Eco-Efficiency in Industry and Science 30

Michael Angrick
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Factor X

Re-source—Designing the Recycling Society

Factor X

ECO-EFFICIENCY IN INDUSTRY AND SCIENCE

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Preface

The conservation of natural resources is, alongside climate change mitigation, the key environmental and economic challenge of this century.

For that reason, the idea was born to launch series of books devoted to the many and varied aspects of resource protection. As President of the German Federal Environment Agency, I am proud of the fact that so many important authors have followed the publishers' call and set out their view of resource protection. For this I am particularly grateful, and I take the contributions as well as an expression of appreciation for the agency and its staff.

Why is the protection of natural resources a key issue of current environmental protection policy?

Resource use has become more efficient in Germany in recent years. In 2008 we required 580 tonnes of raw materials per million GDP, compared to 680 tonnes in the year 2000. In recent years we approached the goal of doubling raw material productivity by 2020, compared to 1994, but unless additional measures are taken, this goal set by the German Federal Government in 2002 in its national sustainability strategy will not be achieved. It is not enough to look solely at the trend in productivity to evaluate the sustainability of resource use. We also need to consider the absolute consumption of raw materials. As a long-term target, a reduction of consumption by a factor of about 10 should be achieved by 2050. Conserving resources is a global task. It is not ecologically worthwhile to increase the raw material productivity in Germany if this is attributable merely to the fact that we are increasingly importing resource-intensive upstream products. Therefore, it is important to develop indicators which also provide us with information on the 'backpacks of raw materials' that are hidden in these imports. The German Federal Statistical Office has analysed these data in a research project for the Federal Environment Agency. The analyses of the Federal Statistical Office show that when these backpacks are factored in, the productivity gains are significantly smaller than previously thought.

Economical use of raw materials not only reduces pressures on the environment but also opens up economic opportunities for individual companies and the economy as a whole, as shown by a modelling study carried out on behalf of the Federal Environment Agency.

From the perspective of environmental protection, efforts must focus on reducing the environmental impact of raw materials extraction and use. To achieve this, raw material consumption must be further reduced in the long term. The short- to medium-term goals must be to harness savings potentials and increase efficiency.

To do this, policy initiatives must provide incentives and set the appropriate framework.

The Federal Environment Agency takes 'natural resources' to mean renewable (biotic) and nonrenewable (abiotic) raw materials, physical space (land) and the environmental media water, soil and air. A close definition was chosen for the raw materials indicator of the German sustainability strategy. Total economic use of (abiotic) raw materials, energy sources, ores, construction materials and industrial materials forms the reference basis for the key indicator 'raw material productivity'. Raw material productivity is defined as the ratio of gross domestic product to the extraction and import, in tonnes, of abiotic raw materials and semi-finished and finished goods. The target of the German Federal Government is to double raw material productivity by 2020 compared to the year 1994.

The use of raw materials (such as energy sources, construction materials, e.g. minerals, metals) is the basis for any economic activity. Raw materials whose substitutability is limited are an important production factor. Global annual consumption of raw materials amounts to about 60 billion tonnes today. This is 50% more than just 30 years ago, with the trend going upward. The main drivers for the continued increase in raw material consumption are global population growth and the growth taking place in newly industrialised countries. In Europe, we now consume 43 kg of raw materials per person each day, compared with 88 kg in North America and 10 kg in Africa.

The rapidly growing demand for raw materials has already led to rising prices for raw materials in the past, and according to experts this trend will continue. For example, copper today costs about three times as much as in the 1990s. The growing consumption of raw materials is not, however, only an economic cost factor. Their extraction, transport and use put pressure on the environment, for instance, in the form of land consumption and emissions. The growing demand for raw materials diminishes their concentrations in deposits, which progressively increases the technical effort needed for their extraction as well as the associated costs and adverse environmental impacts.

The extent of resource consumption (currently, 18% of the global population consumes 80% of the available resources) progressively reduces our planet's capacity to regenerate the resources vital to human beings and animals. Therefore, a turnaround – away from current resource consumption patterns towards a sustainable economy – is needed worldwide. The urgency of the need to act locally according to sustainable principles is also evident from the rapid pace of resource consumption in so-called newly industrialised countries. If we adhered to current consumption patterns, global resource consumption would increase many times within the next 20 years and would then exceed the regeneration capacity of the environment at the expense of the basis of existence of present and future generations. Therefore, all countries should urgently make their economies sustainable by increasing resource efficiency, reducing resource consumption in absolute terms and abandoning resource-intensive consumption patterns in favour of resource-efficient lifestyles.

It is obvious that a switch in the use of natural resources will lead to a redistribution of these resources in coming decades. Attempts will have to be made to reach an agreement on per capita consumption. Clearly, this also implies that rich industrialised countries will have to reduce their excessive consumption while other countries should be allowed to increase their consumption. Mankind has to meet each other in a ‘sustainability corridor’.

This book series seeks to explore the background of the resource issue, provides information and gives relevant actors certainty to the direction of developments in this field. I hope therefore that this series will attract a great deal of attention.

Jochen Flasbarth

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Part I
Sustainable Use of Natural Resources: A Global Challenge

Chapter 1
Global Material Flows and Their Environmental Impacts: An Overview

Uwe R. Fritsche

Abbreviations and Acronyms

BMU	Bundesministerium für Umwelt (German Federal Environment Ministry)
DMI	Direct material input
EC	European Commission
GDP	Gross domestic product
GHG	Greenhouse gas(es)
IEA	International Energy Agency
LCA	Life-cycle analysis (or assessment)
MFA	Material flow analysis (or accounting)
NIES	National Institute for Environmental Studies (Japan)
OECD	Organization for Economic Cooperation and Development
OEKO	Oeko-Institut – Institute for Applied Ecology (Germany)
SEI	Stockholm Environment Institute (Sweden)
SERI	Sustainable Europe Research Institute (Austria)
TMR	Total material requirement
UBA	Umweltbundesamt (German Federal Environment Protection Agency)
UNEP	United Nations Environment Programme
WCED	World Commission for Environment and Development
WI	Wuppertal-Institute for Climate Environment and Energy (Germany)
WRI	World Resources Institute (USA)
WTO	World Trade Organization

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1 Introduction: A Little History

Ta panta rhei (everything flows) is not a mere philosophical quotation accredited to Heraclitus who lived 2,500 years before today in Greece past but a fundamental view on *modern* economies with their manifold transformations of materials, energy and natural resources into products along globalized trade patterns.

In 1972, the report to the Club of Rome *Limits to Growth* (Meadows et al. 1972) stimulated heated debates about future resource use and introduced scenario logics[1] to the wider public: What *would* be the consequences *if* future economic and population growth takes a certain path? And are there physical limits to growth?

> Limits to growth include both the material and energy that are extracted from the Earth, and the capacity of the planet to absorb the pollutants that are generated as those materials and energy are used. Streams of material and energy flow from the planetary sources through the economic system to the planetary sinks where wastes and pollutants end up.
>
> There are limits, however, to the rates at which sources can produce these materials and energy without harm to people, the economy, or the earth's processes of regeneration and regulation. Resources can be renewable, like agricultural soils, or nonrenewable, like the world's oil resources. Both have their limits. (Meadows et al. 2004, p. 10)

In the 1980s, the so-called *Brundtland Report*[2] "Our Common Future" took up the issue again, now linking environmental deterioration to economic *and social* development, popularizing the term *sustainable development* which has to consider production *and* consumption:

> In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development; and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations. (WCED 1987, Chapter 2 no. 15)

In the 1990s, this view on energy and material flows and associated use of natural resources was taken up in the term *industrial metabolism* proposed by Robert Ayres who described it as

> the whole integrated collection of physical processes that convert raw materials and energy, plus labour, into finished products and wastes… (Ayres 1994)

Baccini and Brunner called this view the *metabolism of the anthroposphere* (Baccini and Brunner 1991), providing the conceptual base for material flow analysis (MFA) which is a broader form of life-cycle analysis (LCA).[3]

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[1] The report used a simulation model called World3 operated at the MIT and built with system dynamics software. The key feature of this model (which is, in updated versions, still used) is its ability to handle dynamic linkages between "drivers" of future development, especially population, GDP, resource use and environmental pollution. The approach allows simulating *non-linear* (often exponential) behaviour caused by coupling of those drivers. Previous models were based mainly on *econometrics*, forecasting future developments by means of extrapolating past trends and relying on comparatively simple linear relations between "drivers".

[2] The report was named after Gro Harlem Brundtland, the Chair of the WCED and a former Norwegian Prime Minister.

[3] MFA avoids some of the shortcomings of LCA, especially the narrow focus on a *functional unit* of product output, thus allowing the analytical scope to be broadened to whole systems, such as factories, cities and regions, to whole countries and, ultimately, the entire planet.

In parallel, the term *industrial ecology* was introduced which merged the view with a more practical approach to actually change industrial systems:

> Why would not our industrial system behave like an ecosystem, where the wastes of a species may be resource to another species? Why would not the outputs of an industry be the inputs of another, thus reducing use of raw materials, pollution, and saving on waste treatment? (Frosch and Gallopoulos 1989, p. 114)

In the late 1990s, industrial ecology proved applicable on various scales (Garner and Keoleian 1995), and its key tools LCA and MFA became mainstream not only in the research community (Duchin and Hertwich 2003), including specific journals,[4] but also quite practical for, e.g. enterprises and product developers (Brunner and Rechberger 2003), and the material flows of whole nations were determined (WRI 1997, 2000).

Since the early 2000s, resource issues gained even more attention (OEKO 2007), e.g. UNEP's International Panel on Sustainable Resource Management was established in 2007 (UNEP 2007) and released several studies (UNEP 2009, 2010a, b), and the methods became more standardized both in the EU (Eurostat 2001, 2007, 2009) and internationally (OECD 2008a, b, c, d, 2009).

Since 2010, *resource efficiency* is a key topic on the EU level (EC 2010a; CEU 2010), and UNEP identified it as a core dimension of global environment governance.

Specifically, *rare metals* became an international policy issue (EC 2010b; DOE 2010; OEKO 2009a), in parallel to the ongoing intense debate about the *sustainability of biotic resources* (biomass, bioenergy and biofuels in particular).[5]

2 Resource Flows: What and How to Measure?

The various flows of resources into the industrial metabolism and global trade system are usually grouped into:

1. Abiotic raw materials (e.g. minerals, ores)
2. Nonrenewable primary energy (e.g. coal, oil)
3. Biotic resources (e.g. agricultural, fishery and forestry products)

In the following, the focus is on the first group[6] which can be disaggregated further into metal ores and minerals. Metals are various ores, especially bauxite for aluminium,

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[4] For example, *International Journal of Life Cycle Assessment* http://www.springer.com/environment/journal/11367 and *Journal of Industrial Ecology* http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1530-9290

[5] This text focuses on abiotic resources, i.e. it *mostly excludes* the issue of biomass even if the use of biotic resources has key impacts on other natural resources such as land (Fritsche et al. 2010; IEA 2010) as well as on biodiversity and GHG emissions (CE/OEKO 2010; OEKO/IFEU 2010).

[6] Nonrenewable (fossil and nuclear) primary energy is, similar to biotic resources (see footnote 5), not explicitly addressed here. Still, energy is part of the "system" of MFA and LCA which takes into account energy use for extraction, transport and processing of abiotic raw materials.

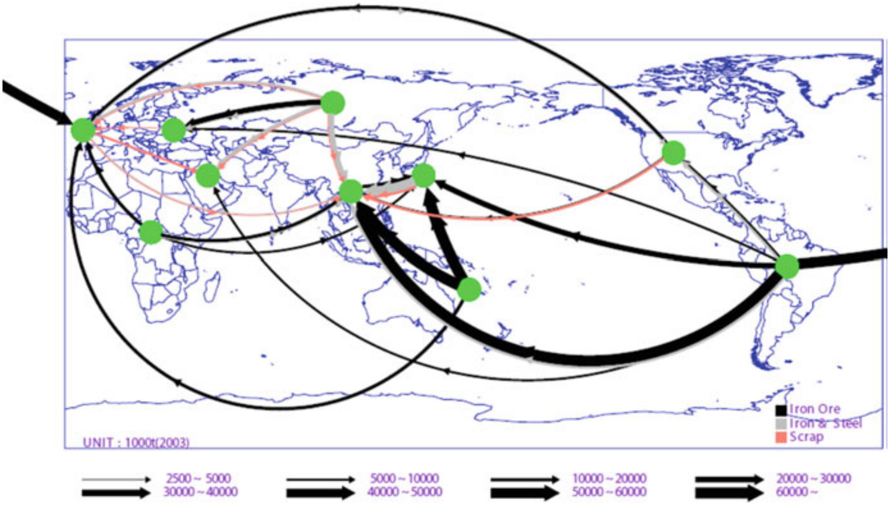

Fig. 1.1 Global trade flows of iron ore, steel and scrap in 2003 (Source: NIES 2003)

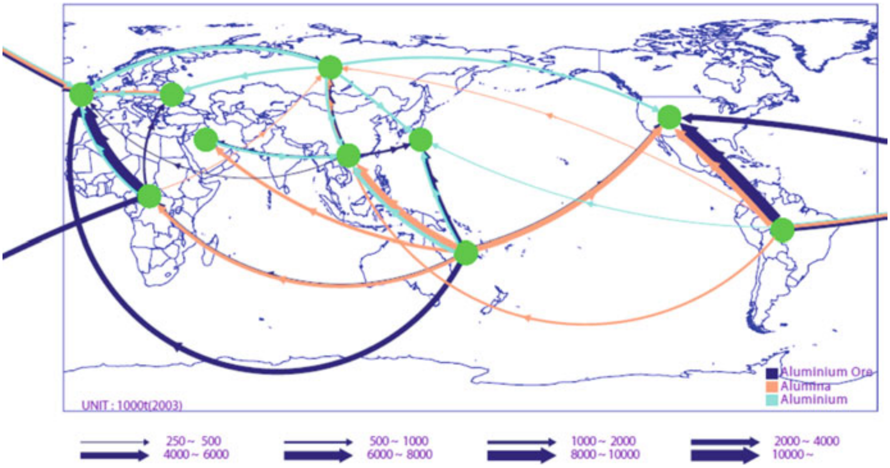

Fig. 1.2 Global trade flows of aluminium ore, alumina and aluminium in 2003 (Source: NIES 2003)

iron for steel and several non-ferrous ones (e.g. copper, lead, zinc). The following figures show the respective global trade flows (Figs. 1.1, 1.2 and 1.3).

The mineral groups consist of a broad variety of bulk materials such as clay, dolomite, sand and stones which are used either directly as construction materials or as raw materials for, e.g. cement and glass production. Most of these resources are not traded internationally but produced and used within countries and regions.

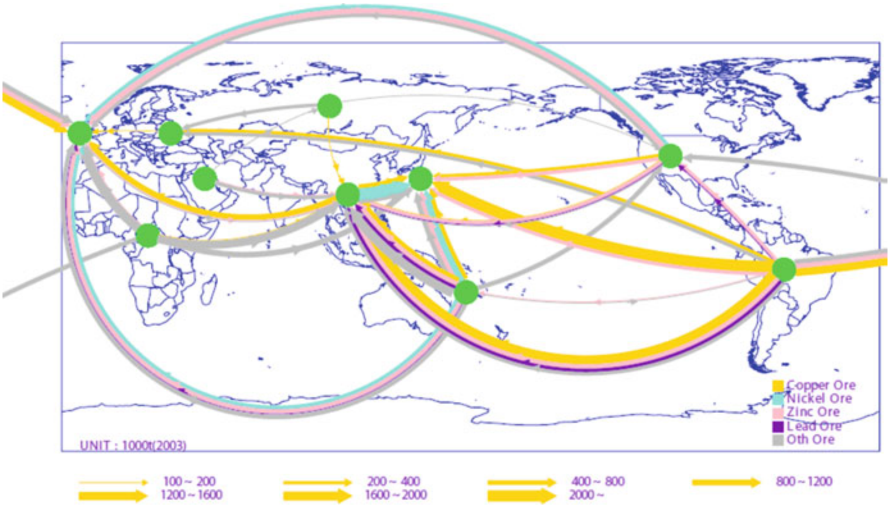

Fig. 1.3 Global trade flows of non-ferrous metal ores (excluding aluminium) in 2003 (Source: NIES 2003)

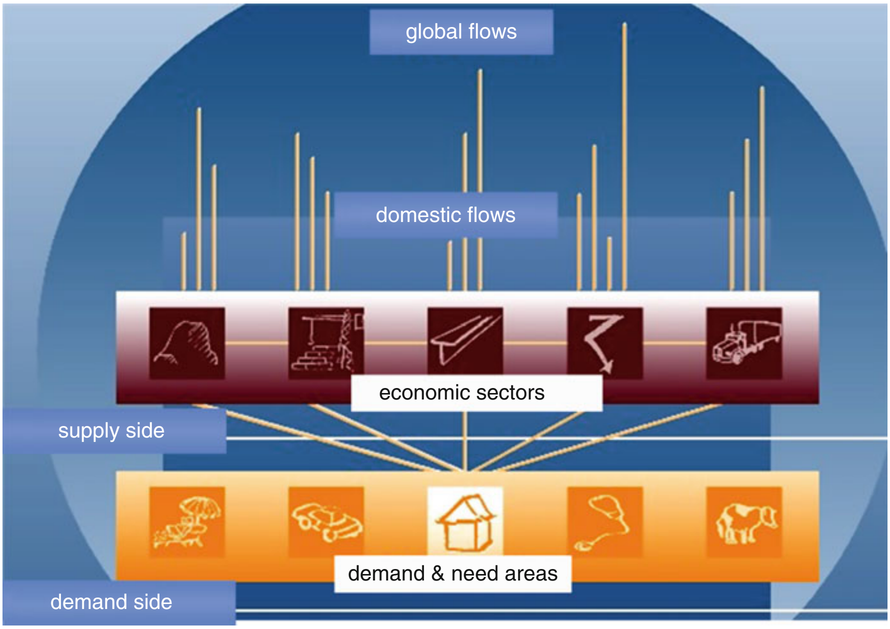

Fig. 1.4 Global material flows and demands (Source: OEKO 2011)

The transboundary nature of resource flows is indicated in Fig. 1.4 which shows the principal links between the demand side (products and services), the economic sectors providing those and their resource inputs.

