entire vehicle and not only to single components. Copper and copper alloys are used mainly thanks to their first-class electrical conductivity. Aluminium, though, becomes more and more interesting as an electric conductor in vehicle electronics due to the increase in price of copper. It offers a high potential for weight savings – particularly regarding small-diameter cables, which represent the biggest part of weight in the car wire harness. Aluminium has generally, however, worse mechanical properties and requires new junctition technologies and connecting concepts.

Possibilities to replace copper by fibre glass exist in the crosslinking of various components of signal transmission in the ambit of infotainment. Different bus systems already are in use here (e.g. the MOST-bus = Media Oriented Systems Transport is a network for multimedia files) that have been developed thanks to their better transmission rates by fibre optic cables. According to statements of experts, wireless applications in other functional areas fail due to their high interference liability.

Copper recycling and urban mining

The recycling of copper is of great importance to import depending consumer countries as Germany concerning two aspects: Cost saving and security of supply. The processing of secondary raw materials – predominantly of domestic origin – lowers the required imports and discharges the balance of trade (RWTH 2002). In view of the price development on global commodity markets, also the German Federal Government attributes a high significance to the increase of metal recycling (German Federal Government 2007, p. 9f). From a perspective of environmental policy, copper recycling offers considerable potentials. Burdens by mining and transport are omitted; the processing of secondary resources requires essentially less energy than the production of copper from copper concentrates and is thus associated with less environmental burdens (Ayres et al. 2003, p. 9). From a perspective of resource policy, recycling of existing infrastructure, buildings, and consumer goods becomes a new resource of raw materials. In analogy to the primary mining in mines, the development of these repositories is denominated as "urban mining". In Switzerland, enquiries have been made already estimating the scale and regional disposition of the anthropogenic copper repositories (Wittmer 2006).

With an average share of copper of roughly 15-20 kg per end-of-life vehicle (year of production 1993) and almost 3.2 m deleted vehicles, approx. 60,000 t of copper would be available to the national raw material cycle. Due to an increasing export of end-of-life vehicles to non-EU states, as such in Africa or in the Middle East, also the national cycle's loss of raw material increases. There are different starting points and options for measures to mitigate this problem. In the following, first proposals are presented that seize and advance suggestions from the project's dialogue process. The recommendations have still to be scrutinised within the scope of further panels of experts on their feasibility in practice.

According to the Wuppertal Institute's assessment, it should be reacted to this complex point of departure with unclear chains of stakeholders by means of a new mix of instruments that comprises regulatory measures, information instruments, and economic incentives. These instruments have to refer to the individual situation of decision and to practices of individual stakeholders or groups of stakeholders. Thereby, different areas of objective are affected:

1. Regarding resource policy, an interest of recycling industry exists to augment the input of end-of-life vehicles into the German and European disposal system.
2. Regarding environmental policy, the necessity exists to impede the export of obviously malfunctioning second-hand cars that would lead to environmental risks if operating further on.
3. Furthermore, existing regulations regarding the prohibition of exports of end-of-life vehicles to non-OECD countries have to be operationalised to such an extent that clear criteria are developed for customs authorities and other executive bodies in order to enable the distinction between old second-hand cars and end-of-life vehicles (i.e. not roadworthy, scrap) and to eliminate illegal market practices like fraudulent declaration.
4. In medium term, an international recycling management has to be set up (UBA 2007, p. 33) that operates with uniform recycling standards. In order to eliminate the technology differential, technology transfer can play an important role in newly industrialised countries.

Informational and regulative measures at the interface between second-hand car market and waste management

Initially, the field of activity has to be rendered more precisely, since it is not the point to generally question the trade with second-hand products. Primarily practices should be eliminated that lead to a geographical shift of environmental problems. Especially vehicles that are no longer roadworthy and/or represent a considerable environmental risk should be consigned to the waste regime. With regard to this, different proposals for measures have been discussed within the scope of the dialogue process.

Proposal for measures 1: Broadly oriented marketing campaign of recycling management and automotive industry

The branches concerned with old car deposition face up to comprehensively with the competitive situation in the second-hand car trade. The acquisition of deleted vehicles for the waste regime is no longer carried out only on the level of small advertisements that are taken out by small disposal firms in advertisement gazettes. In these, disposal firms attract with a disposal bonus of 50 Euros, environmentally appropriate dismantling and taking back, as well as collection and deregistration services within the scope of the End-of-life Vehicle Ordinance (AltfahrzeugV).

A marketing campaign would have for objective to influence the decision-making process of consumers as last owners of a vehicle by clear statements regarding price-worthiness (monetary value) of old passenger cars and advantages of high environmental standards of the German and EU end-of-life vehicle disposal.

Proposal for measures 2: Extended duties of declaration for exporters from OECD-states

Exporters of old second-hand cars (from 12 years on) are generally obliged to the following additional declarations: Declaration of vehicle type (key number), vehicle weight, and destination country of export for each vehicle. This changes the hitherto practice of coupling declaration to certain export value. These declarations conduce to get a reasonable basis for material flow management of old second-hand cars and are presented within the scope of the national monitoring report.

Furthermore, the exporter should be obliged to conduct a functional check that excludes especially the following damage risks for environment and health:

- The leakage of operating fluids to the environment and
- the leakage of airborne pollutant due to a defective exhaust system.

This list has to be extended if necessary by general criteria of suitability for operation. However, it has to be born in mind that an easy verifiability has to be given in order to keep control efforts as limited as possible. The customs authorities thus are entitled to single out risk-entailing vehicles.

3.4 Options for measures in the area of action ICT

In the last three decades, the information and communication technologies (ICT) have pervaded economy and society. Milestones of this development are the enhancement of computing power, the triumphal procession of internet and the transition to mobile telecommunication.

For the development of strategies and measures for an improvement of resource efficiency in the field of action ICT, several market-specific general conditions have to be heeded:

- ICT products are produced increasingly cost-effective by exhausting all approaches possible. A smaller use of copper in appliances leads only to small cost-cuttings.
- ICT products are used more and more shortly due to the high rate of technological innovations.
- Furthermore, the far-reaching price decline of ICT products entailed a throwaway culture.
- The acquisition of data especially concerning small electrical devices for further use, for recirculation, and/or for recycling is inadequate.
- The producing industry has taken already a multitude of actions to satisfy the requirements of the Waste Electrical and Electronic Equipement (WEEE) Directive and other standards.[3]

[3] As examples can be mentioned the activities of the EICTA (European Information & Communications Technology Industry Association) for the implementation of the WEEE directive or the StEP initiative of the United Nations University (Solving the E-waste Problem) in which manufacturers of ICT products face the problem of electrical scrap.