2.1 What to Measure: Metrics and Indicators

There is an ongoing discussion on the "metrics" of sustainable resource use (SERI 2009; UNEP 2008; OEKO 2009b). Simple approaches give just an expression of the mass of the respective resources (e.g. tonnes), while more refined concepts address also related air and GHG emissions, land and water use, and wastes generated during extraction and further downstream processing.[7]

Some scientific effort went into compact indicators such as "footprints" or "rucksacks" (Ecologic 2010; BMU/UBA/OEKO 2009; MIPS) which aggregate several environmental indicators into a uniform or composite measure.[8]

For national MFA studies, the direct and total material inputs (DMI and TMI) are in use since several years, but continuing efforts are made on their improvement, especially to determine the "hidden" resource flows from imports (DESTATIS 2009; SEI/PBL/SERI/SCB 2009).

2.2 How to Measure Resource Flows: Methods and Data Sources

Since the 1990s, the methodologies to "track" resource flows developed rapidly: For LCA, international standards were developed by ISO (2006a, b), and for MFA, methodologies were harmonized especially for national accounting (Eurostat 2001, 2007, 2009; OECD 2008a, b, c, d, 2009).

The *data side*, though, is still subject to ongoing research, especially for the resource flows associated with *imports* (IFEU 2007).

3 Results: The Weight of Nations

The *impacts* of resource extraction and associated downstream flows in terms of total material use, and respective environmental effects, have been investigated in the last 20 years by various studies and institutions[9] but especially in Europe (EEA 2004, 2005; JRC-IPTS 2004; van der Voet et al. 2009). The focus of this work has been mostly on the national level, taking into account global effects from imports.

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[7] Note that land-related biodiversity impacts can also be of relevance for resource extraction, especially mining (IIED/WBCSD 2002, 2003; WRI 2003).

[8] Examples are CO_2 equivalents for GHG emissions in "carbon footprints", tonnes in MIPS and hectares of land in the "ecological footprint". See referred literature for details.

[9] There is a multitude of material and studies also for Japan and the US and a growing number for other countries. See UNEP (2010a) and OECD (2008d) for some of this material and the articles in the respective journals, e.g. *International Journal of Life Cycle Assessment* http://www.springer.com/environment/journal/11367 and *Journal of Industrial Ecology* http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1530-9290.

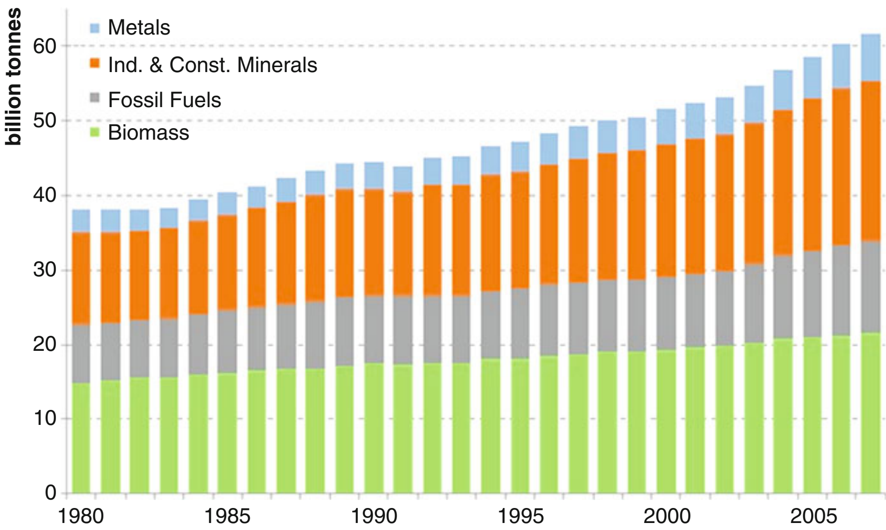

Fig. 1.5 Development of resource extraction from 1980 to 2007 (Source: SERI 2010; metals are expressed as metal ores; biomass is from agriculture, forestry and fishery)

To indicate the significance of *global* resource flows and use, recent results from ongoing research (SERI 2010) are used in the following, with further results for the environmental implications of resource flows.

3.1 Dynamics and Distribution of Resource Use

Global resource extraction grew more or less steadily over the past decades (see following figure), but growth rates were different between the main resource groups.

In particular, the extraction of metal ores more than doubled, while minerals grew by 75% and biomass by approx 50% (Fig. 1.5).

The growth of resource use was also different between world regions, as shown in the following Fig. 1.6.

The main “drivers” for use of abiotic resources in terms of economic sectors (and their respective products) cannot be determined easily due to their interrelatedness, but some studies still tried to identify the key products (e.g. UNEP 2010a; EEA 2004).

There is some recent work on future dynamics of global resource use (IFF 2010; Krausmann et al. 2008), but due to inherent uncertainties in global trade (WTO 2010) and material-flow related policies, these projections describe a broad corridor.

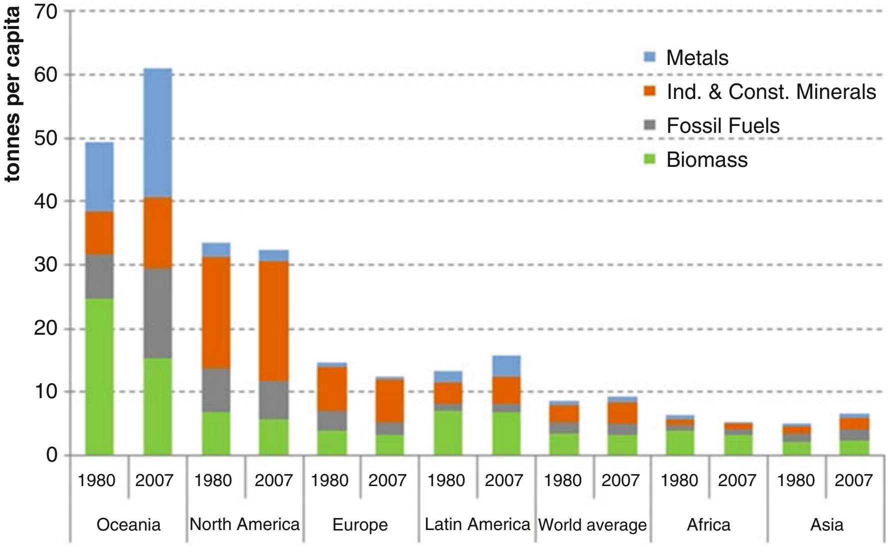

Fig. 1.6 Regionally distributed development of resource extraction (Source: SERI 2010; metals are expressed as metal ores; biomass is from agriculture, fishery and forestry)

3.2 Impacts of Resource Use

Besides the resource use and its implications for scarcity, trade, etc., there are impacts of extraction and downstream processing – including transport – on energy demand and effects on air and GHG emissions, waste streams and land use.

These impacts can occur along the whole life cycle (or value chain) of products and services associated with the resource use (see following figure) and can be geographically distributed as well (Fig. 1.7).

To determine the various environmental impacts, one has – depending on the scope of the analysis – to use LCA or MFA models.

Due to the restrictions in available data for both, adequate information exists only for a limited number of resource flows and product "chains".

One model which is in the public domain and which offers a comparatively extensive database is GEMIS (OEKO 2010). It has been used as a data server for several MFA studies in the last 15 years (e.g. OEKO 2002, 2011, OEKO/IÖR 2003; OEKO et al. 2004; OEKO/DLR-IVF 2009) and is continuously updated.

The structure of the GEMIS database is shown in Fig. 1.8.

Using data from GEMIS, the impacts of various resource uses can be determined, taking into account technological and country specifics.

Table 1.1 gives a short excerpt of results for selected metals and minerals available in the database. Transports and auxiliary energy inputs (e.g. for mining) are factored in, and the data refer to the 2005 situation in Western Europe, unless specified otherwise.

As can be seen from this brief selection, there are significant differences in the environmental "profiles" of resource flows and respective products, and the individual impacts are not well correlated.

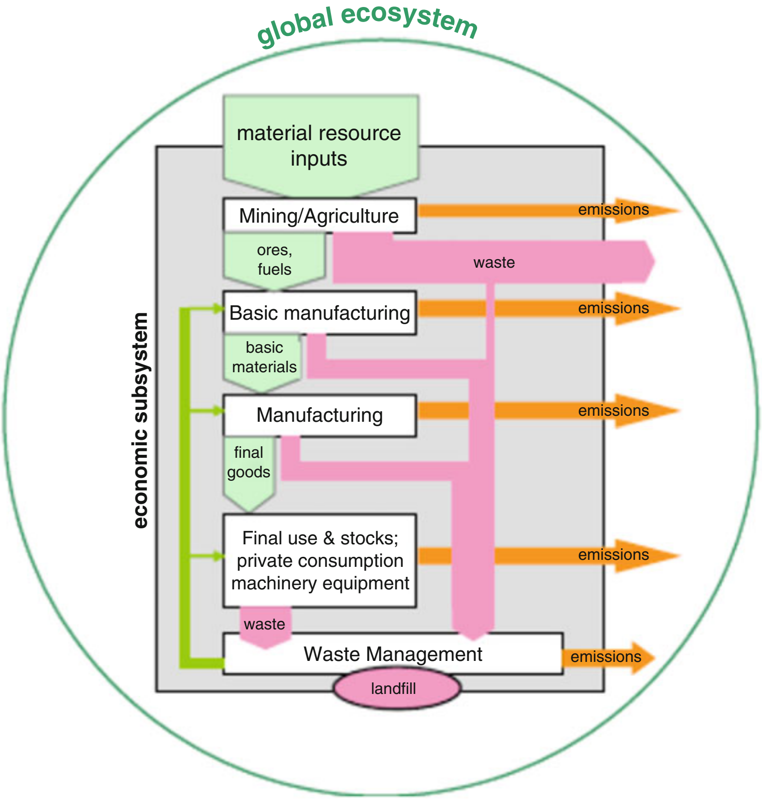

Fig. 1.7 Resource flows and environmental impacts (Source: EEA 2004)

It should further be noted that resource extraction and primary conversion are quite energy-intense so that environmental impacts are significantly influenced by the energy mix (e.g. electricity generation).

The future impacts of resource flows will also depend on the "grade" of, e.g. metals ores in the mine – with growing demands, the energy intensity of resource extraction could increase also. On the other hand, technological improvements, phase-out of old equipment, economies of scale due to concentration and decarbonization of auxiliary energy inputs could reduce impacts as well.

4 Perspectives: Sustainable Resource Use?

Given the global dynamics of population growth, rising economic outputs and material "wealth", abiotic resource flows will remain high or even increase further in the decades ahead if moderate assumptions on technological progress and recycling (use of secondary resources) are made (Krausmann et al. 2008).

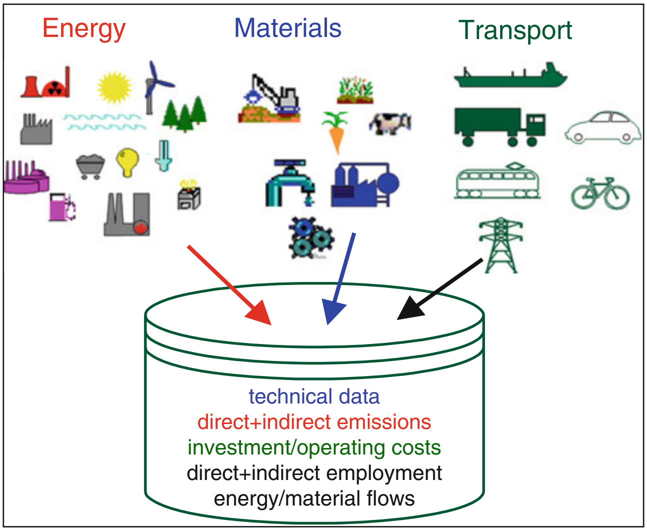

Fig. 1.8 The GEMIS database for material flow analysis (Source: OEKO 2011)

Table 1.1 Specific environmental impacts of selected metals and minerals

Material, country	SO_2eq g/kg	CO_2eq g/t	Non-renew PE [$kWh_{primary}$/kg]	Land use [m^2/t]
Aluminium AU	70	20	44	16
Aluminium DE	54	15	48	63
Aluminium NO	63	9	16	136
Aluminium RU	112	19	60	5
Copper	24	4	13	6
Lead	8	2	7	12
Steel	6	2	7	1
Zinc	16	6	19	18
Lime	1	1	1	0,5
Mineral wool	3	1	4	4
Cement	2	1	1	2

Source: author's calculation with GEMIS (OEKO 2010)
PE primary energy, *AU* Australia, *DE* Germany, *NO* Norway, *RU* Russian Federation

Assuming planetary boundaries for key impacts (Rockström et al. 2009), the future dynamics of resource flows under business-as-usual logics give reason to severe concern.

Massive increases of resource efficiency would be needed to slow or even reverse these trends – those are technically feasible and have occurred in the past, e.g. for steel-making (Henseling 2008), and the potentials for more resource efficiency are significant.

Still, sustainable resource use must consider not only supply-side options but also consumption patterns (OEKO 2007; UNEP 2010a). Given the close relation between income and consumption, this is an issue of global equity (WCED 1987) – as Tim Jackson put it:

> In a world of finite resources, constrained by strict environmental limits, still characterized by 'islands of prosperity' within 'oceans of poverty', are ever-increasing incomes for the already-rich really a legitimate focus for our continued hopes and expectations? (Jackson 2009, p. 17)

There may be *other* limits to growth and other solutions than biophysical ones. Beyond the scope of energy and material flows, the whole realm of social and societal reality needs to be considered, with its own crises, but also its own opportunities.

In that regard, growth beyond the limits of our current understanding of industrial ecology could be healthy, and the concept of sustainable resource use might well need to reflect the *societal* metabolism (Fischer-Kowalski and Rotmans 2009).

Looking beyond efficiency, this endeavour should address the fundamentals of "needs" driving resource use and explore sufficiency as a possibly needed additional issue (Munasinghe 2010). With the Rio+20 UN Conference in 2012 on the horizon, the suggested Millennium Consumption Goals could offer a conceptual start which needs scientific and political substantiation (Munasinghe 2011).

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Chapter 2
Increased Resource Efficiency: The Key Issue for Ecology and the Economy

Michael Müller

1 Giving Progress a New Orientation

The last 200 years of industrial history have been characterized by the massive exploitation of natural resources. Cheap energy and raw materials have up to now oiled the wheels of employment and prosperity. That will no longer be the case. We stand at the beginning of a century of ecology, in which only those economies, businesses and societies will succeed that deal efficiently with natural assets. The question arises, whether this process is today created democratically or whether it will have to be enforced in the future as an unavoidable necessity accompanied by far-reaching cuts.

In order to avert the dangers of resource scarcity and climate change, technical and economic progress requires a new, ecological orientation. This can only be developed and realized with a huge joint effort involving all groups in society: entrepreneurs, providers of capital and trade unions as well as scientists and NGOs.

How well we live in the future, how peaceful and just the future will be, whether we minimize dependencies, avoid crises and conserve natural resources, depends on how we utilize resources. It therefore not only concerns the security of energy supply. The environment-compatible treatment of materials and raw materials is becoming a key issue for the economy and employment. On the other hand, conflicts concerning the distribution of resources will inte nsify, which will have considerable effects on the world economy.

The initial significant factor is resource efficiency. The underlying question concerning the quality of growth has been repeatedly raised during the last 40 years. Radovan Richta and Ota Klein, two intellectual trailblazers of the Prague Spring,

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referred already in the 1960s to problematic effects of the technical and scientific revolution (Richta 1971). They called for greater orientation towards needs in production and services.

In 1972, Dennis L. and Donella Meadows indicated the limits to growth in their report for the Club of Rome (Meadows et al. 1972, 2004), which they linked to forecast scarcities in raw materials and population growth. With overloading of the absorption capacity of natural media, the limits of nature are revealed. This is made clear by climate change. What is more, a paradigm shift is necessary, since the cost of the ecological consequences may no longer be externalized.

New thinking and action are vital. Environment-compatible use of energy, materials and resources through a revolution in utilization provides an insight into how the dangers can be averted. Here, Germany has great opportunities, for it is the lead market for efficient technologies and renewable energy sources that will characterize the next economic cycle. However, it must itself also show that realization of ambitious goals for a resource-friendly economy is possible. This is also in Germany's own interest, since:

1. We cannot afford wasteful treatment of natural resources. Through the late industrialization of large regions of the earth and continuing high rates of population growth, raw materials will become scarce and expensive. Today, around 1.4 billion people use more than 70% of commercial supplies. In the near future, nine billion people will populate the earth, 50% of them in industrial countries. The densely populated emerging countries, in particular, intensify conflicts over access and use. The result could be wars over natural resources. Scarcity is also growing in the case of many precious metals, which are highly important in industrial production. Action must first be taken by industrialized countries.
2. Limitations on the availability of many raw materials are rapidly approaching. Important producing countries are reaching their maximum production level. Oil production in Saudi Arabia, the most important oil-producing country in the world, has probably already reached its peak. In future, manufacturers, service providers and consumers will be much more strongly affected. In view of growing needs as a result of technical developments (specific materials in information and communication technology), as well as growing demand, in particular, in China, India and Brazil, increasing scarcity has to be expected.
3. The earth, as an ecosystem, is reaching its limits in the absorption of pollutants. Natural cycles are failing to function. An ecological collapse threatens. The Intergovernmental Panel on Climate Change (IPCC) has raised its forecast of the rise in global warming in very likely scenarios up to 4°C by the end of this century, compared to the values at the end of the twentieth century. An increase of 1.5°C is no longer to be prevented (IPCC 2007). Limiting the rise to a barely tolerable 2°C will require enormous efforts.

These developments, however, are not inevitable. The first important step in the right direction is a rapid and extensive increase in utilization efficiency.

2 The Efficiency Revolution: The Next Generation of Environmental Policy

The opportunity for an efficiency revolution exists. Labour productivity in Germany has increased since 1960 by a factor of 4. Material productivity has increased by a factor of only 2, while energy productivity has merely increased by a factor of 1.5. An increase in material productivity would have been particularly worthwhile for small trade as well as small and medium-sized businesses, since the average portion of costs for raw materials and supplies in the processing industry in Germany (just under 45% in 2006) is more than double that for wages (just under 19% in 2006). The German Material Efficiency Agency (DEMEA) estimates that in the German national economy, a total of at least 100 billion € in material costs – 20% – could be saved through more efficient production processes.

Possible goals are:

- Ambitious standards for the economical use of energy and raw materials
- Far-reaching strategies for an increase in efficiency and recycling
- The development of renewable energy sources
- The promotion of technical progress on the basis of ecological guidelines

An efficiency revolution is, however, much more than uncoupling growth in raw material use from national product. The aim is a reduction in consumption in absolute terms. From this, new competitive advantages will arise, since reductions in costs can result even with increasing energy, material and raw material productivity. This concept is entitled “Factor 4” – doubling growth and halving resource use. The more ambitious demand is “Factor 10”.

The efficiency revolution makes an important contribution towards a reduction in unemployment, since the unnecessary use of energy, materials and raw materials is replaced by enhanced technology and qualified employment. As a result of such innovation, industrial locations are secured, and dependence on imports from producing countries is reduced. Through higher production processing industry achieves cost advantages in the use of energy, material and raw materials.

Furthermore, in every period of industrial history, there has been a leading-edge or cross-sectional technology: steam engine, railway, electrical engineering, chemical production or mass mobility. They were described as Kondratieff cycles by Josef Schumpeter, a prophet of innovation (Schumpeter 2005). The departure point of innovation theory was studies carried out by Nikolai Kondratieff on “long waves”. The signs are that the next business cycle will be characterized by economical treatment of natural resources; as a result, ecological modernization gains considerably in significance.

The efficiency revolution becomes a strategic issue for the modernization of infrastructure and the economy. Germany plays a pioneering role in eco-efficiency and renewable energy. This “next generation of environmental policy” belongs at the centre of economic and social reforms so that:

- More advantages emerge in international markets.
- The bases for sustainable prosperity are created.
- The ecological collapse of the planet earth is averted.
- Conflicts over the distribution of scarce resources are prevented.
- An important contribution is made to secure peace in the world.

Basic conditions must be changed as soon as possible so that the efficiency revolution can be set in motion.

3 Quality Rather than Quantity

With the economic crisis, products that are easy to manufacture have come under pressure. In the case of quality products, however, a contrary trend can be observed. The advantages of continuously decreasing the use of resources lie in the fact that:

- Through the strategic concept of life-cycle management over the entire process chain, not only environmental pollution is reduced and valuable raw materials conserved but also costs saved to a considerable extent.
- Top-quality products, which offer advantages through longer durability, extensive recycling cascades or intelligent ecodesign, will meet a greater demand on the world market.

As a field of action for cost-cutting and innovation, resource efficiency has great potential for economical use of natural resources with decreasing costs. Rethinking is also essential in the case of consumption. The average German carries heavy "ecological rucksacks".

It is not only a question of greater efficiency, however, since ambitious goals for reduced use of raw materials are unattainable in the absence of lifestyle changes. The key to the efficiency revolution lies in ecological services as well as in intelligent, resource-conserving fulfilment of needs. Closed cycle management is achieved through high material quality, recoverability of goods and recyclability of materials.

The ecological knowledge society makes these goals attainable. They require better qualified employees in order to achieve intensive co-operation between business, science and technology. That is the idea of cluster formation. The knowledge society demands greater creativity and better qualification, more teamwork and personal responsibility. Here, decentralized structures are helpful, since they can make extensive use of the potentials of efficiency and solar markets.

This way, for example, use of materials in the building and habitation area could be halved in the next 20 years through efficient use and increased recycling of materials. Energy use would also drop by about 65% compared to present levels.

Another example is the renunciation of fossil fuels to cut CO_2 emissions by 80% by 2050. Renewable energy sources would then cover around two-thirds of energy demand. This vision is concretized in the 2,000 W Society.[1] A complete switch to renewable energy is possible by the end of this century.

For this purpose, consumer behaviour must gradually be brought into line with ecological goals. In certain consumption areas – for example, organic food – this trend can already be observed; people are prepared to pay more for a better quality product. The public sector must also play an exemplary role through environmentally conscious procurement.

4 Innovation, Growth and Employment

The alternative is clear: Dramatic consequences of the hunger for resources of industrialized countries and the rapidly growing demand for raw materials of densely-populated emerging countries can only be avoided through the initiation of an efficiency revolution. Energy and resource security implies a reduction in the use of energy and raw materials throughout the entire value-added process, without curtailment of desired services such as comfortable space heating, electricity and adequate mobility.

Economic possibilities exist: As a rule, through the linking of a number of technical, organizational and cultural measures, the example of an "energy-efficient power plant" – negawatt rather than megawatt! – makes more economic sense than the development of additional capacity. It involves a new philosophy of avoidance of unnecessary energy use.

Government incentives and regulatory frameworks could accelerate the increase in material efficiency at all levels: better know-how and more education, purposeful innovation, consumer information and efficiency standards, as well as the dismantling of barriers. Moreover, capital expenditure on energy, material and resource productivity has a considerable self-financing effect. For example, experience gained by the German Material Efficiency Agency (DEMEA) confirms that manufacturing costs can be reduced by 20% with existing methods through enhanced energy and material efficiency.

5 Increasing Consumption of Raw Materials and Its Consequences

Due to economic growth, the increase in population and the rising standard of living, more and more natural resources are being consumed. If one includes the associated extraction of raw materials and movements of raw materials abroad in

[1] The 2,000 W Society is an energy policy model that was developed at the Swiss Federal Institute of Technology Zurich. Visit http://www.novatlantis.ch/

the quantity of consumed goods, the total consumption of raw materials in Germany alone – our "ecological rucksack" – amounts to around six billion tonnes per year. Each German accordingly consumes more than 70 tonnes of resources per year. By contrast, in Japan the figure is about 45 tonnes, in Poland 30 and in China 37, while in the poorest countries of Africa and South Asia per capita consumption is less than 2 tonnes per year.

Germany disposes of sufficient reserves of important raw materials such as salt, potash, sand, gravel, lignite and hard coal, while in the case of other key raw materials – in particular metals – it is heavily dependent on imports. In the year 2008, Germany imported abiotic raw materials to the value of around 128 billion €, while in 2004 imports amounted to just 62 billion € (Federal Institute for Geosciences and Natural Resources 2010).

Domestic extraction of abiotic raw materials declined between 1994 and 2008 by 286 million tonnes, or 26%, while imports of abiotic raw materials as well as semi-finished and finished goods rose by 106 million tonnes, or 20%. This means that domestic natural assets are being increasingly conserved and that the burden on ecological cycles associated with the extraction of raw materials and their further processing is being shifted abroad (Federal Statistical Office Germany 2011).

By mid-2008, "raw material scarcity", "gaps in supply" and rising prices for energy and raw materials dominated the political and economic debate. Between the years 2000 and 2007/2008, prices for aluminium and zinc more than doubled; those for tin, nickel and copper increased more than fourfold. Even though the global financial crisis has led to a weakening of global business and a severe downturn in 2008/2009, commodity prices have nearly reached or even surpassed peak levels again in 2011.

With the upturn in worldwide business activity and the associated demand for raw materials in countries such as China, India, Brazil and Russia, shortages of raw materials – metals and minerals, for instance – will again become manifest. In addition, there is growing speculative influence on raw material prices. Large numbers of funds and investors see in the scarcity of raw materials a lucrative field for speculation. This concerns, in particular, metals, oil and foodstuffs.

Future availability of raw materials is estimated in the form of reserves-to-production ratios. Examples for nonenergy raw materials are:

- Lead: 22 years
- Tin: 20 years
- Tungsten: 32 years
- Tantalum: 29 years
- Copper: 31 years
- Phosphate: 122 years

This does not mean that at the end of these periods, reserves of the respective raw material will be finally exhausted, but it does indicate scarcity or shortages in the case of strategically important "critical" raw materials.

Furthermore, as a result of growing raw material consumption, more and more new raw material reserves will be exploited, including those whose exploitation has previously not been cost-efficient. In this connection, and particularly abroad, substantial ecological burdens and social conflicts have to be expected, for example, through:

- Still greater unused extraction in mining.
- Contamination by toxic substances.
- Infrastructural development or destruction of unspoilt ecosystems. Already today, developing and emerging countries bear 80% of "ecological rucksacks".
- Intensification of sink problems, such as the emissions of greenhouse gases, the shortage of landfill sites and the pollutant discharge into ecosystems.
- Low industrial safety standards, wage dumping and health risks for the population.

In conclusion, the discussion on resources should not concern – as it is often the case – long-term, low-cost availability of raw materials for industrialized countries. There is an ecological, economic and social need for action to reduce consumption of raw materials as a whole.

6 Sustainable Resource Policy at a European and National Level

The European Commission presented in July 2008 an action plan for sustainable production and consumption as well as for a sustainable industrial policy. This contains, as a key measure, an increase in resource efficiency. Furthermore, the scope of the EU Ecodesign Directive will be expanded to cover all products of relevance to energy consumption. At the same time, particular consideration will be taken of the energy and resource consumption of such products.

In November 2008, the European Commission presented its "Raw Materials Initiative" with its three key objectives:

1. Fair access to raw materials on the world market
2. Sustainable supply of raw materials from European sources
3. Reduction of primary raw material consumption in the EU through an increase in resource efficiency and greater use of secondary raw materials

At a national level, an increase in energy and resource productivity is an explicit objective of the German Federal Government, whose Sustainability Strategy of 2002 calls for a 100% increase in raw material productivity by 2020, compared to 1994. By 2010, an increase of 47% had been achieved (Federal Statistical Office Germany 2011). However, the rate of increase up to now would be insufficient to attain the set objective.

7 Initiatives of the Federal Environment Ministry Between 2005 and 2009 for Greater Resource Efficiency

The "Resource Efficiency Network" was set up as an important element of the "New Deal for Economic, Environmental and Employment Policy" to offer companies, engineers, researchers and associations an information platform for better co-operation and realization.

In July 2009, together with the Association of German Engineers (VDI), a Resource Efficiency Competence Centre (ZRE) was set up, whose aim is the preparation and dissemination of information and practical applications of energy and resource efficiency technologies. This service is primarily directed at small and medium-sized businesses, which, for a number of reasons, are unable to exploit their resource efficiency potentials.

The research project entitled "Material Efficiency and Resource Conservation", which was initiated by the Federal Environment Ministry in 2008, investigates substance flows, industrial sectors and areas of need related to raw material consumption, on the basis of which it evolves strategies and instruments for ecological modernization. The objectives of this project are the identification of resource efficiency potentials in individual sectors as well as the development of instruments for exploitation of such potentials, an increase in material efficiency and resource conservation:

- Within the framework of the Material Efficiency and Resource Conservation project, criteria should be developed for definition of "ecologically critical" raw materials (initially metals), that is, those of particular relevance to nature. Besides demand for raw materials and energy required for the production of metals, the dissipative use of a particular metal in different areas of application and products is also evaluated – for example, in electronic equipment. Dissipative use of metals generally has the result that they are insufficiently recovered by means of established recycling infrastructures and methods and are therefore lost to the business cycle.
- As a result, the following ten relevant metals have been identified: gallium, gold, indium, manganese, nickel, palladium, silver, titanium, zinc and tin. For these metals, courses of action have to be developed to minimize their impact on the natural environment and metal losses.

The Federal Environment Ministry launched an initiative in 2006 entitled "Recycling and Efficiency Technology – RETech" to strengthen export opportunities for advanced German disposal technology and thereby the modernization of waste management abroad. RETech target groups are companies, scientists, consultants and investors in the recycling and waste management industry both at home and abroad.

8 Contribution of Waste Management to the Conservation of Resources

Waste management constitutes the mainstay of supply not only of energetic but also of nonenergy raw materials, whereby a significant contribution is made to increased resource efficiency. The use of secondary raw materials in Germany substituted imports of raw materials to the value 3.7 billion euros in 2005, and in 2007 – due to increased raw material prices – to the value of 5.3 billion euros. This supplemental added value was accompanied by an employment effect of around 60,000 jobs (Bardt 2006).

The ecological benefit of the closed cycle management of secondary raw materials is, on the one hand, the conservation of natural deposits, landfill sites and thus the natural environment; on the other hand, recycling generally has a better ecobalance than the production of primary raw materials. This benefit is particularly evident in the recycling of metals, which results in substantial savings in energy and CO_2 emissions (e.g. 56% the case of steel, 36% for copper and 93% for aluminium).

What is more, the use of secondary raw materials also offers advantages to domestic companies, which are largely dependent on imports of raw materials, through the availability of an additional source of raw materials.

9 Prospects for Resource-Conserving, Closed Cycle Waste Management

The markets for secondary raw materials are also integrated in the business trend of the economy as a whole. Since the historic level of prices in the summer of 2008, both demand and prices for numerous secondary raw materials – such as metal waste, recovered paper and waste plastics – have fallen drastically in the course of the decline in global business.

The sustained global demand for raw materials suggests the likelihood of a medium to long-term market recovery, also for secondary raw materials. For instance, in February 2009 there was, for the first time since mid-2008, excess demand on the global copper market triggered by high imports of copper by China (up to 52% compared to the previous year). Of the 2.9 million tonnes of copper that were produced worldwide in January/February 2009, more than 390,000 tonnes were produced from waste, 8.2% less than in the same period of the previous year. That could be an initial indication of further "waste scarcity" (Webber and Blas 2009).

In the future we should increase our efforts to make greater use of wastes and to recycle wastes in high-end applications, that is, to actually close waste cycles, instead of engaging in "downcycling". The focus of research and development was therefore set on the following points:

- Optimization of the recovery and utilization of raw materials from the building stock ("urban mining"): There is an enormous quantity of raw materials in the building stock. Already today, the recovery of raw materials (e.g. copper) from buildings – in the new federal states, the former GDR, around 1.1 million flats are uninhabited – through the selective deconstruction or demolition of buildings, is an important resource issue. The quantity and distribution of raw materials in this building stock will be the subject of current and future research projects. The objective is the achievement of the highest possible quality and the greatest acceptance of secondary raw materials through the recycling of building elements and enhanced deconstruction and material preparation technology in order to tap the full potential of resource conservation.

- Integration of recycling strategies in product development: New products demand adapted strategies for sustainable closed cycle management in their end-of-life phase. For instance, new, and to some extent rare, strategic metals and chemicals are increasingly used in component parts in the energy, information and communication industries (such as indium in LCD screens and PV modules). This "intensity of future demand stimuli" for significant raw materials and technologies of the future is currently being investigated by the Fraunhofer Institute for Systems and Innovation Research (ISI). It appears, for example, that expected future demand for gallium will exceed the level of current supply by a factor of 6, while for indium the factor is 3.3 and for platinum 1.6.

These products are wastes of the future. It is therefore essential that we concern ourselves in good time with their recovery and reusability, as well as with the recyclability of such materials. Besides the application and upgrading of existing regulatory instruments (such as product responsibility), for this purpose the future course should already be set in product design.