Package of measures “resource efficiency in telecommunication networks”
In the last decades, technologies have established that base on different networks: Cable- and on-grid systems (landline and cable network with high share of copper) as well as radio systems (terrestrial as well as satellite mobile communication). In parallel to the offerings of the new media (high-speed data transmission, wireless communication, mobile navigation, download of films, etc.), the demand for high-capacity transmission paths for huge data volumes grows.

Possible orientations of measures in this complex of issues are:

- research projects concerning life-cycle-assessment (LCA) of data transmission via landline and mobile radio as well as the comparison of copper and fibre optic cables;
- research programme: low-cost fibre glass interface ICT;
- Set-up of a material-oriented infrastructure cadastre of telecommunication networks.

Package of measures “recirculation and recycling of small devices in everyday life”
Due to data regarding the collection of WEEE with little validity, statements concerning the effectiveness of collection and recycling of copper are hard to make. The orderly collection (return and collection) of ICT products no longer serviceable probably is the biggest problem in recycling of copper-containing appliances. This problem does not arise primarily due to existing collection systems that either have been developed on basis of the EEE Act (ElektroG) or have been initiated already beforehand by ecology-minded companies. In the commercial sector, an orderly disposal of ICT products is largely common. It is conjecturable that the private consumer is an essential weak spot in collection. Causes on the part of consumers can be an inadequate awareness regarding the recoverability as well as barriers in returning of old ICT products. This is confirmed by stakeholders of the recycling sector and the producers of secondary metals who speak out clearly dissatisfied on the insufficient recirculation of WEEE as for example mobile phones.

Possible measures in this complex of issues are therefore:

- simplification of returning small ICT products (collection bins analogue to the collection of batteries or combination of the existing collection schemes, very high rating by participants in the conducted dialogue workshops);
- deposit for small electrical and electronic products;
- material flow management for ICT waste products with an enhanced data recording;
- combination of collection schemes to simplify the returning of for example small ICT products;
- consumer campaign and (scholastic) education projects: timeless design and sustainable utilisation of products (very high rating, see above);
- prolongation of legal warranty period;
- against this background, it should also be thought about an adjustment of the EU recycling strategy in order to labour a differentiated collection of rare metals.

3.5 Comprehensive strategies – international regulations of material flows

The outflow of secondary raw materials in economies with low ecological recycling standards is evaluated as important issue concerning the achievement of higher raw material productivity. For instance, the recycling share of copper in Europe has declined from 49% in 2000 to 41% in 2005 (ICSG 2007, p. 22). Copper-containing wastes as cable and electrical scraps became wanted merchandises due to the massive price increases of copper. Since in China and other newly industrialised countries, environmental and social standards are essentially lower than in Europe, recycling companies from these countries realise much higher profit margins and can pay much higher world market prices for scraps. At the same time, the Chinese government subsidises the import of scrap materials out of strategic reasons. The export to Europe, however, is cut off by export tariffs. Thereby, secondary raw materials flow unilaterally to China and are withdrawn from an environmentally appropriate recycling in Europe. This gap in material responsibility impacts negatively on resource productivity and resource conservation. The low capacity utilisation of recycling facilities resulting herefrom lowers the readiness to invest and slows down modernisation of the recycling sector. The following comprehensive strategies and measures are evaluated as particularly relevant: [4]

Clear rules for exports throughout the EU

The interface of exports of second-hand goods and waste is a central issue in order to achieve higher raw material productivity and resource conservation. A presently not quantifiable share of all EU second-hand goods exports is incorrectly declared. Obligatory criteria for a clear demarcation between second-hand and waste goods are missing. Generally, stricter physical exit controls in EU ports and external borders are necessary. Illegal scrap car exports and fraudulent declarations of WEEE take centre stage in the enquiry.

The Regulation on shipments of waste effective in all EU Member States prohibits the export of hazardous waste for the recovery in non-OECD countries. Here, the contact point guidance effective from 2007 on concerning the shipment of WEEE shall help to differentiate electrical equipment into second-hand goods and waste (Focal Point Basel Convention 2007). An example hereof is the verification of operability in order to determine whether an old appliance is serviceable and thus exportable or waste electrical equipment. This directive, however, is not mandatory so that different executions by customs authorities are possible and effectively implemented rules are missing (Ökopol/iiiee/RPA 2007).

Also the fuzzy distinction between second-hand cars and scrap cars is problematic. Here, clear criteria are required. A vehicle's roadworthiness could be determined on the basis of criteria like for example the state of tyre equipment and exhaust system, leakages, or similar. Such arrangements have to be made uniformly throughout the EU in order to prevent evasion effects to ports of neighbouring countries (cf. UBA 2007). According to the Wuppertal Institute it has to be examined whether or not separation and export of electronic assemblies from scrap cars should be subject to similar rules as electrical appliances. Furthermore, the whereabouts of 2.5 million passenger cars decommissioned annually is not exhaustively statistically surveyed in Germany. In this case, as well as in the case of electrical scrap, better monitoring and statistical surveying is required.

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[4] Regarding further-reaching measures that include particularly also the primary production, it be referred to the study of the Wuppertal Institute concerning the international dimension of sustainable resource management (Bleischwitz/Bringezu 2007).

WTO agreement regarding secondary raw materials

Copper scrap, in contrast to electrical scrap and scrap cars, is allowed to be exporter to China and other non-OECD countries. A WTO agreement should include the following conditions:

- Definition of international processing, recycling and disposal standards on a high level of environmental protection similar to that in Germany
- Reduction of trade barriers and distortions of competition by import subsidies and export tariffs in order to enable an ecologically sustainable recycling in Europe further on (cf. also German Federal Government 2007, p. 11).
- The European Union should levy short-term export tariffs on copper scraps as a response to low Chinese recycling standards and foreign trade practices.

The following proposals are viewed as further important measures:

- Uniform high standards for recycling facilities in the EU. Within the EU, non hazardous wastes and scraps can be traded freely via the common internal market. Thereby, the German landfill prohibition for shredder light fraction is evaded by exporting (cf. Lower Saxon Ministry for Environment 2007).
- Bilateral co-operation in installation of a modern waste disposal infrastructure and redistribution logistics. Crucial points of such co-operations could be the setup of a modern waste disposal infrastructure, technology transfer, and the development and implementation of environmental standards. These co-operations could be supplemented in medium term by bilateral trade agreements between the EU and China as well as other newly industrialised countries.
- Erection of a global recycling industry. Prerequisites for a global recycling industry are more transparency regarding the actual material flows, worldwide installation of powerful local recycling infrastructures and the setup and observance of global environmental standards for recycling.

Altogether, it can be stated that an increase of raw material productivity by recycling requires an integrated policy approach. In the short run, measures against the outflow of secondary raw materials are required. In the medium term, multilateral trade and environmental regulations can prevent a race to the bottom in environmental standards. The dialogue with the PRC and other newly industrialised countries represents great opportunities. Germany could promote the installation of recycling managements by a transfer of environmental standards and technologies.

4 Steel Sector

4.1 Trends and impediments

The most important trend in the **sector of emphasis steel** at present is the strong and growing world demand for steel, driven by the newly industrialised countries in general and China in particular. This has several consequences:

- The prices for these raw materials have risen continuously over the last few years. This holds for iron ore and coal, but also for iron and steel scrap.
- Because steel is bound in products for longer periods of time, the accumulation of scrap lags markedly behind the increase in production. The share of secondary material is limited due to a lack of availability. A high percentage of the steel produced today will remain in stock for the long term.
- Various legislation have caused an increased tendency of steel to flow abroad, e.g. through the export of scrap car bodies (Karle 2005).

At present only a limited amount of steel scrap is available. This is mostly a problem of growing markets and one that will perhaps alleviate itself in the future. Scrap accumulated at the present (in 2005, German accumulation of steel scrap totalled 21.3 m t, 4.6 m t of which came directly from steel mills (IKB 2007)) depends in both quantity and quality on steel utilised in the past. For steel used in infrastructure and construction this means that the amount of scrap that accrues today is determined by the much less intensive global use of steel 50 to 100 years ago. Thus, even if scraps are used to their fullest, the use of such secondary material in growing markets is necessarily limited. It is for this reason that a retirement of blast furnace capacity in Germany would likely result in a one-to-one replacement of that capacity somewhere else in the world and a corresponding relocation of CO_2 emissions of at least equal size (Lüngen 2004). Taking into account the low productive efficiency and higher CO_2 emissions in steel production outside of Western Europe, an increase in CO_2 emissions seems the more likely scenario.

In the steel sector – more so than in many other sectors – the effects of globalization are palpable. The sustained growth of the sector worldwide is being driven primarily by dynamically growing demand and production in Asia, especially in China (Monhaupt 2006). This goes along with rising demand for iron ores, which could potentially lead to growing use of lower-quality ores, which require higher resource, and energy use (van Berkel 2006; Ritthoff 2006). In Germany, however, such a trend can as yet not be recognised.

A pronounced trend of German steel manufacturing, however, is the orientation towards high quality products. This focus has allowed a highly productive and capable steel industry to survive. In contrast, the automobile industry in the United States, for example, is incapable of meeting all its high-grade steel needs with domestic production alone (Büchner 2006). In addition, after a long process of market concentration and consolidation most German steel manufacturing plants are favourably situated with regard to transportation networks. This is particularly true of the remaining blast furnaces, which are supplied in a cost-effective and resource-saving manner via seagoing vessel or large pusher trains. A good illustration for the capabilities of the German steel industry and the trend towards high quality products is the foreign trade in stainless steel. In this area Europe has a considerable export surplus while North America and Asia are net importers.

German manufacturers can distinguish themselves by offering customised products, which meet high standards as regards accuracy and quality of both material and workmanship.

Such a strategic orientation affords steel companies great sales opportunities, because demand for such products in many important industrial sectors, as well as in energy sector, is rapidly rising in the wake of increasing globalization (Monhaupt 2006; BMU 2006). The use of steel materials such as high-strength steels often allows for a reduction of the amount of material used and therefore also reduces the amounts of material inputs needed. This is further enhanced by new join and forming technologies. This interplay of new steel materials, join and forming technologies allows for considerable savings. An important impetus for the development of these new technologies is the competition of steel with other materials such as aluminium and synthetic materials.

4.2 Potential for Increases in Resource Efficiency and Conservation

The „Lead Markets of the Future““ (BMU 2006) are good guides to the future development of demand and potential for innovation in the steel industry. Given the lead markets „Energy Technologies“, „Sustainable Mobility Technologies“, „Efficiency Technologies“ and „Life Science Technologies“ it becomes clear that the development of technologies, processes and materials that are fit for the future is of great importance. Steel, given its versatility, has the potential for major contributions to technological innovation in all of the identified future markets (BMU 2006). In the course of the modernization of power generation capacity the use of high-temperature steels can increase the efficiency of power plants. The search for resource conserving and climate friendly solutions for mobility is ongoing. Many of the present and future efficiency technologies are not only suitable for use in Germany but also have great export potential and can make great contributions to resource conservation. Two different markets should be distinguished:

- Markets in industrialised countries: Infrastructures are already present to a large extent and only need to be maintained, modified and renovated. Demographic transition will cause problems. In this area, there are several long-term commitments, be it because of high expenses on infrastructure, the mutual dependence of plants and infrastructure or long-term supplier relationships. Germany can be considered one such country. The question is how the restructuring, maintenance and connection to the demand systems can be performed in a cost effective and resource efficient manner.
- Markets in newly industrialised and developing countries: Infrastructure is still very much under construction and demand is rising rapidly. Many have to make do without adequate infrastructure, have no access to clean water, sewage disposal and many other amenities. Cost effective and resource efficient systemic solutions to these problems are of utmost importance.

In both markets, there is potential for increased resource productivity – especially through to the application of novel technologies, and improvements in the areas of energy supply and transport, water, sewage and waste disposal. Detailed analyses and the development of alternative concepts and systemic solutions that span the entire value creation chain will be necessary to realise these potentials.

For most products and services the resource intensities vary over the life cycle of the product. Here, too little consideration is often taken of the extraction of raw materials. In production the aim is often to reduce the use of materials in the production process (e.g. new materials, zero loss management) or in the product itself (e.g. material efficient product design, increasing the expected useful life). Product design also plays a significant role in the use of the product as it determines the necessary resource use throughout the phase utilisation. If the greater share of resource use is during the consumption phase of the product the integration of the user into the design process is absolutely central as it allows for the development of products and services whose entire life cycle is tailored to the needs and wants of the user. High resource intensity in disposal, i.e. in the last phase of the product life cycle, make approaches like cascade use and urban mining the most suitable candidates for increasing resource productivity. Additional approaches can be found in the processing of materials. Several materials are, for instance, being developed which have to conform to specific requirements (e.g. special finishes for material surfaces).

If one wants to increase resource productivity more drastically than has hitherto been the case, one needs to go beyond firm-level and sectoral solutions and develop systemic solutions. Such systemic solutions allow for technological and organisational-institutional leaps in development. Thus, not only are gradual improvements in technology production processes and the product itself possible, but also substantial increases in resource productivity ('radical innovation', 'disruptive technologies'), which are often accompanied by lucrative economic potentials (including export possibilities).

On this basis we will attempt to define two fields of action that have considerable potential for increasing resource efficiency. Both fields are capable of improving the international competitiveness of steel production and application. Their implementation could probably be aided by appropriate policy measures.

4.3 Possible Measures in the field of action "High Strength and Ultrahigh-strength steels, Join and Forming Technologies, Resource Efficiency in Steel Production"

An essential strategy for weight reduction and the associated savings in input quantities is the development and use of higher quality steels and optimised processing. In the long term, this may lead to a lower growth of quantities produced. An additional possibility is the increased use of secondary materials (Moll 2005).