The Revised Waste Framework Directive, which was finally adopted by the Council of the European Union on 20 October 2008, introduces new instruments and regulations that support the objectives of intensified closed cycle management of wastes, including a five-step hierarchy of waste management options (which underpin the importance of reuse and recycling), recycling quotas and waste prevention programmes for selected waste flows.[2]

10 Conclusion

In the long term, only those economies will be successful that focus on massive increases in efficiency in the use of materials and raw materials. Beyond that, there is an ecological and social need for action on sustainable treatment of resources.

The main objective is the decoupling of quality of life from consumption of natural resources through innovative treatment of resources, that is, exploitation of all resource efficiency potentials and an absolute reduction in resource consumption.

[2] See the article of Michael Angrick, Chap. 11.

To achieve this objective, measures and strategies have to be applied at different levels:

- Promotion of ecological product design through the entire product life cycle, for example, for the selection of new and the substitution of scarce materials and raw materials, for the development of more durable products and for the increased reuse of products in cascade systems
- Development of the reuse and recycling of wastes with proven instruments, such as product responsibility, and through implementation of the Revised Waste Framework Directive
- Promotion of institutions, such as the Resource Efficiency Competence Centre and the RETech initiative
- Promotion of dialogue processes, such as industry dialogues, within the scope of the Resource Efficiency Network and “Resource” conferences
- Laying down and realization of ambitious resource efficiency objectives
- Promotion of R & D projects – for instance, in the “urban mining” area – and of innovative, nature-friendly resource efficiency technologies

In the future, rebound effects – that is, the phenomenon of substitution and quantity effects – that counteract and frustrate attained increases in efficiency have to receive greater attention and be prevented.

An increase in resource efficiency combines ecological necessities and economic opportunities in a win-win situation. This means that, besides relief of the natural environment and security of raw material supply, through the development of leading-edge technologies, the competitiveness of our business locations and employment will be secured.

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Chapter 3
Economic Growth and Sustainable Development

Niko Paech

1 Growth as Modern Progress Construction

Multiple crisis scenarios shake the possibly last consensus which holds together modern societies in spite of the heterogeneity of all other interests, namely the growth dogma. Before the first report "The limits of growth" (Meadows et al. 1972) was presented to the Club of Rome social progress could be translated into an unconditional growth imperative. Undisturbed by material or ecological restrictions, the efforts made in the economic and scientific fields have led to an increase in logic associated with key categories such as prosperity, freedom, justice and peace. With economic growth and technological progress having been interlocked, the elimination of all scarcities and obstacles getting in the way of the imperative for modern self-realisation seemed to be only a question of time. Thereby, it was not only necessary to constantly increase the choice of means for the individual search for happiness qualitatively but to make it accessible to an ever greater number of inhabitants on earth through a quantitative growth to approach the great historical project of a peaceful mankind.

In this connection Simmel speaks of a "substantial progress": When succeeding in increasing the stock of values, the "human tragedy of competition" may be relieved, namely, in the form of diverting the fight between men to a fight between man and nature. "To the extent as further substances and forces from the still unoccupied stocks of nature are involved in human use those stocks already occupied will be released by the competition for them" (Simmel 1900). Following up the logic of progress already established by Bacon and Descartes, it could be proceeded

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on the fact that earthly goods of nature are waiting for being acquired and utilised. Yet, it becomes apparent that the means to be permanently increased according to this in the service of freedom, prosperity and peace have not brought about a different appearance than a global temple of consumption which preferably should be open to all.

When in 1972 the legendary heckling of the Club of Rome sounded, it was stated that the modern industrial and consumption complex was responsible for the ecological scarcity, but the belief in the omnipotence of technology, science and growth had not been really shaken. As a matter of fact, the contrary occurred. The antiquated paradigm of nature control à la Bacon and Descartes concentrated its optimism solely on the efficiency of acquisition of natural goods. With the idea of an ecological modernisation, a by far more naive confidence in progress has been recently spreading. The last mentioned is not only content with further increasing the materialised symbols for freedom and prosperity. It pretends to implement this even in an ecologically harmless way.

The now double faith marks the birth of the "qualitative", "sustainable" or "decarbonised" growth. Here, the Promise is no less than the following: The output of an industry-based worldwide supply chain is to continue to grow indefinitely – whereas, at the same time, the strain on the maltreated biosphere is to be reduced. The starting point is making a distinction between qualitative and quantitative growth. This suggests that the industrial value added may be split up at will into two dimensions. Firstly, purely qualitative values are concerned—to put it more clearly, the utility providing functions why goods are actually produced. These actually immaterial purposes shall be separated from the second dimension, namely, the real und thus problematic ecological form of output. The quality thus neatly separated is to grow further because it is ecologically harmless, increases the use for consumption striven for and brings about market sales which increase the gross domestic product (GDP). Memories of Bacon awake as he, with his formula "disseccare naturam", made the dismemberment of nature a concept. The elements supposedly separable and the individual effects should thus be converted into a construction kit with the aid of which unexpected new creations up to a tailor-made world were to be mounted.

2 Growth Dawn

Decoupling strategies are, in principle, directed to increase the ecological efficiency or consistency. Both strategies may also be combined. Efficiency here means to minimise the input of energy, materials and other ecologically relevant resources required for providing a specific result of the value added. Yet, the ecological consistency which may also be referred to by terms such as eco-effectiveness, biomimicry, upcycling, recycling or bionics is not aimed at reaching a quantitative reduction but closed cycles and using of renewable energies, i.e., a value added embedded completely ecologically. In spite of conceptual differences, both approaches are united by the same basic idea: primarily the present prosperity and growth model is to be protected by decoupling it from ecological damages due to the technological progress and other innovations. As innovations are effective growth drivers, it is thus possible to magically convert a formerly problematic growth into a "problem-solving growth" now. The expectations thus roused are reflected in promising terms such as "double dividend" (Bovenberg and Mooji 1994; Goulder 1995), "Factor four, double prosperity – halved consumption of resources" (von Weizsäcker et al. 1995), "Third (or already even fourth?) industrial revolution" (Machnig 2007) or "Green New Deal". Instead of making "less" the subject of discussion, a commitment to a supposedly purified "in different ways" or "better" is made.

However, this decoupling euphoria in the sense of the best of all (consumption) worlds has lately no longer been taken up as unanimously as usually. The discourse on a sustainable perspective is polarised at the latest with the crisis triumvirate appearing – the climate change is dramatised, the basis of resources for the prosperity model is threatened by a "Peak Everything" (Heinberg 2007) and the financial world experiences an unprecedented chaos. Whereas one side takes the bull by the horns speaking about an "acceleration of growth", there is mounting evidence for a second discussion on growth elsewhere. Meanwhile, there is a discourse about "Economy beyond growth" (Daly 1997), "Prosperity without growth" (Jackson 2009), "Décroissance" (Latouche 2006), "Post-growth economy" (Paech 2008, 2009), a "Forward to moderation" (Binswanger 2009), a "La decrescita felice" (Pallante 2005) or an "Exit" (Miegel 2010) from the growth dogma. What are the reasons for this scepticism to growth?

2.1 Decoupling Not in View

The fiction of decoupling the economic value added from damages to the natural capital based on ecological efficiency and consistency is getting more and more unfounded in empirical and theoretical respects. This becomes especially obvious in climate change issues. In spite of the enormous technological progress for increasing energy efficiency and also using renewable energy sources, the global CO_2 load goes up rapidly. This is proved by the study of the "Global Carbon Projects" (Raupach et al. 2007). Here it becomes apparent that the reduction of the intensity of emission of a primary energy unit (ecological consistency) as well as the decline of the demand for primary energy per unit of value added (ecological efficiency) have come to a standstill. Instead of a decoupling rather a rematerialisation is to be observed. But even in preceding phases, where a decoupling effect was to be detected, this had not nearly been able to prevent the dramatic increase of CO_2 emissions.

"Rebound effects" – this collective name comprises the phenomena causing failing or ineffectiveness of decoupling measures – do not occur by accident (Paech 2005 b). In a system, in which the sole direction of development lies in the extension of possibilities, even the criticism of this logic of increase is ultimately subject to it; i.e., it is transformed into the necessity of further growth. That is why a change of energy would correspond to a growth of biogas plants, photovoltaic elements, wind power plants, passive houses, low-energy bulbs, hybrid cars etc. Yet, as long as these measures are firstly additional measures and secondly may never be entirely implemented without an energy input (keeping in mind the "indirect" energy underestimated mostly), a dilemma is threatening. If these new objects required for decoupling will not replace the so far existing less sustainable artefacts, a material growth will result. If, however, the stocks will be renewed, the cases of material disposal will increase. Ways out of this "selection dilemma" (Paech 2005a) require to give up the growth dogma.

2.2 The Logic of Social Growth Is Ambivalent

Fighting against poverty by means of economic growth is closely connected with the claimed advantages of international division of labour. Now, the main theorem of the trade theory according to which free trade is superior to the autarchy solution according to the Stolper-Samuelson theorem (1941) involves explicitly that this is connected with losses for specific branches. As long as these losses will be exceeded by a growth of the prospering branches, the winners may compensate the losers and nevertheless gain an increased income. But how safe is it that this transfer will actually take place and the trading profits will not simply be reserved to the betterment of an elite or the middle classes and thus the situation of the poorest parts of the population will get even worse as compared with the autarchy solution? It speaks for itself that notably Samuelson (2004) moves in for the kill against the free trade doctrine established by himself and others, explaining that given the conditions of globalisation gaining of net profits by free trade may fail and secondly doubting that if this will occur, a compensation of the inevitable losers of free trade will take place.

And a structural effect is added as the tempting chance of growth of material wealth promising a consumptive lifestyle which is, at the same time, based on a specialised gainful employment is bought at the costs of an essential social drop height. By means of the course of past famines, Sen (1982) presented that individuals giving up their ability to (an at least partial) self-supply in favour of a gainful employment paid by money may get even then into a threatening plight if sufficient goods will be available in the respective region to provide for all inhabitants. External supply based on money implies that the entitlement to goods depends solely on the purchasing power of the money income. Increases in prices as well as reductions of income may reduce the purchasing power below a limit which Sen (1982) calls "starvation set": The maximum of goods which a consumer can afford on the basis of his money income and the actual price level will not be sufficient for securing his livelihood. The recurrence of such scenarios proves to be very likely not only remembering the inevitable consumption competition between (bio)energy and food, whereby the prices of nutrition as a result may increase. In contrast to that these self-supply patterns, partially based on own work and local exchange relations, ensure a modest prosperity based on goods, yet are independent of globalised and therefore “remote-controlled” value chains. Thus, they reduce the social risk.

2.3 Will Growth Enhance Individual Happiness?

The “science of happiness” which lately was paid much attention to, as well in economic sciences, leads to the insight that an increase of the per capita income from a certain level does not bring a further enhancement of happiness (Comp. Layard 2005). A theoretical explanation of this finding which may be empirically verified for all modern consumer societies has already been given by Hirsch (1976). According to it, the benefit of consumption of many goods of a symbolic or demonstrative type is based on the social prestige, distinction and being part of a specific social group. Such “positional goods” are influenced by competition “aimed at reaching basically a higher position within an explicit or implicit hierarchy and thus profits for individuals are only possible by losses for others” (Hirsch 1976).

That is why an even higher consumption expenditure is required to maintain a specific, no longer augmentable feeling of happiness: With each upsurge specific consumers may improve their status. If this, however, will happen necessarily at the expense of the relative position of others, a further growth will be required to finance the increased demand for consumption of the last mentioned. This feedback – growth will require a new growth – has further effects as satisfaction with life is also based on human relations, the integrity of the social surrounding, success and recognition based on own abilities, health, security and an environment felt to be intact. An exhaustion of such aspects bringing happiness does not require money but time. On the other hand, financing an ever higher material living standard means maximising gainful employment. That is why less time remains for activities so far carried out by own work such as bringing up children and maintenance of the household or a garden which now also have to be converted into acts of consumption or services and financed which, on the other hand, increases the demand for work paid by money. If the selection of consumption options will explode, however, this conflict will aggravate. Thus, the minimally required time for exhausting consumptive options will become the bottleneck factor. “Having much will be inconsistent with living good” (Sachs 2002).

2.4 Peak Everything

The economy grounded on a permanent increase of consumption and mobility of modern industrial states is – to put it in a roughly simplified way – based on an expenditure side and a receipts side. The firstly mentioned comprises the expenditure of the required input concerning fossil energy carriers – primarily crude oil – and other resources. In the mean time in some former developing countries, a “revolution of consumption" (Myers and Kent 2005) is going on. The development of global middle classes extended by approx. 1.2 billion of "new consumers" forces the raw material prices up by an additionally induced demand for goods. Whereas recently there was still talk about "peak oil", this designated phenomenon has already long ago extended to "peak everything" (Heinberg 2007). Here, the absolute reduction of the quantities extracted is not decisive but the price drive caused by growth on demand which contributes to an erosion of the economic basis of further growth.

The receipts side of the northern prosperity model has so far been based on an international competitiveness considered to have an unassailable lead, in particular in the branch of scientifically and technologically intensive export goods. This advantage due to innovation has been melting away in the mean time. The climber nations mentioned before – China and India ahead of the others – will be increasing, due to investment in education, modern infrastructure and last but not least due to the global mobility of the "new consumers", in a position to conquer the markets which before have been the sphere of the technologically superior industrial countries. In the foreseeable future the transfer economies will be in a position to dispute the former winners of prosperity the right to all comparative cost advantages.

3 The Alternative: Post-growth Economy

A sustainable development deserving this name is not a project of additional achievements, but an art of reduction. In this sense a "post-growth economy" (Paech 2012) is aimed at overcoming the expansion imperative, the most important of which is a lifestyle depending completely on an external supply paid by money and based on global division of labour. Since demands satisfied formerly by craft activities, own work, subsistence, local supply and social networks, or which, if necessary, were even met with renunciation, have now been covered step by step by products for sale and automatisation/mechanisation generating services, the securing of existence is fatefully delivered to a growing supply with money. The individual, completely supplied by external resources, needs access to inexhaustible money sources supplied by gainful employment in the industrial and service sector, by company profits or by external transfer. The dependence on money augments with increasing culturally induced claims to material self-realisation. In addition, a way of life based on consumption and specialised gainful employment results in the trend towards stunting of all abilities for securing the existence (without money), notably for self-supply.

With specialisation increasing, requiring an ever bigger distance between consumption and production, the number of value added levels, with demand for investment and thus capital of which contributes to requiring economic growth, goes up. In this sense a post-growth economy is, first of all, oriented to the interplay between two developments supplementing each other: a moderate adaptation of claims (sufficiency) to the possibilities provided by own abilities or near, not multipliable options and resources (self-supply). This does not mean to turn back to the Stone Age, but a new balance between self-supply and external supply. An important key would consist in a reduction and redistribution of the average gainful employment. Assuming that the average hours of gainful employment would be reduced by a specific factor, the industrial external supply system could be scaled down to a certain extent. Thus, simultaneously time would be free to be used for providing market-free supply services.

3.1 Sufficiency: Reduced to the Max

To approach the target of a sustainable development, a pure replacing and improvement of former consumption solutions by supposedly more sustainable variants will not be sufficient. It is necessary to adapt the consumer demands to the possibilities of their sustainable satisfaction. This is not only supported by ecological arguments. Who risks sinking under a flood of nearly incalculable possibilities of consumption will not renounce if he will get rid of superfluous things. On the contrary, throwing off ballast which takes time, money, space and ecological resources providing otherwise scarcely additional benefit means more independence of the increasingly chaotic market process, money and gainful employment, i.e., freedom from stress. The sufficiency principle confronts the desperate search for a further increase of the prosperity of goods and comfort with a simple counter question: Which are the energy slaves, consumption and comfort crutches of which luxurious lifestyles and finally the whole society could get rid of?

Getting rid of such consumer objects, which take one of the most valuable resources, namely, time, will add to this. A minimum of attention – which is time – will have to be devoted to consumption activities to bring about benefit. Yet, as the options offered are actually exploding and a day has now as before only 24 h, the consumption competition for the time which cannot be multiplied, if it is to be distributed to an ever bigger number of consumption objects, is aggravating. A lower quantity of attention is increasingly paid to each of them. Thus, the minimally required time for exhausting consumptive options will become the bottleneck factor. Sometimes the point will be reached when time will be just only available to search for consumer goods and identify, compare, check, buy and store them – and then possibly not to use them because the time required for that has been already taken by the sum of innumerable selection and purchase actions. Notably the last-mentioned time input to be provided before proper use goes up rapidly, since, in the mean time, consumers waste their time in a sphere satiated by stimuli. The lot of news, alternatives and respective information to be processed in a time-consuming way increases continuously.

Only concentrating on a calculable number of options which then will receive sufficient attention will be helpful in this respect. Only those who will get rid of an overflowing prosperity ballast in an elegant way will be protected against becoming disoriented in the hamster wheel of buyable self-realisation. According to information given by the Ministry for the environment, every German citizen possesses on average 10,000 objects. A strategy of a sustainable clearing out would aim at reducing this stock slowly. This would be possible by slowing down the cycle of buying new things. Many durables such as instruments, cars, books etc. could be borrowed or jointly used with neighbours instead of every individual being equipped with everything. In addition, objects could be found which are no longer used or exist in the household twice. They could be passed on via second-hand markets or even free of charge via giveaway markets. In this way, not only ballast will disappear, but production will be saved because things will remain longer in the cycle of use. Establishing infrastructures suitable for that will be most easily successful on the local level. Clearing out life to feel more easy, free and independent does not only refer to material objects. Equally important is a removal of many services made use of, in particular, transport and food.