Many steel grades are the result of a sustained trend towards higher strength steels. They have become commonplace for specific applications and have helped to cut down on the input quantities needed there (Still 2007). But the **use of high and ultrahigh-strength steels** allows not only for such reductions in inputs (and thus the reduction of iron ore based steel production). In the medium run this would raise the share of secondary steel. Here, questions of efficient steel production and the development of new steel grades interact with each other. In many cases the performance characteristics of buildings and facilities can be improved (carrying capacity of bridges and steel girder constructions e.g. for robot arms) or the energy use of mobile steel products (automobiles, moveable machinery) can be reduced because of their lower weight.

In the area of structural steelwork, the use of higher-strength microalloy steel grades, whose main features are their greatly enhanced breaking and tensile strengths, has enabled a significant reduction in quantities used. During the construction of the Øresund Bridge, for example, the use of 82,000 t of microalloy steel reduced the necessary amount of steel by 15,000 t (Bleck 2007), a reduction of about 15% compared to the amounts usually required for such constructions. This is also roughly the savings in resources input, because the energy required to produce these steels is not greatly higher than for more traditional steel grades. Because they are microalloys, only minute amounts of alloying additions are required. In this respect, too, there is no significantly higher resource use.

At this point a differentiation must be made between the technologically enhanced steel grades described above and those steels, which are enhanced by the addition of alloying elements. These are characterised by a 20-25% higher price and a markedly higher share of other metals such as manganese, chromium and nickel in the alloy. The abovementioned does not apply to these grades. The resource use of these is substantially more intensive and a large-scale deployment of such grades is therefore not advisable. Typical high quality steel is about two to three times more resource intensive than unalloyed steel from blast furnaces and about five to ten times more resource intensive than steel produced in electric arc furnaces. The precise factor depends on the indicator chosen, whether TMR, water, cumulative energy use or global warming potential.

The economic factor (alloying elements are relatively expensive, expressing a fundamental relationship between resource use and market prices) limits the use of such steels to a minimum (e.g. classical high quality steels for use in the food industry or in chemical engineering). High strength, fine-grained steels whose microstructure has been specially enhanced can be developed as low-alloy steel just like normal strength steel grades can (this is the case at an alloy component of less than five percent). The alloy component is broadly similar to those of normal steels, perhaps even lower because the alloy elements can be embedded more specifically into the microstructure. It can therefore be safely assumed that the micro alloying of steel will lead to a reduction of the amount of alloy elements necessary and be advantageous in terms of resource efficiency. Because the smelting of the average alloy element is from four to twenty times as resource intensive as the production of raw steel, such a reduction of such alloy elements is useful in most cases. Thermo-mechanically shaped steels are easy to weld due to their low carbon content. In many cases preheating the weld joint is unnecessary (Hanus 2000). By making use of high-strength steels the size of the welding seam’s cross section can also be reduced thus further reducing costs and energy use (Schröter/Martin 2007).

If efforts towards resource conservation are to be intensified, it may be worth looking into whether the lessons learned and experience gained with respect to savings in materials and resources during the construction of large bridges can be transferred to other areas. Considering that drastic improvements in efficiency were possible even with engineering works that have to withstand even severe stress it should be very much possible indeed to make such transfers. Special attention must, of course, be paid to the specific static and dynamic stresses which can vary widely between different applications (e.g with respect to bending tensile strength, torsional strength, streakiness, carrying strength and serviceability).

It also becomes clear that using high-strength steel grades alone is not enough. Instead, several aspects like tensile strength, fatigue strength and workability must be optimised together. The endurance limit of steel, for example, rises with the tensile strength. The endurance limit of welds, however, does not. Of the endurance limit of a component as a whole is to be increased, special attention must therefore be paid to the optimization of the joins (e.g. through appropriate reworking or further treatment (Nitschke-Pagel 2007). Up to now, the lack of fatigue strength of welded joins was the main reason for the slow adoption of higher strength steel in applications in which fatigue is an issue. Reworking welds does as yet not belong to the standard repertoire of procedures in the construction industry because the existing norms do not allow the resulting advantages to be recognised when calculating the necessary girder strength (Kuhlmann et al. 2007). It is therefore necessary to look into not only new materials and techniques but also at their practical applications so as to develop guidelines that can be used later on to develop norms and standards.

In a number of cases the replacement of building materials with steel offers further relevant resource savings. In the case of power pylons, for example, steel has proved to require vastly fewer resources than steel-reinforced concrete. In an analysis of pylons for 110kV power lines, steel lattice masts were found to use 60 percent fewer abiotic resources

(Merten/Liedtke/Schmidt-Bleek 1995). Using high-strength steels would likely further increase this advantage. Most of the pylons these days are steel lattice structures, but – like in many other countries – a trend towards using leaner steel and steel-reinforced concrete pylons can be observed. These pylons have a smaller footprint and therefore use less land area. In Austria, e.g., these pylons are therefore more common than in Germany.

New and improved **shaping and join techniques** are a requirement for structures that carefully balance out the distribution of forces, a further important necessary factor for the optimal use of steel. On the one hand, optimised shaping and join techniques allow for significant weight reductions through constructions that are both cheaper and better suited for the distribution of forces. On the other hand, the expense of producing components can be reduced (e.g. when an energy and material intensive process can be reduced, minimised or replaced altogether). For any given technology, the application of the most appropriate production technique can therefore contribute to sizeable material savings.

In general, some production techniques are prone to high resource and energy use. Separating machining tasks such as turning, drilling or surface processing through grinding and sanding are notoriously energy intensive. In addition these tasks always involve the loss of some of the material. Their resource use is therefore doubly high. Mechanical deformation tasks (e.g. forging, bulging and bending), in contrast, are much cheaper. These tasks, too, require a considerable amount of energy but often much less than laborious sanding and grinding. At the same time, mechanical deformations seldom result in great loss of material.

Similar things hold for joining methods. These methods often compete with the separating methods described above. By joining multiple, smaller parts instead of manufacturing the part from a larger precursor energy and resource use can potentially be greatly reduced. It should be noted, however, that the energy and resource efficiency of various joining techniques varies widely, both between different groups of welding techniques and within such groups.

The advantages and disadvantages of these several welding techniques can be found in any user manual in structural steelwork. The focus of these manuals, however, is never the conservation of resources but on energy saving and even more importantly on work intensity. A competitive advantage in the market place is most often created by a reduction of labour hours required which is supported by certain welding techniques. There is therefore a need for changing the user manuals so as to put more of an emphasis on resource efficiency. ThyssenKrupp, for example, has developed a flange-less joining technique, which uses considerably less material. When selecting a joining technique due consideration should be given to the energy and resources used. To achieve this, the appropriate information and data needs to be made available to practitioners and perhaps illustrated with exemplary resource efficiency profiles.

Resource Efficiency in Steel Production

Because value creation is higher in high quality grades of steel (e.g. for high-strength, high-temperature resistant or deep-drawable grades) and these grades represent an emphasis in German steel production, these areas are of relevance for the development of resource consumption of steel industry and steel applications. In the long run, it is possible that other concepts of steel recycling have to be taken due to an increased use of high-quality steel grades possibly in combination with a decreased amount of input of steel.

The biggest amount of high-value steel products is produced hitherto by means of blast furnaces and converters. If a decelerated growth of steel quantities led to a lower demand for primary steel, ways to use electric arc furnaces also for the production of products of flat steel would have to be found more urgently. Here, it is of particular importance that such steel grades usually exhibit particularly high requirements regarding purity and thus, up to now, can not be produced by means of electric arc furnaces. An augmentation of secondary material's share in steel production would thus promise a considerable increase of resource efficiency. Therefore, the possibility is rather limited to substitute steel from electric arc furnaces for such produced in blast furnaces (Still 2005). It is important to distinguish here also between new scraps, which are sorted very well and exhibit low impurities, i.e. such from further processing of steel as for instance in automotive industry, and old scraps, which exhibit partly significant impurities and alloying additions.

Developments as the ‘Compact Strip Production’ (CSP) can be of interest in this context. In the CSP process, liquid steel is cast to a thin slab and subsequently fed to the hot strip mill. Thereby, a high-value hot-rolled strip (plate) can be produced up to a thinness of less than one millimetre. The advantage of the CSP process is that these plates can be produced by soaking with a uniform temperature, that is and without interstand cooling or cold rolling mill. By this kind of manufacturing of steel strip, a reduction of energy consumption by about 70% is possible in comparison to hitherto techniques (sms-demag 2007). This can save energy considerably. Additionally has to be mentioned that the production of special steel is carried out also in electric arc furnaces with high shares of special steel scrap. In all processes of steel recycling, considerable losses of alloying elements occur due to oxidation, which is notedly unfavourable both, from an economic perspective and regarding resource consumption, especially because the production of the most alloying elements consumes significantly higher amounts of resources than steel production. Simultaneously, however, this effect countervails the accumulation of unwanted alloying elements in the steel cycle. In the long run, the actual negative aspect of material loss secures thus the recyclability of steel.

In spite of the manifoldness of steel, many applications exist in which a combination of materials together with an optimal utilisation of their respective properties (amongst other tensile strength, elastic modulus, weight, operational stability, thermal expansion, temperature resistance, and heat conductivity) enable a far-reaching optimisation. Such a combination of materials requires, however, a very high degree of know-how concerning materials science. Considering that an appropriate material selection – inclusively the associated possibilities of processing and designing – is a crucial aspect of environmentally compatible product design, too less attention is paid to this fact up to now in education and training. Material combinations usually are associated with join techniques: e.g. ferroconcrete, galvanising, or sandwich components. This complicates, amongst other, the recycling of the single materials which impacts, in turn, negatively on resource productivity. On the other hand, the joining of two or more materials elongates a product's useful life (e.g. galvanised steel plate) and/or enables it in the first place (e.g. insulated cables).

Known examples of material combinations are compound materials (e.g. ferroconcrete), which combine different properties and thus enable new enhanced property profiles in comparison to the input materials: Ferroconcrete is more efficient if compression or tensile load exists. Neither higher-value steels can absorb compression loads better since the material steel is characterised anyway by outstanding tensile but not compression strength. In this case buildings of ferroconcrete can be more efficient in which the steel absorbs the tension and the concrete absorbs the compression. Also to steel materials applies that some application areas can be developed. Besides compound materials, also other combinations of materials can tap resource savings potentials. Here, quite different material combinations come into question. On the one hand, compositions of different steel materials or metallic materials like various steel grades for automotive plates, high-temperature resistant steels, and nickel-base alloys for power station construction or steel and synthetic material for lightweight steel sections as e.g. flange beams.

Also the use of steel in combination with materials other than composite sections and systems in construction could be promising. Here, already the use of normal-strength steels promises potential for a resource conserving utilisation of steel. The use of high-strength steels usually is neither required nor competitive due to the rather limited forces. An extended use of common steel grades could tap already considerable potentials by a skilful combination of various materials (and material properties). A modelling of supporting formwork by means of the Finite Elements Method, for instance, helps in form optimisation in which material potentials can be exactly determined and tapped.

In all cases, the point is to select the most favourable material combinations with respect to resource savings, recyclability, costs, functionality, etc that entail the most advantageous product properties together with the lowest life-cycle-wide resource consumption.

Need for action

Research and development (R&D) in material and application technology are central foundations for an optimised application of materials regarding resource efficiency. In order to secure these foundations further on, particularly the Lisbon Objectives should be implemented, that is an augmentation of R&D funding from presently approx. 2.5% to 3% of GDP (BMBF 2007). On European level, the following fields of research are important in order to make steel industry a leading branch regarding competitiveness and sustainability: secure, clean, cost-efficient and capital extensive technologies (energy efficiency, flexible and multi-functional process chains, intelligent production), steel applications for end consumer (automotive, construction and infrastructure, energy sector), attractiveness of the branch for qualified labour, the safeguarding of next generations and of qualifications, the rational utilisation of energy and resources, and the by-product management (cf. ESTEP 2005).

Up to now, environmental research and technology development still are conducted separately in many cases or the connection remains rather vague, although frequently an obligatory consideration is effected concerning environmental or sustainability aspects in technology projects. Thus it seems necessary to foster more intensively interdisciplinary research in order to achieve a link-up of material technologies and sustainability aspects.

Since the availability of a series of important alloying elements for high-value steel grades, especially nickel, is far more limited than that of iron raw materials whilst additionally their extraction requires an particularly high resource expense, the development of new alloys that make do without or with least possible amounts of such potentially more resource intensive alloying elements is an important measure in order to facilitate a enduringly resource efficient use of steel. The developments inserting alloying elements on microstructure level into steel structure head for this. By means of changes in the steel joining, it is tried to change properties that to achieve has been possible up to now only by commingling different metals (iron and alloying elements). Since the extraction of unexceptionally all alloying elements is more resource consuming than the extraction of iron, a reduction of the first usually contributes to resource conservation. Therefore, however, also the utilisation and recycling phase have to be included in the life-cycle-wide analysis. The classic stainless steel, for instance, indeed is resource intensive, but it prevents corrosion and is outstandingly suitable for recycling. A comparison of galvanised steel and stainless steel would lead to different favourites for different products. From an economic perspective, this outcome can be observed usually also occurring via price mechanism. The development of new steel grades will be particularly important, as well, if the share of electric arc furnace production in total production increases significantly and perhaps flat products that hitherto could be produced exclusively via blast furnaces have to be manufactured by means of this processing method.