3.2 Urban Subsistence and Regional Supply: Regaining Economic Sovereignty

Due to resource shortage the globalised consumption model might no longer be financed in the foreseeable future. A reduction of social vulnerability requires supply structures with the smallest possible distance between consumption and production. Of course, external supply may be only gradually and selectively abolished. Who outwit dependence on consumption, at least partly by his own abilities, shows resilience. A rich continuum of various degrees of external supply lies between the extreme points of subsistence and consumption of products proceeding from globalised value chains. Here, the motto is applicable: as local as possible, as global as necessary. A new adjustment of the balance between local and external supply in favour of the first not only does create sovereignty but a sense of achievement, augments self-consciousness and reduces fears for the future. By reducing and redistributing gainful employment, self-supply and external supply may be combined in a way that the dependence on money and growth will go down.

The food domain in connection with urban agriculture (comp. Meyer-Renschhausen 2004) lends itself to reactivate the ability to satisfy independent demands beyond commercial markets. Community gardens of which more than 700 are solely existing in New York do not only make a contribution to economic independence. Apart from this, they provide many other advantages: healthy food, improvement of the city ecology, climate adaptation, the creation of CO_2 sinks and primarily promotion of social community. Community gardens are places of meeting, integration and acquiring practical abilities. In addition, they form green islands of slowdown in the hectic big city routine.

Further fields follow directly from the above-mentioned remarks on sufficiency. A disarmed stock of objects would be connected with using them longer and more intensive. Here, not only providers of hire and repair services would play an important part but also local self-help stations. Citizens could independently take over the service and maintenance of many an everyday object (if required, under the direction of skilled staff). Handicraft enterprises and educational establishments would have to contribute to reactivate the respective abilities. Especially children and young people should learn in a practically oriented way that own work, do it yourself and handicraft competence are of a high value. It is an expression of individual strength to surround oneself with things which can be serviced, maintained, repaired and adapted due to own abilities.

Manual and handicraft abilities as an element of urban subsistence do not only serve the own work but make also a contribution to community. The establishment of social networks for mutual support, i.e., independence of money and commercial markets, will be successful most easily if all participants will have abilities supplementing each other. Their synergy may be used through local exchange trading systems, networks of self-help and neighbourhood help, agenda 21 groups, volunteer agencies etc. Subsistence in modern societies does not mean that everybody will be able to do everything alone but that a coexistence based on division of labour will be possible on local level. Interesting approaches relating to that are contained in "Transition Movement" (Hopkins 2008).

Much of the demand exceeding this could be covered by regional markets and value chains up to concepts such as Community Supported Agriculture (CSA). "Local money" (North 2004) would have to play the role of completing the spectrum of supply systems at a decisive place. While pure subsistence forms at least under present circumstances are of a limited practicability – especially due to an educational system destroying each ability for that systematically – the consumption based on global division of labour should be regarded rather as a residual parameter to reduction (though not complete abolishment) of which should be striven for. Regional currencies combine advantages of specialisation as a pragmatic middle course. This is carried out largely deglobalised by concentrating on a regional context, i.e., at the same time ecologically more compatible and socially more stable. As regional currencies direct the purchasing power from the globalised markets to the local economy, the local demand for labour will be strengthened. Complementary currencies support also the exchange of products, services and manpower supply not marketed on commercial markets. Thus, they extend the effect striven for by local exchange trading systems: Persons, whose abilities are otherwise not demanded, are given the chance to engage themselves partly through regional cycles. If regional currencies have in addition a circulation securing in the sense of "rusting banknotes", they reduce, at the same time, the growth imperative induced by the interest rate system.

3.3 Material Zero-Sum Games

The residual consumer demand, which may be neither cleared out nor substituted by urban subsistence or regional supply structures, would have to be covered within an much reduced industrial system based on division of labour. However, industrial products and infrastructures could be optimised through the still unused possibilities of extending useful life or intensifying use in a way where values will be created largely without additional material production. In a physical-material perspective, growth neutrality means to find the way back to the natural rhythms of growth *and* shrinkage. Accordingly expansions would be bound to a compensatory contraction. The idea of "material zero-sum games" (Paech 2005a) comprises two perspectives:

- To keep the extent of material and energy flows, new possibilities of use are extracted from the pool of objects already produced and areas occupied. This involves systems of use to cover the demand and services for reassessing, reusing, recombining, converting or optimising the use of the existing consumption and production hardware without production. Changes are concentrated on a cautious redesigning of the already used spaces and resources instead of creating new material artefacts. Accordingly, the energetic restoration of an old house should be preferred to build a new passive house.
- If material objects would be added and ecological capacities would be additionally used, this has to take place with a compensating subtraction elsewhere. Thus, every further sealing of areas would have to be accompanied by a compensatory unsealing.

Material zero-sum games may consist in a combination of various change modes compensating each other by addition and subtraction, namely, innovation, exnovation (Comp. Yin 1979; Kimberly 1981; Clark and Staunton 1989) and renovation. Growth neutrality requires accepting the addition and loss of elements of the range of possibilities as equal principles. The innovation motto "how comes the new into the world?" has to be supplemented by the exnovation orientation "how can old formerly innovative things which, in the mean time, have become a problem leave the world again without inflicting damage?"

A by far more adequate approach consists in avoiding a difficult ridge walk to take place between an expansion (innovation) and contraction (exnovation) balancing each other. This will be possible most easily by applying the formal principle of renovation relating only to changes within the given space of option. Refurbishing, maintenance, repair and functional reassessment of existing objects may be applied to many goods. As an essential share of the total energy input made during the physical product life is irretrievably bound in the substance of the product forms of conservation, intensification of use or extension of useful life should be frequently preferred to the replacement of old by new hardware – which anyway is frequently not successful in view of the selection dilemma. This applies especially where objects may be improved by taking flanking measures as to their energy efficiency or consistency.

Apart from the energetic rehabilitation of buildings, plants and equipment, reuse systems for consumer goods (comp. Paech 2005a) by refined forms of second-hand trade provides an interesting perspective. Covering consumer needs without production in a circulating world of goods would be in a severe contrast with the traditional linear flow economy. Instead of creating new options of use by an additional physical production, they would be formed by a reassessment of elements coming from the fund of the already existing things. If we combine the change modes (innovation, exnovation and renovation) in the sense of material zero-sum games, a four-level search corridor for sustainable solutions will be obtained:

1. Direct connection between innovation and renovation. Example: Product innovations provide a high degree of growth neutrality if they do not generate new consumer needs but satisfy the previous needs more efficiently or consistently so that neither a motivation to early throw out things nor to parallel purchase them will be provided. Only products where the useful life cannot be by any possible means and all appropriate potentials any longer extended will be replaced.
2. Direct connection between innovation and renovation: Example: The sustainability performance and useful life of some products and structures may be increased by comparatively small material additions. Insulating materials of renewable resources (product innovation) may be used for energy efficiency of old buildings (product renovation).
3. Indirect connection between innovation and renovation. Example: Specific service innovations such as maintenance, refurbishing and repair may contribute to extending the useful life or intensifying the use of the existing product stock (product renovation). Institutional innovations such as the establishment of effective intermediaries for second-hand goods trade may also allow the renovation of objects of consumption. In contrast to the preceding strategy, renovation is reached here by a largely immaterial addition.
4. Indirect connection between innovation and exnovation. Example: Car-sharing approaches as a service innovation may result in the fact that the former owner of a car will not buy a new one after scrapping the old one (product exnovation) but will make use of mobility services.

By the direct connection of two principles of change is meant that they start with the same object category, if a *product* innovation and a *product* exnovation will materially cancel each other. An indirect connection of two change modes, however, consists in the fact that they start with different degrees of materialisation, namely product and service. An indirect coupling of innovation and exnovation might, e.g., mean that a *service* innovation will replace material objects, i.e., is connected with a *product* exnovation.

The criterion of growth neutrality suggests a prioritising ranking of the above-mentioned search fields. Accordingly solutions based not on material objects but on services (option 4) should be searched to cover a specific demand. If solutions of this type will be excluded possibly because services replacing property may not be consistent with market and cultural conditions, there should be searched in the next field (option 3) for possibilities to include the product property. Here, services would be concerned which maintain the material stock, i.e., prolong or intensify the flow of benefit to be gained from them. Only if this strategy will not provide suitable alternatives, product innovations will come into consideration, namely, first of all, as an insignificant supplement to an existing object for upgrading or improving efficiency (option 2). Only as a last possibility, a conventional product innovation is applied (option 1), however coupled to an exnovation to not increase the stock of material objects.

4 Result

Altogether five steps mark the way to a post-growth economy, namely (1) sufficiency as an act of clearing out or throwing off ballast, (2) new adjustment of the balance between self-supply and external supply, (3) deglobalisation by regional cycles and complementary currencies, (4) material zero-sum games and (5) institutional innovations. The last mentioned comprises, in particular, two basic conditions.

Firstly, a currency reform and a land reform are indispensable to alleviate system immanent growth pressures. Regional currencies equipped with an interest-free circulation securing could contribute to implement the currency reform. In addition, changed rights of ownership or use of estates and other essential resources would be of importance. An adequate measure is strengthening and reactivating so-called Commons (Barnes 2006).

Secondly, the still lacking assignment and limitation of environmental impacts could be remedied by expressing the elastic sustainability term by individual CO_2 balances in concrete terms. Accordingly products and services should be marked by means of a life cycle assessment (LCA) in conformity with the CO_2 quantities caused by them. Alternatively companies could publish their average values for the CO_2 footprint of their products in the internet. In this way each person may make his/her individual CO_2 balance the criterion of a sustainable lifestyle. Here lies the Achilles' heel of the social transformation required: Never before there have been so many people making a contribution to the flourishing sustainability discourse, distinguishing themselves as experts and living well on explaining others the world from the perspective of sustainability – whose lifestyle, however, could not be farer from it. This nearly schizophrenically appearing gap between knowledge or speaking, on the one hand, and individual actions, on the other hand, has long ago developed into a mass phenomenon spreading to the middle classes of other continents oriented to consumption and mobility.

The communication on sustainability, in the mean time, even increasingly globalised is no longer part of the solution but part of the problem: Mostly self-realisation practices based on consumption and mobility equipped with a sustainability symbolism are the object of social diffusion. The last mentioned is based on products and engineering solutions of a mostly additive character, yet the relative progress of efficiency or consistency remains ineffective as long as the demand grows faster than each potential decoupling effect. What will be the use of a 3-l car if its owner will drive it three times as much as the owner of a 6-l car, and the number of cars will increase without limitation? What will be the use of a passive house against a conventional house if the owner of the first one will go by air once a month, whereas the owner of the last mentioned will go by train?

Strictly speaking, "sustainable" objects (products, services, technologies, infrastructures etc.) do not exist but only sustainable lifestyles. That is why the only congruent target variable of a sustainable development may be the individual CO_2 balance. Accordingly, each person would have the same right to an annual emission quota which would total two to three tons on average. However, these emission rights could be transferable and tradable between persons. That means if inhabitants of the richer hemisphere will apply for a higher demand, they would have to acquire the lacking rights from the inhabitants of less prospering countries which would thus ensure a global adaptation of the monetary wealth. In this way the sum of all available quotas would be not higher than the total load which would be compatible with the 2°C target of climate protection. It seems to be clear that this condition required for the protection of earth will not be possible my means of a decoupling strategy but only by a post-growth economy.

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Chapter 4
Economic Growth and Resource Use

Andreas Breitenfellner

1 Economic Growth: An Energy-Driven Phenomenon

The recently ended *Great Recession*, which was the worst since the end of World War II and whose effects we will undoubtedly be feeling for a long time to come, clearly shows how very dependent our socioeconomic system is on growth. When GDP slumps, unemployment and government deficits increase, and financing for social security, health care and other entitlements, as well as environmental expenditures, is more difficult to come by. But if the economy grows by more than 2% per year (as was the case prior to the recent economic crisis), the exact opposite occurs. Employment rises, which in turn swells the coffers of the social security administration, and a balanced budget suddenly seems well within reach. Hence, the only real yardstick for the success of politics is economic growth – social partners and economic theorists agree on this objective too.

And while economic growth is something that we moderns take for granted, it's in fact a relatively recent phenomenon (Maddison 2001). Since the dawn of human civilization, economies, such as they were, grew at a snail's pace. During the first millennium AD, the world economy grew at an annual rate of only 0.01%, rising to 0.22% over the ensuing 820 years. Economic growth did not really hit its (heretofore unimaginable) stride until the advent of the Industrial Revolution in England in the late eighteenth century. Between 1820 and 1998, world GDP rose at an annual rate of 2.21% and, despite economic crises, over the past decade reached an average of 3.5%. And for 2010, world economic growth of around 4.5% is nearing the precrisis highs of

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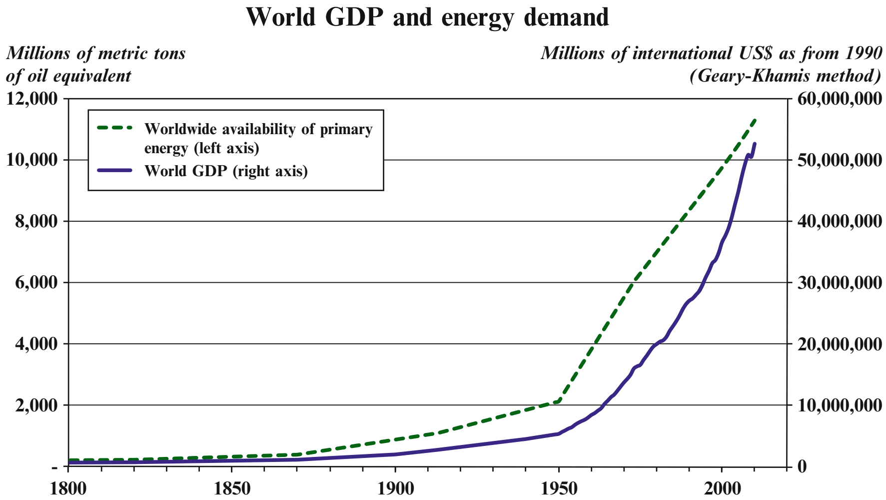

Fig. 4.1 World GDP and energy demand. Source: Maddison (http://www.ggdc.net/maddison), plus proprietary calculations

more than 5%. This constitutes exponential growth, which means that the absolute amount of economic growth also increases. A relatively low economic growth rate of 2% would represent a doubling of production and consumption every 35 years. And if even the relative percentage rises (as suggested by the figures above), then strictly speaking we are in the presence of mega-exponential growth. Five per cent growth would equate to doubling of production and consumption in a mere 15 years.

Needless to say, economic growth needs to be viewed against the backdrop of the global population growth rate, which has declined from 2 to 1.15% since the 1970s. Thus, we need only minimal economic growth nowadays to ramp up the most telling of all economic statistics, namely, per capita GDP.

Economic growth is driven by a number of factors, including productivity growth, employment rates, savings and investment rates, and foreign trade, to name only a few of the usual suspects. However, energy consumption is rarely taken into account in this regard – a presumably unjustified tendency, as Fig. 4.1 shows. The Industrial Revolution ushered in an era of stepped up energy consumption on a par with economic growth, although increased energy efficiency is also a relevant factor here – but one that did not take on major worldwide importance until the 1970s. In other words, energy resource availability is a critical factor when it comes to the growth potential of the global economy. Even the rosiest scenarios that forecast a rapid rise in energy efficiency and an optimal use of renewable energy unavoidably presuppose that our primary energy resources are finite. Indeed, a causal link between energy consumption and economic growth would imply the existence of an endpoint of economic growth, albeit its effective date might be difficult to determine.

Analogies from nature can be useful up to a certain point when it comes to a critical analysis of the economic growth process. For example, biologists take it for granted that any continuously growing system will run up against its own limits at some point, for in a finite environment unending growth is simply not possible. That's why most economic growth curves are S-shaped which characterizes capacity or saturation limits. According to system theory (Matthies 2002), this phenomenon is attributable to the fact that a system's dynamism and stability are determined by positive and negative feedback, whereby the latter keeps ecological systems in a relatively stable equilibrium. Positive feedback, on the other hand, normally leads to exponential growth that ultimately jeopardizes system stability. However, it is not really possible to extrapolate from system theory something along the lines of a "general law of the impossibility of exponential growth" – if only in light of the latest cosmological discovery to the effect that the universe is expanding at an ever increasing rate despite the countervailing force of gravitational pull.