The enduring and secure access to natural resources as to secondary materials is of crucial importance to steel industry and the resource efficient and environmentally sound steel production. Crude steel can be produced from iron ore and carbon; high-value steel grades require, however, specific input materials of high quality and specific machinery that enable only little tolerance in equipment. Simplifying, it can be stated: the fineness of input materials determines technique and fineness of products – and resource productivity. Only if high-value raw materials can be used, production processes reach high efficiency. Due to barriers to free trade, however, interventions distorting competition do not cease to occur, e.g. in form of tariffs. The purpose of policy in this case is to reduce barriers to trade. Examples for such barriers are the Russian export tariffs of 15% for steel scrap (von Wartenberg 2005) as well as the American punitive tariffs for steel imports (Kormann 2002) that have been introduced temporarily in 2002 and were primarily a protective measure in favour of the US steel industry that was neither economically nor ecologically competitive anymore (In 2006, the use of reducers per t of raw iron in steel industry in the NAFTA area lied approx. 5% above consumption in Germany (Ameling 2007)).

A big potential to increase resource efficiency of steel lies in the optimisation of its utilisation. Important aspects are the minimisation of weight as well as reparability and recyclability. These potentials for improvements are far less determined in comparison with the potentials in production (Still 2005). This is primarily due to the fact that these are not exactly definable procedural potentials. Such “soft” factors frequently are blanked out.

Anyhow, e.g. a repair-friendly or modular design of products (e.g. of cars: dumpers of steel that can be ‘reshaped’, simply replaced and recycled, or further used with scratches – instead of varnished plastic panels) can certainly contribute to an at least roughly assessable improvement of resource efficiency. But, as can be observed very well at this example, so many different factors have to be considered (e.g. design or customer demands) that projections are more than difficult.

The face of affairs is quite another if relocating the innovations or changes to the ‘invisible’ sector. If material or product changes are not visible or otherwise perceptible to the designer or the client, optimisations can be implemented more easily: e.g. Tailored Blanks in the interior of a passenger car’s door (customised composed sheet metal blanks of various sheet thicknesses and from different materials). The potential recyclability in recycling can be increased – e.g. by resolvable composites or purity – whereas it is unequally more difficult to influence the actual recycling flows. The intensified search for systemic solutions and life-cycle-wide optimisation should therefore increasingly be moved to centre stage. The influence of product design (on basis of the service to be rendered as e.g. clean laundry or transport of A to B) – including the economic life-time and recyclability as well as the use of products – frequently offers much bigger potentials for reduction of resource consumption than a material production that is already optimised to a large extent.

4.4 Options for Measures in the Field of Action 'Penetration Strategies of Resource Efficient Technologies'

Considerable potentials for resource efficiency are to be expected in fields of application where up to now in many cases simple steel qualities are used, thus for instance in construction, shipbuilding, as well as partly in machine and plant construction. On the other hand, however, they can be expected as well there, where a particular vicinity of already existing techniques to new applications is observable. The sectors machine building, construction, steel construction and shipbuilding together have a share of 25% in the domestic steel utilisation. The possible savings potential thus is considerable in absolute quantities, as well.

In transferring new techniques and materials to broad application, especially in SMEs arise significant difficulties. Causes are seen in the partly relatively uncontrolled circumstances of production, like on construction sites. An exploitation of the possible strength is inhibited by the fact that processing defects can not be excluded as well as by the partly limited knowledge of materials and processing techniques which both lead to the imperative to provide for higher tolerances to increase security. The practice in construction, for instance, shows that usually is calculated 'to play it safe' and thus with higher material requirements. The simple reason for this lies in the above mentioned labour costs that are additionally required by more precise techniques. The possible efficiency potentials by use of high-strength steel grades therefore possibly can be tapped only incompletely. This underlines once more the necessity to develop application guidelines as, e.g., the guidelines of the DASt (German Committee for Steel Construction) that enable the exploitation of these efficiency potentials for instance by a loading-oriented dimensioning of structural members and the avoidance of weak spots.

The automotive industry frequently leads the way with regard to the application of new processing techniques – not regarding the development of particularly environmentally compatible and resource conserving products. The technical prerequisites of other applications differ, however, partly significantly from those of cars, so that not every material or joining-technical novelty can be transferred. In machine construction, e.g., frequently – though not always – the stiffness and not the strength of a component is decisive. In such cases is the use of high-strength steels possibly not profitable since the elastic modulus of high-strength steels is not higher than that of normal steels. Insofar, the potentials especially in machine tool building depend to a high degree on the single application. The use of high-strength steel grades can pay off especially in those cases in which great forces have to be transmitted. That applies, e.g., to car bodies to which it can mean an improved protection against accidents or to bridges and to the heavy industry or power plant construction. Here, particularly contracting authorities can accelerate the development by considering in awarding contracts criteria as durability, lifespan costs, minimisation of maintenance costs, or resource savings. Possibilities to such holistic considerations exist also according to today's directives (Kuhlmann et al. 2007). Furthermore, branches have to research for new materials and join technologies independently from the dynamo automotive industry. The branch of renewable energies can take the pioneering task of generating new potentials of offshore or wind power plants in general.

Lightweight constructions are more susceptible to corrosion damages due to their little thickness. Besides has to be considered as well that repairs at lightweight constructions are significantly harder to conduct since, on the one hand, it is necessary not to influence the distribution of forces and, on the other hand, the deployed steel grades can suffer significant losses of strength for instance after thermal influences. Both can lead to damages or even destruction of the component. Lightweight construction, therefore, makes it necessary to develop new strategies for the use and repair of goods.

An accelerated diffusion and dissemination of modern techniques of steel utilisation thus also makes it necessary to consider qualification of applicants. This can concern both, the academic and the further education, and can include export markets, as well. Here, the university and also the dual education are in demand.

The dissemination of technologies can be accelerated notedly if the application of these technologies is specifically promoted at decisive points as for example in pilot projects or in state investment decisions. This can happen for instance at the renovation of buildings and infrastructure as well as by the creation of mandatory criteria for the facilitation of foreign investment. To this day, many investment decisions are made exclusively regarding short-term economic optimisation. Long-term thinking and the additional consideration of ecological criteria could conduce to changed decisions and the dissemination of new technologies.

Standardisation, standards and technical precepts are further aspects that have to be considered if modern techniques and materials shall be used. Therefore, the use of high-strength steels is limited in construction also due to lacking possibilities to incorporate their higher strength. Thus in Eurocode 3 (DIN EN 1993-1-1; DIN EN 1993-1-12), only steels with a yield stress up to 700 N/mm² are included although steels are available with an elastic limit up to 1100 N/mm² and recent research findings indicate that the determination rules from Eurocode 3 are applicable to strengths beyond 700 N/mm² as well (Völling et al. 2006).

The strong penetration of the automotive sector with modern steel applications makes evident a general problem: Many modern techniques do pay off only at high numbers of units. Therefore, an important task has to be to rend profitable the applicability of these techniques also at smaller piece numbers.

The evolution of automotive industry to a lead industry for the efficient and innovative deployment of steel has been advanced massively by the competition with aluminium. In many other areas of application like machine building, no similar situation exists. Innovations for more resource efficiency, thus, have to be generated more extensively by a targeted promotion.

The developments of the last years show as well that the passenger car body becomes ever more a conglomerate of various materials. Steel has to face here as well the competition from synthetic materials and magnesium. This, in turn, will confront the disposal and recycling of passenger cars with new challenges.

On basis of the developments of the last years it can be assumed that these reductions in weight due to lightweight construction will continue successively in all passenger car segments – amongst other also due to the still rising weights resulting from new safety and comfort features.

5 Dialogue Process and Evaluation

The overall project combined a **dialogue and a communication process** that included all those involved, beginning from the contracting authority up to the workshop participant. Herefrom, some transfer products emerged like an internet platform (www.ressourcenproduktivitaet.de) as well as background papers and papers presenting measures concerning the three sectors of emphasis, presentations, and three emphasis-specific brochures. The organisation of a dialogue process has been designed conceptually within this R&D project as a cross-sectional task that stretches out over the entire project duration. After the first stage of analysis that had led to a definition of three sectors of emphasis, a screening of the range of stakeholders that were relevant to the respective sector was conducted. A personal contact was carried out with important decision-makers in order to win them over to participate in the dialogue process. At the same time, already existing dialogue and learning processes were considered in order to avoid the development of redundant structures. The general networking (e.g. contact databases, exchange with key stakeholders) assists the communication and dialogue between all those involved as well as it enables the constructive consolidation of various viewpoints and the transfer of these into innovative ideas, i.e. proposals for measures.

During the project duration, the public presence led to a considerable increase in the circle of parties interested in the contents of the project. The contact database includes about 400 interested persons. Altogether, the stakeholder and interest groups split as follows during the workshops and activities: Representatives from business and industry were the overall largest group of participants (59%) followed by business and research (20%) and politics (15%). A rather small circle was represented by environmental and conservation organisations with 5%. Altogether, all three events have been attended by about 200 persons, 10% of whom visited all three events and participated actively in the dialogue process.

In all sectors of emphasis, an integration of different fields of knowledge has been achieved. At the same time, the complexity of the objective ‘resource productivity and resource conservation’ could be reduced by strict orientation on measures and focusing on single areas of measures. Abstract political specifications have been contextualised technically and further concretised. A connection between various levels and types of knowledge (theory-practice-relation) could be established by the inclusion of experts from different sectors. The project had therefore contributed to the improved transformation of knowledge between sciences, politics and practice in different fields of application.

The possibilities to organise concrete transfer achievements within the scope of this project in the sectors media relations, consultancy, and education was limited (e.g. co-operation with educational establishments and consultancy centres). Cross-project networking is of special importance in order to achieve a higher continuity and also initiate subsequent activities in these issues. Self-supporting structures need a medium-term framework that reaches considerably beyond the common project durations of about two years.

A feedback from the dialogue experiences from this project to other projects and the design of research programmes and tendering procedures is desirable. Such a process could be initiated by the contracting entity subsequently to the experiences from the present dialogue process in which a content-oriented platform has been established where dialogue-oriented projects can exchange their experiences with concrete areas of activity.

6 Resource policy – instruments and international connectivity

6.1 Resource efficiency and policy mix

The project's areas of objective "raw material productivity" and "resource conservation" can be assigned to different fields of policy: Resource conservation is a classic objective of environmental policy whereas raw material productivity as objective is located in economic and/or resource policy. By the concept of an ecological industry policy and – as well – a sustainability policy, it is bridged between both sectors. The necessity to coordinate objectives and instruments in both fields of policy is associated thereto inevitably. By the initiated dialogue processes, yet another perspective on instruments and measures became apparent. Starting from concrete problems, proposals for measures were developed that should lead to results within a manageable time span and context. Thereby, strategic aspects and issues of policy competencies initially have taken a back seat. The important issues here were the advances in cognitions and processes in a manageable time span as well as the achievement of sets of measures on which consensus could be reached. Against this background, the question arises whether the results of the dialogue process can be tied in with existing instruments and policies. In order to respond to this question, the selected measures have been assigned to different types of instruments in a first step. From this, altogether, a kind of policy mix from economical and fiscal, administrative regulatory, institutional, and information instruments emerged.

Considered altogether, the proposed measures can be connected up to the general concept of an 'ecological industry policy' to a high degree. However, it can be observed that the strategic element gets a raw deal. From the single measures does not yet become clear whether they represent strategic core areas, the application and dissemination of which in terms of a lead market strategy would pay off. It became clear in all areas that an 'intelligent ecological industrial regulatory framework' is indispensable. It can promote the processes of searching, discovering, and developing of an economy (Bardt 2006), improve the climate for innovations, balance interests of lobbies, and advance processes of competition to increase resource productivity. In the following, the most important instruments of all three sectors of emphasis are presented in a synoptical table (cf. table 3).

Although price signals of commodity markets presently support resource efficiency policy, important areas of resource policy remain still in need of regulation. This applies especially to material flows in secondary raw materials industry and to technology standards to treat these material flows. Finally, the high-quality as well as single-sort recycling of steel and copper can be used for an international commercialisation of the respective techniques and thus lead to an export of the new recycling technologies. Maybe, yet additional incentives for an accelerated market launch of innovative technologies as well as innovative organisational solutions could be created in this field.

Table 3: Instruments of an ecological industrial regulatory framework

Construction & habitation	Copper	Steel
Fiscal and economic instruments		
• Development of programmes to introduce innovative and resource conserving building materials and structural elements/building components on the market • Expansion and further development of KfW funding programmes for energetic renovation	• none	• none
Administrative regulatory instruments		
• Law of tenancy and tax law reform (resolve user-investor-dilemma) • Reform of tax law: allow for more shortly write-offs as well more than 3 years after acquisition of a building	• WTO level: Reduction of trade barriers and distortions of competition in trade with secondary raw materials	• Simplification of rules and standards for the application of steel • Adjustment of the list of types of scrap
Information instruments		
• Development of an ecological rent index • Marketing and information campaign regarding the construction in existing building/Elaboration and dissemination of an integrated offer of information for various target groups	• ICT: Consumer campaign: Small appliances as resource of recoverables for sustainable use • Improved monitoring of material flows considering the problems in the second-hand car market	• Improved survey of material flows. Modelling of stocks scrap accumulation.
Innovation instruments		
• Material research/ development of new ecological building materials • Further development of the energy certificate for buildings to a resource certificate • Supply of targeted further education concerning construction and habitation in existing buildings for various target groups (e.g. architects, workmen/tradesmen, etc.) • Creation of networks regarding resource efficient construction	• Vehicle manufacturing: Material reductions and miniaturisations via new conductor and contact technologies • ICT: Simplification of return of small ICT products	• Lightweight construction: Deployment of high-strength steels and new join and shaping techniques • Qualification of stakeholders especially SMEs. • Networking to interlink knowledge.