But when it comes to our own Earthly system, a good case can be made for the physical limits to grow, particularly in an economic system. Indeed, the economic evolution of advanced industrial countries strongly suggests that exponential economic growth is merely a passing phase. The economic history of the post-war era would appear to indicate that many European economies have already transitioned to a linear growth phase; that is, they are growing by fixed amounts but not at a constant percentage rate (Bourcarde and Herzmann 2006). That said, the implicit determinism of this concept appears to have been repudiated by the dynamic economic growth of the decade leading up to the 2008 financial crisis. The growth during this period led numerous economists to the conclusion that elevated growth rates can be *sustained* even in highly developed economies. This concept is implicitly endorsed by publications such as the OECD's Going for Growth study (issued at 2-year intervals) or Weißbuch Wachstum, which was issued by the Austrian economic think tank WIFO (Aiginger et al. 2006). The main thrust of such publications is that growth potential, employment and the public finances can all be strengthened through supply side reforms – namely market deregulation and liberalization, and ever more privatization of government activities and assets. But the financial crisis has dampened such hopes, at least temporarily. For one thing, the crisis illustrated that therefore most part private and public debt financed economic growth, we had been experiencing far exceeded the actual growth potential of the real economy and were merely pumping air into an ever expanding financial bubble that was bound to burst. And secondly, the crisis not only made us lose the ground that had been gained but also put a major wrench in the works of growth potential for the foreseeable future (Gaggle and Janger 2009).

Although countless examples of warnings about the limits of growth stretching back to the early days of economics could be cited, the attendant predictions have tended to be wide of the mark. For example, in the late eighteenth century, the British economist Thomas Malthus' failure to take account of agricultural production growth caused him to reach the unfounded conclusion that unchecked population growth would inevitably lead to widespread poverty. And in the 1970s the Club of Rome made a similar gaffe when, having conducted model-based simulations of economic growth, population growth, life expectancy, available natural resources, pollutant emissions and farm production, they predicted the collapse of the world economy in 2030. And a 2004 update of the Club of Rome's projections (Meadows et al. 2006) predicted that most of the Club of Rome's scenarios where the limits of economic growth are exceeded will lead to an economic collapse at some point between 2030 and 2100. The argument often advanced against such apocalyptic scenarios is that humanity has always managed to get itself out of a tight squeeze by means of ever new solutions and that technical progress has always enabled us to expand our horizons ever further. But there are two problems with this view. First, just because previous prophecies have proven wrong does not necessarily rule out the possibility that one of them might prove to be right this time around. And second, if it was not for our awareness of the limits of economic growth, it is unlikely that there would be any interest in solutions that would allow us to transcend those limits. In other words, such forecasts serve a useful purpose even if they do not come true.

2 Natural Resources: A Peak Experience

The recent skyrocketing of raw-material prices has rekindled debate concerning the possibility that our natural resources are anything but unlimited. Between 2000 and 2008, the price of oil, which is the benchmark for all other energy prices, rose 500% to an all-time high of $ 145 a barrel. In the wake of the financial crisis, the price of oil fell to less than one third of this price, only to rise again to about two thirds of this level.

In point of fact, steadily rising prices for exhaustible resources is a perfectly plausible economic reality. Some two centuries ago the British political economist David Ricardo warned of diminishing marginal returns from minerals, while *Hotelling's rule* (1932) states that the soil scarcity rent of an exhaustible resource will increase over time in proportion to the market interest rates. Viewed from this perspective, the era of low oil and natural resource prices from the mid-1980s to the mid-1990s was an anomalous blip on the radar screen of history. During this period, Saudi Arabia abandoning its defence of OPEC prices and rising North Sea oil production increased supply, whereas demand declined owing to lower energy use in the OECD region, the Eastern European transformation crisis, and the ensuing Asian financial crisis.

The latest spate of raw-material cost increases is mainly attributable to the mammoth demand for such resources in burgeoning economies, notably China and India but also in the Middle East and Latin America. The pivotal factor here is the growth rate, rather than the absolute level of consumer demand in newly industrialized countries. More than 60% of world oil demand still stems from the OECD region, although consumption here has been on the decline since 2008 owing to the recession and high oil prices.

At the same, this demand has been somewhat stifled by limited resource availability. According to the US Energy Information Administration (EIA), average oil production has stagnated for the past 3 years, resulting in reduced stores of oil. This has provided ammunition for advocates of the so-called peak oil hypothesis, which holds that maximum worldwide oil production has already been exceeded and that production is bound to decline gradually, along the bell-shaped Hubbert curve (Energy Watch Group 2008). Even oil companies have embraced a scaled down version of this theory, their key reservation in its regard being that it applies solely to readily accessible oil, but not to unconventional sources of oil such as oil sand, deep sea exploration and Arctic oil exploration. However, activities of this nature will need to clear monumental technological and environmental policy hurdles, not to mention the costs involved, some of which may exceed the 100 dollar a barrel mark. And then there are skyrocketing mining costs, which are partly attributable to insufficient capital investment and professional training during the low-raw-material-price era of the 1990s. Even the International Energy Agency (IEA) (2010) acknowledged that conventional crude oil production never will regain its all-time peak reached in 2006.[1]

These endemic shortages have facilitated the resurgence of OPEC, although pinning most of the blame for resource price increases on this organization would be overstating the case. Even without a price cartel for each individual state, resource nationalism constitutes rational behaviour, which also takes into account the stewardship of national wealth for future generations. This evolution results in postponement of essential capital investments, although until mid-2008 the reserve capacities of OPEC member states were extremely low. As oil production declines in the North Sea, Gulf of Mexico and now Russia as well, responsibility for the world's energy supply is increasingly falling on the shoulders of the OPEC states. The fact that the OPEC region is not exactly known for its political stability is certainly no accident, for resource affluence and economic development are negatively correlated – except in industrialized countries. Disquieting news reports about geopolitical tensions chiefly provoke greater price volatility.

The extent to which speculation has contributed to our current predicament has given rise to some lively debate. In some quarters, speculation is seen as a destabilizing and deleterious practice, particularly when it involves attempts to manipulate prices by means of mammoth transactions. But there are also those who take the view that speculation promotes transparent and efficient pricing via liquidity. Even in cases where speculation drives prices above the basic price trend, it can serve the cause of optimal resource allocation in that high oil prices draw attention to untoward evolutions such as the possibility of shortages down the road. High prices send a signal to consumers to save energy and a signal to oil producers to develop additional sources.

The view that financial and capital markets tend to overshoot is undisputed by economists. Speculation adjusts to trends and overshoots them temporarily, but in a manner that is commensurate with fundamentals. What's involved here are not so much short-term-oriented speculators looking to make a killing, but rather (1) institutional investors who, in times of financial market turbulence and increasing investor unease, diversify and in so doing gravitate towards more secure raw-material

[1] Thus, increasing demand can only be met by additional natural-gas liquids and unconventional crude oil.

asset classes, and (2) energy consumers and producers seeking a hedge against price fluctuations. One indicator of the impact of financial markets on raw-materials price is the latter's correlation with the exchange rate of the US dollar, whose weakness has in all likelihood been a driver of oil price increases (Breitenfellner and Crespo Cuaresma 2008). However, opinions vary as to the impact of harmful speculation. Although the volume of transactions involving the raw material derivatives known as paper barrels has tripled since 2005, an unlimited supply of these products is available. Moreover, futures prices are regarded (particularly in Rotterdam) as a benchmark for spot markets and for long-term contracts. That said, Nobel Prize Winner Paul Krugman (2008) has impugned this concept, contending that if the financial markets actually generated artificial scarcity, this would be mirrored by large-scale resource hoarding. But at first glance the scope of today's stockpiles does not support the "oil bubble" thesis – although recent research reveals that hoarding is practised in the oil industry. That said, if oil and raw-material prices are mainly determined by fundamental forces of supply and demand, expectations and speculation nonetheless promote excesses (Breitenfellner et al. 2009).

Oil price increases in turn drive up the price of many other resources, in that relative to nonenergy resources, oil constitutes either input (energy), a substitute (biofuel) or a competitor for key capital goods such as excavators. According to a World Bank study on the food crisis that caused quite a stir (Mitchell 2008), 75% of the increase in corn, wheat and soybean prices is attributable to biodiesel and bioethanol production. The study author also shows that the lion's share of unmet demand can be laid at the doorstep of biofuel. The other oft-mentioned causes such as higher energy and fertilizer costs, the weakness of the dollar, drought, speculation and changes in dietary practices are only marginally responsible for these evolutions. Export embargoes on the part of developing countries, which are likewise often blamed for such evolutions, are in fact merely a reaction to rising prices and have mainly impacted rice prices.

Against this backdrop, one can speak in terms of a basic energy crisis, on whose resolution the development of the resource supply mechanisms for the world economy hinges. In its World Energy Outlook (International Energy Agency 2010), the IEA warns of high prices over the long term. Despite the financial crisis and the recession, energy demand is expected to continue rising, particularly in newly industrialized countries, to the tune of a 36% increase by 2035. But supply is having ever growing difficulty keeping pace with demand. An increased oil supply will mainly come from the nationalized oil companies in the OPEC member states, but the concentration of primary fossil fuel energy in non-OECD nations will increase our dependency in this regard. An even greater trend towards concentration is in the offing for natural gas, since three countries (Russia, Iran and Qatar) have more than 60% of global natural-gas deposits, although *unconventional* natural-gas reserves in the US will provide some relief in this regard. But in any case oil remains the most important energy resource, even though coal and renewables are taking on greater importance.

The financial crisis has not only put a brake on energy demand but has also, through low energy prices and restricted credit access, prevented much needed capital investments from being made in new energy resources and technologies. Long-term energy resource shortages are likely to be the result – if only for the simple reason that currently producing fields are gradually depleting. It is essential that this supply side deficit be offset via new sources. Short-term price volatility aside, it seems that the era of cheap oil is over.

3 Hopes for Resource Efficiency

The IEA has called for an *energy revolution* involving the production, conversion, use and consumption of energy resources (International Energy Agency 2008). Improved energy efficiency and increased use of renewables will ultimately also aid the cause of climate protection. Higher oil prices promote efforts to achieve energy efficiency at low or even negative net cost. The estimated cost (1.1% of annual GDP) of developing and using low-carbon-energy technologies by 2050 will entail at least the equivalent savings on fossil fuel costs. An efficient counterstrategy will necessitate higher energy efficiency, lower energy demand and the use of more environmentally friendly technologies. At the same time, optimized energy efficiency and increased use of renewables will reduce our dependency on fossil fuels and ensure that there are enough resources to go around. An energy sea change also appears to be necessary from an economic standpoint, as it would, over the long term, promote energy price stability, lower the cost of achieving climate protection objectives and open up opportunities for sustainable growth and high employment. But these goals simply cannot be achieved unless we create the requisite incentive framework by restructuring our tax system, which would mean reducing high taxes on labour, increasing taxes on natural resources, implementing the relevant regulatory measures and funding innovation.

To achieve an annual economic growth rate of modest 2% while at the same time reducing carbon emissions to 20% below 1990 levels, resource productivity for fossil fuel use will need to increase by around 5% annually. We also need low-resource strategies that comprise more than promoting zero energy consumption business processes, but without deluding ourselves that economic growth can ever be compatible with a scenario involving full dematerialization (Liedtke and Kaiser 2007). The world's industrialized nations account for 20% of the global population but consume around 80% of the resources that are used worldwide. If the entire world population were living this high on the hog, we would need three additional planet Earths.

Already in the past, increased resource productivity has delivered impressive results, often in the absence of any particular policy strategy, a case in point being the 2.5% annual energy efficiency increase achieved across all OECD states in the industrial sector between 1965 and 1995. But unfortunately, the growth of OECD economies outpaced their resource productivity during this period largely due to the so-called rebound effect. A rule of thumb factor of 4 for guaranteed absolute reduction of resource use (energy, materials, water and land) has been posited

(Weizsäcker et al. 1995), although many experts say that we will need to halve resource use in order to achieve a sustainable worldwide resource use level. If this latter estimate proves to be right and if at the same time all human beings are to be guaranteed reasonable access to natural resources, the industrialized nations may need to ramp up their resource productivity by a factor of 10. And this in turn would require us to make giant technological strides the likes of which humanity has never achieved before.

But in spite of all this, bullishness about the potential saving graces of technology is not completely unreasonable from an economic standpoint. Dematerialized economic growth is a viable theoretical possibility (Acemoglu et al. 2010), the only problem being that the empirical way forward in this regard has yet to be mapped out. Up until now, the economic and environmental policy debate has revolved around the Environmental Kuznets Curve (EKC), which hypothesizes that the relationship between per capita income and the use of natural resources or sinks (e.g. for CO_2) has an inverted U-shape (Brock and Taylor 2005). According to this specification, at relatively low levels of income, the use of natural resources increases with income. Beyond some turning point, economic growth promotes a fundamental change that promotes environmental protection, and the use of natural resources declines. The curve for local emissions has been empirically substantiated (e.g. for sulphur dioxide, which causes acid rain), whereas convincing scientific evidence concerning worldwide pollutant load or resource use has yet to be adduced. Intriguing exception in this regard, however, are fluorocarbons, whose use is now banned worldwide. This measure apparently gave rise to the technological bullishness of the new Europe 2020 strategy, which calls for a “resource efficient Europe” with a view to “help[ing] decouple economic growth from the use of resources” (European Commission 2010, p. 4).

If our politicians genuinely get behind sustainable economic growth (as was the case with the Brundtland report), it is far more likely to occur. Nonetheless, in view of the tremendous uncertainties involved and the potentially catastrophic consequences of failure, it would be nothing short of irrational to put all of our environmental and economic policy eggs in one basket. In other words, although strategies aimed at ramping up resource efficiency are indisputably needed, it also makes good economic sense to consider alternatives to a paradigm that calls for economic growth without end.

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Chapter 5
Resource Protection Policy: An Opinion from the NGO Perspective

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The natural resources are randomly distributed over the Earth, without giving regard to the presence of humans. Until recently, the human population and, particularly, the industrial societies did not consider this to be a problem. Except for the discussion about dwindling oil reserves, the debate about natural resources that are worth being protected has rarely raised any awareness among the general public. In recent years, however, a change has been observed in this regard. Such change may be attributed to the fact that politics and society have started to approach the issue not only from the aspect of the Earth's carrying capacity. This means that the central question is apparently whether ecosystems are able to cope with the exploitation of resources. Rather, it means whether there is a sufficient stock of special and strategically important resources available and thus, whether the existing economic structures can be maintained. Eventually and at last, people seem to recognize the limits to growth with regard to the supply of raw materials for human needs. Such scarcity cannot always be attributed to geological causes, as meanwhile acknowledged as a fact for the raw materials, copper (strongly increasing annual consumption), oil ("peak oil" was already reached in 2006) and phosphorus (recognized as being available for another 100–240 years) (IEA 2010; Morf 2007). Unrest in industry and industrial policy has been caused, firstly, by individual nations exclusively securing for themselves the access to raw material deposits all over the world (political scarcity). Secondly, the mining of many raw materials is already now dominated by a few companies having a monopoly position. As a result, the development of prices and dependency of processing establishments and entire national economies has become unpredictable (economic scarcity). Scarcity should also result if due to exploitation of sources of raw materials important ecosystems disappear from the Earth's surface

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or human rights are violated, because this would make mining impossible. However, such considerations do not play any role (or at least none that would be relevant for decisions) among those who decide on the mining of raw materials. In this regard, there is a need for changes in the future. A fragile ecosystem like that of the Arctic must not be freely available for the mining of raw materials, nor could inhumane conditions in the extraction of raw materials be accepted as a basis of our consumer products. The emergence of such a situation would require economic and political stakeholders to act in a way so that this would also lead to a scarcity of raw materials, because in such a case, the mining of raw materials would be inadmissible, in spite of existing deposits. In fact, it is impossible to make a clear distinction between the different definitions of scarcity. Also, this is not always required because any conservation of resources will also be to the benefit of biological diversity and inter-generational equity. It is an objectionable fact that still sustainability issues hardly play any role in raw material policy. Nevertheless, the fact that the current policy regarding raw materials exists at all should be seen as an opportunity to establish a successful resource protection policy – no more, but also no less than this.

1 Resource Protection Policy: Why Is It Necessary?

In the past, the volume of energy-producing and that of mineral raw materials exploited were dominated by the demand from industrial countries. Meanwhile, however, a progressive orientation towards consumption and purchasing power in developing and emerging countries has been additionally boosting the demand for products and thus, for raw materials. This effect is intensified by a steadily growing world population requiring increasing quantities of materials to be extracted from the Earth's crust. In addition, many technological developments have led to an increasing demand for rare elements by mankind. We doubted whether such demand is always justified with regard to sustainability. For example, purchasing a fresh mobile telephone every second year is in no way compatible with the notion of sustainability. Meanwhile, modern information and communication technologies are using 50 and more different chemical elements to make a single product. Firstly, these elements are rare, and secondly, many of them are available only if associated with the mining of other raw materials. As a result, the weight of the "ecological rucksacks" of such materials is very high, as a rule. In addition, the valuable materials mostly become irretrievably lost at the end of the utilization phase of the products because the number of such appliances subjected to high-quality recycling processes is by far too small.

Another example of resource overexploitation is presented by industrial agriculture as we know it. It will come close to its ending in within two centuries because the supply of phosphorus required for the production of fertilizers can no longer be maintained. At the same time, however, renewable raw materials are becoming *en vogue*. There has been a great variety of initiatives by the industries producing building materials, plastics and other materials to do so on the basis of renewable resources. This approach carries the promise of independence from oil and other fossil raw materials, and being ecological, it provides a favourable image for the industries. However, these renewable resources will often depend on the application of artificial fertilizers and thus, are threatened by indirect scarcity. In addition, the land area available to cultivate renewable resources is limited, thus thwarting conversion and alleged eco-friendliness. If not even earlier, the general public became aware of this problem when there were the debates about the cultivation of renewable raw materials as bioenergy sources competing with food crops. This will be the same when discussing the use of renewables as materials for production (which is to be classified as more meaningful than that for energy). In addition, changes with regard to land use have other negative consequences such as soil erosion, emission of greenhouse gases and shortage of water for the ecosystem and the human population as its user. Another counterproductive factor is the allegedly efficient use of genetically modified organisms, which is increasingly propagated and practised in the production of raw materials. Such genetically modified crops are increasingly reducing the biological diversity, including species, habitats and genetic information, thus contradicting any sustainability targets. At this point, it should only be mentioned that a reduced biodiversity also means that ecosystems may provide fewer services for humans and become less and less resistant and adaptive.

In addition to immense greenhouse gas emissions, a use of resources is also associated with damage to ecosystems. Thus, the mining of raw materials below or above ground will interfere with habitats and involve a movement of residual materials, for example, of mining wastes. If taking this into account, this would mean, for a number of parameters, a further increase in the figures for material consumption by mankind beyond the levels commonly observed today. In addition, for example, the use of chemicals to extract certain substances such as gold with the aid of cyanide has far-reaching consequences for the entire environment.

The only conclusion to be drawn from the variety of these and many other examples and facts that could be mentioned must read as follows: Ways of thinking and acting that strive to broaden and enhance the access to resources are taking the wrong approach. Accepting these ways would mean to tolerate resource consumption to continue growing year after year despite knowing that this would exacerbate the problems outlined above as examples, as well as many others. As a result, future generations would be left with a plundered planet.

2 What Does Resource Protection Policy Mean?

Resource protection or resource conservation policy constitutes an alternative to the dilemma described. According to calculations by the Global Footprint Network, nearly three Earths would be required if the entire human population consumed resources at the same rate as what the population of Germany has been doing (WWF 2010). However, there is only one planet Earth. Nevertheless, the absolute resource consumption by mankind has been on a steady increase. This may also be illustrated by means of another indicator representing the overexploitation of our resource base on which life depends, even if there was a shift towards using renewable resources wherever possible. Since 1986, the Earth Overshoot Day, also known as Ecological Debt Day, has been in existence. It marks the calendar date in the course of the year when the human population begins to use more resources than Earth's annual bio-capacity can regenerate. After this date, mankind enters into ecological debt. The new indebtedness has been growing from year to year, which becomes evident by the fact that each year, the Earth Overshoot Day has fallen on an earlier date than in the previous one. In 1986, the day was December 31. In 2010, all annual resources theoretically available were used up already on August 21. The calculation of this day is based on data describing the ecological footprint (WWF 2010).

This is the reason why a policy of sustainable management of resources, that is, massive savings in the use of resources and the absolute annual resource consumption, respectively, is indispensable. Such policy should take effect in the fields of economy, infrastructure, research, environment and agriculture and likewise, in foreign and trade policy. It is true that Germany and Europe alone will not be able to resolve the most urgent issues by pursuing such a resource policy. Nevertheless, being a high-tech and specialized consumer society representing one of the spearheads of resource wasting, they will have to curb such wasting and constitute a good example of how to reduce resource consumption in the future. The incorruptible logic of this conclusion corresponds to that drawn in climate policy: As an actor having to accept both historical and contemporary responsibility for the problem, an industrial country should pursue appropriate reduction targets aiming at minimizing the per capita environmental impact to a sustainable level that corresponds to a global average. Experts at the World Resource Forum agreed that this threshold value should amount to about 6 tons of resource use per year and per capita (WRF 2009). Such per capita consideration has become known from climate policy where a CO_2 emission of 2 tons per year was estimated to be a justifiable and fair value.

2.1 Disclosing Resource Consumption Levels

In Germany, the annual per capita resource consumption has clearly surpassed an amount of 30 tons, that is, more than five times the level admissible in terms of a sustainable raw material management (SERI et al. 2009). This illustrates why a global initiative for a sustainable raw material management is required. Such initiative will only result in successful political and economic decisions if based on conclusive data, indicators and concepts. In contrast to financial flows, resource flows can be observed only incompletely at present because their documentation has not been compulsory. This is the point where resource protection policy has to start by setting clear provisions for a transparent recording and compulsory documentation of material and substance flows.

This is supported by official statistics of resource flows (integrated environmental-economic accounting). First signals have already become evident in this regard. In Germany, such type of accounting exists already ("Umweltökonomische

Gesamtrechnung"). In December 2010, also the European Parliament supported the EU Commission's efforts to introduce a unified and integrated environmental-economic accounting as a compulsory measure. It is envisaged that from 2012, it will be possible to publish also the gross ecological product of the European Union, in addition to the gross domestic product.

Also the manufacturing and processing industries and trade will be faced with so far unknown tasks in the context of resource protection. With a view to sustainability, each enterprise should know and be able to document the upstream and downstream value chain. However, as long as the origin and processing of resources are not traceable in an appropriate way, it will neither be possible to avoid conflict-prone regions where human rights are ignored, nor to principally prevent the introduction of pollutants into products. It is up to each stakeholder in the value chain, from the raw material miner to the recycler, to make production and product flows transparent in this way. Thus, each enterprise will have to make up an overall balance of its resource consumption. In many places, the stakeholders have already started to reduce the consumption of materials. This fact demonstrates that there is an awareness of resource protection, on principle, also in cases where an increase in material efficiency is only based on rising prices as a motive. In many fields of economy and society, very concrete indicators of material consumption are recorded – the consumption of office paper by an enterprise or the consumption of drinking water in a city, for example. The procedure will become more complicated when it comes to the consumption of highly technical or agricultural resources and to extended value chains involving many processors. Neither soil erosion on agricultural land nor the use of rare earths in mobile phones or computers and the resulting "ecological rucksacks" are exactly stated by enterprises.

Hence, it is a fact that there are two extremes that need to converge. Firstly, there are global and thus very abstract indicators that can be described. Secondly, there are resource consumption figures that are most limited due to their local or sectoral origin. There is no common system which would allow an exchange of data and prevent them from becoming duplicate entries in statistical records. An important objective should consist in a transparent recording of resource flows within enterprises by a corresponding balancing including indirect material flows over the entire value chain, going along with environmental-economic accounting (e.g. by means of the MIPS concept; cf. Schmidt-Bleek 2000).

In addition, to ensure the provision and use of global consultancy on resource protection, it is important to strengthen the influence of the International Resource Panel. This panel of experts presently affiliated with the United Nations Environmental Programme needs to assume a consultative status that is similarly important as that of the IPCC in climate policy.

2.2 Formulating Resource Protection Policy

Politics must have a model, and there is a need for objectives and measures to adhere to this model. The model of resource protection, sustainable raw material management and resource efficiency requires rather general objectives. These objectives should not only comprise target parameters as described above but also more concrete demands. This is the reason why non-governmental organizations, together with the European Environmental Bureau in Brussels, are advocating a factor-four improvement of resource consumption by 2030 within the EU. In order to achieve this, for example, resource efficiency would have to be doubled and raw material consumption would have to be halved. In the long run, that is, by 2050, it will be necessary to achieve a factor 10 to approach the target of 6 tons of annual per capita raw material consumption, as explained above. Resource protection policy consists in breaking down these objectives and thus, making them practicable. In this regard, Japan may be held as an example, at least what concerns politics. That country has set itself the target to massively increase resource efficiency by 2010 and at the same time, to reduce the absolute consumption of raw material. There have been hesitating approaches to such a policy also in Germany. It is a goal of the federal government of Germany to become the country with the most resource-efficient national economy by 2020 and therefore, to double resource efficiency as compared to 1994. In this respect, however, the shifting of German resource consumption towards abroad due to the import of semi-finished and finished goods should also be taken into account, a fact which continues to be often omitted from considerations.

2.3 Integrating Resource Protection Policy into Sustainability Objectives

Support programmes and awards involving benefits for both the environment and regional economies are consistent with the notion of sustainability and therefore, necessary for resource protection policy. This is why the German Materials Efficiency Agency (Deutsche Material Effizienz Agentur – demea), the efficiency agencies of the German Federal Countries or initiatives such as the Resource Efficiency Network are important. However, these initiatives alone do not suffice to establish a resource protection policy. Resource policy is a trans-sectoral issue being of relevance to a great number of political sectors. Therefore, it should be coordinated by means of sustainability policy. A disadvantage consists in sustainability strategies of governments, regions and enterprises being quite general regarding their objectives and setting only a few concrete targets. Rather, resource protection requires very clear targets and measures. Nevertheless, a basis for this can already be found in the latest Progress Report on the National Strategy for Sustainable Development by the German federal government, which also included a chapter on sustainable raw material management. Since the Earth Summit held in Rio de Janeiro in 1992, sustainability has been a political goal ratified by governments all over the world. These are the management rules of sustainability relevant for resource use that were adopted by the German federal government in 2010 (Bundesregierung 2010):

- Basic rule: Every generation must solve its own problems rather than passing them on to future generations. At the same time, it must make provision for foreseeable future problems. This applies to conservation of the natural resource basis on which life depends, to economic development and to social cohesion and demographic change.

- The consumption of energy and resources must be decoupled from economic growth, as must the volume of transport. At the same time, every effort should be made to ensure that the growth-related increasing demand for energy, resources and transport services is more than offset by efficiency gains.
- Renewable natural resources (such as forest stands or fish stocks) should only be utilized to an extent which allows them to regenerate. Nonrenewable natural resources (such as minerals and fossil energy sources) may, in a long-term perspective, be used only where their functions cannot be replaced by other materials or energy sources. In the long run, the emission of substances must not exceed the ability of ecosystems to adapt accordingly, for example, that of climate, forests and oceans.

So far, none of these three rules has been successfully complied with. Sustainability has been debated again and again. It has even been abused, by means of arguments defending the economic well-being of individual enterprises or industries, to prevent ecological innovations or systematic ecological reforms of the economy. An example is provided by the often cited loss-of-jobs argument of the automobile industry: So far, it has been successful in preventing a reorganization of mobility services, which would be urgently required in a densely populated country like Germany and should reduce motorized private transport, which is associated with a 23-h average daily stand-still period of private cars.

Nevertheless, painting a gloomy picture would not be appropriate to the current situation. Scientists agree that it is not yet too late to reorganize the management of natural resources. Although the time window is a small one, there is a realistic chance to use it because changes may also hold enormous economic opportunities. A few examples to be mentioned include the financial savings that may be expected from enhanced resource efficiency or the potential of a society using services instead of products.

Nevertheless, it is somewhat more difficult to propose clear directions for a resource protection policy than for climate protection policy: Resource protection policy is more complex and has to go far beyond a mere pursuit of energy saving and shifting to renewable energy sources. Resource protection policy offers an opportunity to set more concrete targets than sustainability policy has done so far. The success of such efforts depend essentially on the signals and incentives received by politics, economy and society at the third Earth Summit on Sustainable Development in Rio de Janeiro in 2012.

2.4 Combining Resource and Climate Protection Policies

The aims of resource protection policy should include a generation of effective solutions to satisfy needs, the elimination of unnecessary patterns of consumption and the development of pioneering approaches to recycling and efficient use of materials in the sense of environmental compatibility and the Earth's carrying capacity. The first task to be accomplished should consist in a radical change of the consumption habits of industry and society. This does not mean to perform abnegation. Rather, it will result in reducing current austerity which is reality due to resource overexploitation. We will have to abandon the traditional general commitment to growth which is based on the use of natural resources and to the strengthening of material-using industries. The availability of raw materials is difficult to predict and shows great differences with regard to the geology, biology and logistics involved. This is precisely the reason why both humans and nature have a vital interest in reducing the annual consumption of resources and increasing the efficiency of their use. In addition, the availability of resources is only part of the problem: There is evidence that the quantity of greenhouse gases emitted as a result of the production, processing, use and disposal of natural resources has disastrous consequences for the global climate. For example, Germans are responsible not only for their domestic greenhouse gas emissions but also for those resulting from the production of a toy bought locally but produced in the Far East. Hence, not only the use of the sources (raw materials) is limited but likewise, the disposal capacity of the atmospheric sink. In many similar cases, resource and climate protection policies will have to act jointly.

Resource protection policy can and has to learn from the experience as well as from the mistakes made by climate and sustainability policies. The former has generated successful instruments such as the Renewable Energy Sources Act, which made the onward development of renewable energies a joint societal task (Bundesgesetzblatt 2008). Society has learnt that ambitious targets such as those referring to heat insulation and efficiency of energy-generating plant are indispensable to achieve, within short periods of time, improvements that are tolerated by the ecosystem.

2.5 Resource Protection, Security of Raw Material Supply and Closed Cycle Management Policies

Policy areas committed to and having to take into account the use of raw materials already exist. In these areas, the relevance of resource protection policy has already been largely realized. There have been single timid steps to strengthen resource protection policy, for example, in the sector of closed substance cycle management, the former waste management. Regrettably, policy regarding closed substance cycle management in Germany does not focus on resource protection but on the recovery of energy, and there is a shortage of coordinated and targeted policy regarding resource protection everywhere. From our point of view also, the draft of the new German Closed Cycle Act (Bundesgesetzblatt 2012) does not comply with the principle of high-quality recycling and has failed to implement an objective corresponding to the European five-step waste hierarchy and the notion of cascade utilization systems. The reuse and recovery rates of materials have fallen considerably short of the limit of what is technically and economically achievable. Waste incineration is funded by state subsidies because it is neither subject to energy tax nor included in greenhouse gas emissions trading. A basic obligation for industry and population to separately record secondary raw material flows has not been introduced. The use of recycled materials in the production of important building materials such as concrete has remained on a minimal level although this approach would save large quantities of natural resources. An EU framework directive on biological waste in Europe is still missing, which would put into practice closed cycle substance management at least for this partial sector of waste management. In Germany, it is more or less left to industry whether industrial wastes undergo high-quality processing and thus, are recycled as often as possible. There are no objectives regarding the avoidance of waste generation, which means nothing else but resource protection, let alone targets of waste avoidance whose non-compliance would incur sanctions. In this way, it is impossible to achieve a 100% recycling rate to the benefit of climate and resource protection. However, this is the only option to secure a sustainable supply with raw materials, and it could in addition make a contribution to reducing the dependency of raw material supplies on the prevailing political conditions in other countries.

In addition, closed cycle management policy and raw material securing policy obviously continue to pursue opposing objectives: Startlingly, the German government's raw material strategy (Federal Ministry of Economics and Technology 2010) has turned out to be an instrument of raw material securing policy. Although the strategy's core objectives include the demand "to improve the framework conditions for recycling", carefully reading will reveal that the document actually strives to secure the access to and the utilization of primary raw materials. Savings in the use of materials are neglected as much as the onward use of products or recycling of wastes, although these constitute the essential principles of a sustainable raw material management. Also development policy and biodiversity policy have been pursuing resource protection objectives. Nevertheless, they have so far been unable to promote an integrated political approach in accordance with the national sustainability strategy of the German federal government.

To begin with, different priorities would be required for the promotion of research in Germany. Presently, extensive funding of the high-tech strategy of the federal government or of biotechnology constitutes a preferential contribution to supporting the development of resource-wasting uses. Helpful research programmes such as FONA (Forschung für Nachhaltige Entwicklungen – Research for Sustainable Development) have clearly been dwarfed by the ones mentioned above.

3 Resource Protection Policy in Concrete Terms

The indicator to test resource policy in the German sustainability strategy consists in what is referred to as raw material productivity. In its annual indicator report, the Federal Statistical Office has evaluated Germany's performance as not being utterly negative. The term raw material productivity denotes the relation between the annual consumption of materials and the growth of the gross domestic product. The lower the ratio of quantity of materials used to economic output, the more sustainable the development will be. At the same time, however, it is pointed out that this indicator is of limited evidence because it fails to represent the indirect material flows ("ecological rucksacks") and will improve with Germany's development towards a service society: The consumption of materials recorded only takes into account the quantity of raw materials mined in the country itself and the products imported into the country while failing to consider material flows outsourced to other countries such as excavation material from mining. By the new indicator Raw Material Consumption (RMC) it is at least achieved to account the direct material intensity of upstream semi-finished products. Also the graphical representation of this indicator in the indicator reports published on a biennial basis does not reflect the indirect material flows. The raw material productivity could only be increased by less than 40% within a period of 14 years. As mentioned above, a major part of this increase has to be attributed to nothing else than the structural change towards the less material-intensive service sector and the relocation of manufacturing steps at sites abroad. This means that also according to the official assessment by the sustainability strategy, the German policy for a sustainable use and conservation of natural resources is still at the very beginning and will require considerably more effort to be made.

Japan has shown that things can be handled in a different way: Since 2008, recording has included all material flows caused by society, including the hidden (indirect) material flows that are relocated to production sites abroad. The development towards a sustainable raw material policy is also supported by other political objectives as formulated, for example, in 2010 by the European Union in "Europe 2020: A European strategy for smart, sustainable and inclusive growth". The strategy is focused on a flagship initiative for a resource-efficient Europe. But again, the way how to achieve this goal remains undisclosed, although the precautionary and sustainability principles have been clearly formulated in the EU treaties. Other and more concrete goals are required because experience has shown that setting goals without a simultaneous adoption of measures and intermediate objectives is useless, as has been demonstrated by the increase of raw material productivity in Germany.