Source: Wuppertal Institute

Lead markets and resource efficiency

Measures like the creation of a favourable legal and regulatory framework, the definition of standards, a facilitation of access to venture capital, and the support of application-oriented research could contribute to the creation of lead markets (Aho et al. 2006). "The capability to be present in these lead markets with innovative technologies determines decisively the international competitiveness of a country. Lead markets are markets of the future that are not determined exclusively economically but include sociopolitical leading ideas." (BMU/Roland Berger Strategy Consultants 2007, p. 8) The (economic) factors of a lead market can lead to price or cost, demand, export, or transfer advantages.

A suchlike strategy also is consistent with the objectives according to communication concerning a Lead Market Initiative for Europe (KOM 2007, p. 860) that mentions explicitly the areas sustainable construction and recovery as promising fields of strategy. In the Atlas of Environmental Technology for Germany (Umwelttechnologieatlas, BMU/Roland Berger Strategy Consultants 2007), six lead markets for environmental technologies are identified to which an essential significance for a future-capable development:

- Raw material and material efficiency
- Environmentally friendly energy generation and storage
- Energy efficiency
- Recycling management
- Sustainable mobility
- Sustainable water management

For the lead market raw material and material efficiency (ADL/ISI/WI 2005; Kristof et al. 2007) outstanding growth chances are predicted. In 2005, the six lead markets in Germany had a world market volume of about 1,000 bn Euros. Till 2020, the turnover of environmental industries is going to exceed doubling and escalate to 2,200 bn Euros according to the Atlas of Environmental Technologies. Presently, Germany represents – depending on the market segment – a share between 5% and 30% of global markets. By material and process innovations as well as a efficiency-oriented product planning from design phase (waste prevention, recyclability, disposal requirements and logistics, usage of raw materials produced in a sustainable manner) up to the product's disposal, already 80% of all product-related environmental burdens can be influenced according to an enquiry of the European Commission. In combination with politically induced incentives for a sustainable resource consumption, up to 11 bn Euros could be saved only in the manufacturing business according to ADL/ISI/WI (2005).

For the further development of recycling technologies, distortions of competition are important barriers to investments, e.g. the state-aided scrap acquisitions in the German market by companies from newly industrialised countries. Also illegal exports, enforcement deficits, and different environmental standards are problems that result in an increased outflow of secondary materials from Germany and Europe. Insofar, the challenges are to achieve mandatory regulations regarding an efficient recovery of specific material flows (e.g. WEEE, scrap cars) within the scope of international agreements.

6.2 International connectivity

Raw material productivity and resource conservation have an international dimension: This is revealed by the raw material mining, which happens predominantly abroad, and parts of their processing as well as the export of products and secondary raw materials. In spite of raw material poverty and simultaneous export orientation, economic chances can emerge. Technologies for the enhancement of resource efficiency and renewable raw materials, for instance, offer interesting future markets.

By its ambitious strategy for an enhancement of raw material productivity and resource conservation, Germany can tie in well with the current EU policy. In its resource strategy of 2005, the EU argues for a considerable increase of resource productivity (3% per year). Likewise, new EU initiatives concerning energy security, climate and energy policy (cf. EC 2008), and lead markets for eco-innovations, sustainable construction and recycling (cf. EC 2007) can be connected to a high degree. Furthermore, the programme for action for sustainable consumption and production as well as a communication regarding sustainable industry policy are announced.

Marketing campaigns by the recycling management and automotive industry as well as in construction and habitation can be accompanied by the European industry associations. At the same time, initiative can be taken for a corresponding campaign on EU level. Generally, it is purposive to accompany campaign in Member States on EU level. Measures for a unification of recycling standards on a high level and for the creation of lead markets for recycling correspond to efforts of the European Commission.

The framework for these activities is set by the EU strategies of Lisbon (increase of competitiveness) and Gothenburg (improvement of sustainability) that both aim on a decoupling of economic performances and resource use. In the broader sense, Article 2 of the Treaty establishing the European Community (TEC), which stipulates the objective of sustainable growth, Article 6 TEC, which includes the objective to integrate environmental protection in all fields of policy, Article 95 TEC, which stipulates a higher level of protection, and Article 174 TEC, which comprises general principles of environmental protection are relevant.

Altogether, connectivity, as well as, however, a partly substantial need for coordination within the EU derived from relevant regulations concerning the European internal market, results regarding a multitude of strategies, instruments, and measures, (cf. Pelkmans 2006).

The European integration of resource-political strategies, instruments, and measures will be highly important. Beyond the EU, the necessity of an internationally oriented strategy arises. Given all the advantages of material efficiency, it still remains to consider: If companies or governments externalise internationally ruthlessly costs by means of overexploitation and shift them thus to the general public, politics have to have the possibilities to charge consequential costs to the originator. The WTO rules, therefore, should be examined and adjusted in the medium run. An internationalisation of product and material responsibility as well as an international closing of hitherto open cycles, primarily regarding consumer goods, would be important steps for the mitigation of potential trade conflicts.

6.3 Improved resource productivity in global value creation chains

In the remainder, the in this project disclosed international debate on measures and instruments that deal with the possibilities of an enhancement of resource productivity in global value creation chains within the public and private sector are presented briefly on the basis of a paper elaborated within the scope of this project (cf. Herrndorf/Kuhndt/Tessema 2007). The paper provides some insights into international perspectives and presents practical examples. Thereby it draws on results of material flow analyses that show insistently how material flows increasingly cross national borders (Moll/Bringezu/Schütz 2005).

The document is based on the results achieved by the dialogue project and advances them. Following the issue, this is done by revealing possibilities of an international perspective that subsequently are explained by means of practical examples from the public and the private sector.

The paper likewise supports most recent international activities in this subject area including the Marrakesh Process and the International Forum for Sustainable Resource Management. Resource productivity is a new field of issue on the international agenda. In this context, the document provides an initial exploration and represents a first starting point for future enquiries and discussions.

Resource productivity within the global value creation chain implicates (within the scope of the paper on hand) the following issues:

- Prerequisites for and impacts on resource productivity in resource-rich and exporting countries;
- Resource productivity in manufacturing process of products and services;
- Resource productivity during consumption phase within other countries;
- Products exporter by German companies for recycling or final processing.

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