3.1 Corporate Responsibility

When it comes to resource protection, both enterprises and political stakeholders should be guided by the walk-the-talk principle – that is, to give an example by their own action. In this context, enterprises take on a particular strategic role because they have the best know-how and the strategic potential to save resources. They play a decisive role in placing consumers in a position to act and shape their demand in a sustainable way. Probably the best instrument to turn resource protection into a permanent issue in enterprises is provided by the environmental management system, EMAS III. Meanwhile, this system can be used all over the world. It is based on independent verification of corporate goals by external experts. Enterprises are required to continuously improve their environmental performance, however, in whichever way they prefer to do so. A decisive contribution to resource protection is made by knowledge on the origin of the raw materials and products used or their strategic purchasing taking into account the criteria of resource protection. Transparent disclosure of such data will facilitate checking and prevent misuse in dealing with these issues. As proposed above, data should be acquired by means of standard procedures (MIPS, “ecological rucksack”, etc.). In addition, each enterprise in Germany should assume responsibility for environmental and social standards abroad, that is, wherever it has products produced or purchases goods.

In the sense of industrial ecology, economic stakeholders should already at present form networks together with other enterprises in order to mutually benefit from their know-how and to be able to optimize production processes. Other approaches such as production-integrated environmental protection (also referred to as cleaner production) offer additional chances for enterprises to put resource protection into practice.

However, the above approaches may only be implemented if decisions concerning resources are made on the management level instead of being delegated to the purchasing, sales or marketing departments. In cases of doubt, the latter might decide against resource protection and in favour of short-term financial profit maximization. Nevertheless, it will still be required to establish a “design for recycling” instead of a “design for marketing” or to align promotion and marketing with the principles of resource conservation.

3.2 Political Responsibility

There is a general awareness of the problem of resource availability and overexploitation of natural resources and its dimensions. Also, little by little, the need for taking action has been acknowledged in many circles. So far, however, there has been no successful launching of sufficiently effective policy initiatives. Still, there are many reasons for increased resource protection efforts: More urgently than ever, they are needed for ecological reasons and in addition, could allay concerns with regard to a scarcity of resources. They may slow down climate change and help to conserve biodiversity on Earth. To this aim, the entire range of political creativity should be exploited. For the lack of time alone, the human society cannot afford to first study single trial runs of resource protection measures, then implement them as a part of pilot projects and eventually, decide about their effective introduction on a large scale by means of political decisions. Given the dramatic situation regarding the overexploitation of resources, it is an established fact already today that the problem does not consist in whether different political measures should be combined but only how this should be done. It is important to realize that increases in efficiency alone will not be sufficient to resolve the problem of resources. Often enough in history, enhancements of resource and material efficiency that were lacking appropriate political monitoring led to increases in raw material consumption. Such rebound effect has often been described with reference to the efficiency enhancements achieved by the introduction of the steam engine: Its introduction on a broad scale resulted in a massive increase in raw material consumption because the processing of raw materials had suddenly become cheaper and simpler than before. This rebound effect may also be exemplified by modern energy-efficient flat screens or efficient car engines: In both cases, technological development has resulted in larger dimensions and growing numbers of devices and motor vehicles being sold. Accordingly, also resource consumption has increased as compared to the previous situation. Politics could, however, anticipate this mechanism and avoid it by means of steering instruments which will be discussed in the following.

When it comes to the challenge of resource protection, regulatory policy will not impede economic activity and functioning of the markets, but instead, it will make them possible in a sustainable version. In the future, more requirements will have to be set up to determine the eco-design of products and production methods, with regard to their effects not only on the consumption of energy but also on the entire consumption of resources. This will even include mandatory requirements taking into account that a product or its components should be reusable, free from harmful substances and readily recyclable. Such integrated product policy will also have to result in minimum standards being introduced for new products whose dynamics will be determined on the basis of the "top runner" approach. As a result, it will no longer be required to fix limit values, but instead, the technical improvements proper will provide for a steady increase in the minimum standards in the future.

There are already some suitable approaches to a promotional policy. However, these are still lacking a widespread effect. Within the current financial frameworks, it will also be impossible for these approaches to develop broad effects on their own. Rather, they will probably only be able to generate a kind of élite in the manufacturing industry, which will have an (at least) efficient niche status and exist alongside with standard manufacturers. Approaches to be mentioned include programmes to increase corporate resource and material efficiency as initiated by the Federal Ministry of Economics and Technology and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Although it will probably meet with considerable public disapproval, also tax policy will have to play an important role, which in the case of resource protection means increasing the financial burden to sanction high resource consumption and reducing the latter to promote resource-efficient management. Tax policy should be sophisticated not only with regard to the quantity but also with regard to the quality of the materials used, that is, also scarcity, "ecological rucksacks" and recyclability should be taken into account. The simplest form of fiscal resource protection policy will consist in abolishing environmentally harmful subsidies. A classic example of such subsidies is provided by the fiscal incentives for commuters by means of the commuter's tax allowance, but they also include the exemption from energy tax for power stations burning pre-sorted waste. Steering charges of different kinds and designs may be meaningful. Thus, a tax levied on beverage packagings depending on the type and quantity of material used would result in an increase of the market share of reusable bottles and avoid the consumption of up to 400,000 tons of plastic materials. Another fiscal instrument to be considered should be a tax levied on the extraction of resources for mass building materials. This could, for example, enhance the use of recycled materials in the building and construction industry and reduce the negative impacts on mining regions, most of which are important for biodiversity. This list could definitely be extended to other sectors.

In addition, cross-sectoral political instruments for resource protection should be used that are aimed at consumption patterns and product designs. They could promote a change in attitudes both on the part of consumers and that of strategic decision-makers and marketing experts in the production field. In this way, a specific procurement of resource-efficient products and services by the public sector and private companies, respectively, will enhance the sales prospects and market presence of the corresponding solutions also in the private sector. Owing to the new German legislation on public procurement (Act on Modernisation of Public Procurement Law) which took effect in April 2009, this is possible already today but still far from being a standard feature. After all, as much as 25% of the demand in Germany consists of orders by the federal government, country governments and local governments. Regulations on procurement of this type may promote the use of recycled materials, a transparent labelling and the selling of service solutions instead of products. By 2015, Germany should have implemented a public procurement sector which is based on a 100% ecological orientation, similar to what has been accomplished in Finland (Finish Ministry of the Environment 2009).

There are a great number of sustainable and thus resource-efficient lifestyles. What they all have in common is the need for a radical change in habits regarding many fields of action. This will apply as long as a plus in (financial) consumption is tantamount to increasing consumption of resources. A debate on values to be held within the society is therefore indispensable and will have to be supported and guided both by political stakeholders and commercial enterprises. Once there are new resource-effective markets and the market power of resource-consuming industries will have dwindled, it will be easier also for the end consumer to put resource protection into practice. Nevertheless, everyone is in the position to make resource-saving consumption decisions already today. Examples could include deciding to move to a home in an urban agglomeration near the centre of one's vital interests, deciding not to own a car, or deciding to use craftsmen's services instead of purchasing all sorts of special tools. In July 2008, the Action Plan on Sustainable Consumption and Production and Sustainable Industrial Policy was published by the European Union. This plan means a proper approach to resource protection because consumers' and manufacturers' responsibilities are jointly taken into account. Nevertheless, the ten EU rules on sustainable consumption are not particularly helpful and rather trivial. On the one hand, they include daily consumption-related decisions such as purchasing products with ecolabels. On the other hand, factors are omitted that are extremely decisive with regard to an individual's resource consumption such as the choice of one's home or place of residence. Nevertheless, it remains important to support and develop the awareness and the resulting decisions by means of intensified educational measures in favour of a resource-efficient thinking both in economic activities and everyday life. Thus, the issue of resource conservation should be included in the curricula of schools and universities, in training schedules and also in professional onward education schemes.

Other opportunities to promote resource protection include the legislative competence on the federal and on country levels. For example, it is important to properly implement the sustainability assessment of envisaged legislation recently introduced on the German Federal level. This will support the adoption of legal regulations being in fact limited to those promoting resource protections instead of encouraging increased consumption. In this way, for example, the car scrappage scheme would never have passed such resource protection assessment.

3.3 Sustainable Raw Material Policy Should Go Beyond Resource Protection Policy

The raw material policy of the German federal government must not undermine other political goals. As already mentioned, dealing with the problem of access to raw materials for industry will at any rate remain inappropriate if it fails to be considered in the context of resource protection and sustainable raw material management. This will not only mean to make resource protection efforts a first priority and the ultimate objective. Rather, it should also take into account the prevailing situation in world trade, in external economic policy and development policy.

To be able to conduct a successful resource protection policy, developing and emerging countries need support in creating environmental and social standards, and they should also have appropriate monitoring facilities. To begin with, such activities will provide for human rights reviews and environmental impact assessments by independent bodies to become a prerequisite for being granted export credits, investment guarantees and untied financial loans. Eventually, they will also include the approach to using the wealth of natural resources of developing countries for a sustainable poverty reduction. As soon as politicians will ask how development cooperation is contributing to a sustainable and secure raw material supply for Germany, they should in turn be able to answer the question whether German foreign, economic and financial policies are making an essential contribution to sustainable development in those countries where the raw materials are mined. In order to be able to address and resolve conflicts of this type in the first place, political processes such as the development of the raw material strategy should only be carried out with the involvement of all stakeholders, a prerequisite which so far has been omitted. Given the aim to align the raw material strategy and the high-tech strategy with the objectives of the sustainability strategy, such approach should succeed in the future and in contrast to the course political processes have taken so far.

4 The Key Role of Resource Protection Policy

One could have the impression that politics have lost their importance in more and more fields of public and economic life. Rather, from now on, they will have to play an essentially more important and influential role in resource protection. Neither economic actors nor consumers have even begun to implement resource protection on their own initiative. To do so, they need clear political targets and regulations that are based on knowledge about international, national, resource-specific and general societal issues. The temporal horizon to have developed a sustainable raw material management in the industrial countries by 2050 is a narrow one. However, it also makes the success of future political activities come within reach.

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Chapter 6
Legislation on the Protection of Natural Resources: Basic Considerations and Legal Perspectives

Ulrich Smeddinck

1 Introduction

For ages, there have been human activities resulting in an overexploitation of resources.[1] Contemporary environmental law has seen a comprehensive development. Nevertheless, resource protection has only recently become an important topic of environmental policy.[2] As a logical consequence, the question arises as to which extent the legal system takes account of this topic. New challenges and necessary adaptations will have to be identified.

This present chapter will highlight characteristic aspects of the field of resource protection law. However, a quite dynamic development is under way in this field. The Federal Environment Agency (Umweltbundesamt – UBA) has identified the need for action at an early stage and assumed the role of an initiator by launching some corresponding research projects.[3] In contrast to many other presentations, the present chapter is looking for an individual approach to the topic by using a different perspective: Resource protection law shall not be discussed as a mere extension of legislation on wastes (cf. Wendenburg et al. 2009). Likewise, it is not the intention of this chapter to cover the entire development of legislation in this field.

In the course of this presentation, a number of basic considerations (including conceptual ones) will be developed and presented (Sect. 2). The latter are found to be in contrast or in agreement with a variety of innovations and activities in the field of legal policy which have already been put into effect or have to be implemented (Sect. 3). The contribution is completed by a conclusion and outlook (Sect. 4).

[1] Blackbourn (2008).

[2] For former approaches, cf. Radkau and Schäfer (2007).

[3] Brandt and Röckseisen (2000), Roßnagel and Sanden (2007).

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2 Basic Considerations

In this section, a number of considerations are presented which may serve as a basis for the development of resource protection law in the near and the more remote future. It is discussed whether resource protection constitutes a value in itself (and in this context, also the concept of resources itself is addressed) (Sect. 2.1). The concepts of resource protection, sparing use of resources and resource efficiency are considered in depth (Sect. 2.2). The relationship between resource protection, product responsibility and waste management is analysed by conceptual criteria (Sect. 2.3), and current preliminary considerations on the operationalization of resource protection are presented (Sect. 2.4).

2.1 Does Resource Protection Constitute a Value in Itself?

There are doubts as to whether the concept of resource protection could serve to achieve an accentuation opposing the predominantly waste-based discussion of legal policy. This would be the case if resource protection could be defined as a value in itself. To resume the above interpretation,[4] resource protection should aim at the actual protection of resources, in the sense that resources are worthy of protection as a component of pristine nature, on the one hand, and as a potential to be used also by future generations, on the other. Inevitably, attention should focus on the term resource itself, for further elucidation.

The concept of resource already implies the perspective of use because a resource is something to be utilized for human activities and interests. Initially, understanding is dominated by resources as raw materials for treatment and processing.[5] Hence, the basic constellation already seems to imply an anthropocentric perception. The latter, however, appears to be hardly compatible with a classification as a value in itself, which, after all, represents an ecocentric perception. Does this not provide a potential for substantiation of a paradigm shift and guidance towards a view of the emerging legal field from an opposite angle? Upon a closer look, the concept of resources becomes more complex, and the use as a raw material is supplemented by at least another important function.[6]

According to the "freedom thesis" (German: Freiraum-These), the precautionary principle in emission control law in the sense of a planned resource economy also takes provisions for future excess pollution loads (Jarass 2007). This also includes

[4] See Sect. 2 above.

[5] Resource: (a) Natural means of production for economy and (b) something that can be used for support or help, reserve and capital (Dudenredaktion 1982, definition translated from German); Resource refers to "reserves" as designating those amounts of a raw material which, although presence has been demonstrated, cannot be exploited for technical or economic reasons, plus those expected to be exploitable on the basis of calculation (Angrick 2008).

[6] On a resource concept encompassing creativity in addition, cf. Göhler (2008).

the preservation of intact habitats (Couzinet 2007). Hence, resource provisioning is to be considered as one dimension of the precautionary principle, in addition to that of risk prevention. In this capacity, it is aimed at safeguarding economic and ecological freedom by means of largely avoiding or reducing pollution of the environment (Calliess 2006).

From the angle of natural philosophy, also intrinsic rights of all parts of the surrounding creation can be substantiated, including landscape and the elements of earth, water, air and fire (Meyer-Abich 1984; Bosselmann 1992). This notion is based on the principle of equality. Two things are to be treated as equal according to their similarity and as different according to their different character. The human species has emerged from natural history as one of millions of genera on the tree of life, together with animals and plants, earth, water, air and fire. This historical relatedness is associated with conformities categorically justifying the use of the principle of equality between humans and the other parts of nature (Meyer-Abich 1984, p. 174).

As an enhancement of the intrinsic value, also the concept of human heritage could be rendered fruitful in this context. Human heritage includes objects which are subject to national sovereignty in the individual sectors but, nevertheless, are of material or nonmaterial importance for all nations across national boundaries. Examples include culture, nature, environment, flora and fauna and factors affecting climate such as tropical forests, coral reefs and health. These are goods all nations are simultaneously interested in. At least what concerns their inexhaustibility, they should not be subject to unrestricted and selfish use. An approach is envisaged to develop a mechanism ensuring development and fair or even balancing utilization and protection against harmful influences for all stakeholders. Making reference to mankind as a carrier includes, on the one hand, the perspective encompassing all nations and people, and on the other, the temporal perspective directed towards future generations (Paech and Stuby 2001).

A variant consists in the demand to keep the natural capital at a constant level in order to provide for intergenerational equity. The exploitation of nonrenewable resources may only be substituted by capital widening in the field of renewable resources. In the individual case, it is envisaged to permit appreciation of values if the cost of replacement of nonrenewable by renewable energies is too high, with the burden of justification to be met in favour of the preservation of natural capital.[7]

Article 20a of the Basic Law[8] aims at the prevention of impairment or even destruction of the natural habitats and conditions of life for present and future generations of the human species (Erbguth and Schlacke 2009b). The prevention of harm is a paramount constitutional obligation. The preservation for use by future generations is an additional requirement. Furthermore, Article 20a of the Basic Law forms the basis for deriving an objective legal mandate for management of environmental media insofar as this is required for safeguarding the interests of future generations.[9]

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[7] Wieneke (2006). The attempt to establish the notion of intergenerational equity in the Basic Law has failed so far. Cf. Kahl (2009).

[8] Dated 23 May 1949 (BGBl I p. 1), as last amended by the Act of 29 July 2009 (BGBl. I p. 2248).

[9] Kluth (1997), pp. 105, 107 with further references. For a critical view, cf. Groß (2009).

Hence, the resource concept can be attributed a core meaning which claims a need for protection, although not in the ecocentric sense. Thus, the concept encompasses a worthiness of protection which goes beyond a mere provisioning of raw materials.[10] Again, this brings benefits for humans, although in an indirect way. Nevertheless, it can be clearly substantiated in this way that resource protection from the waste perspective is insufficient and inappropriate for the issue concerned. This is exactly why an accentuation is desirable that could serve as baseline, opposition and counterbalance, even if eventually, the perspective of use may assert itself again. Accentuation may be transported by using the concept of "resource protection law". Such understanding of the concept will have implications for further operationalization and instrumentalization. A development of concepts will also shape the contents (Schulze-Fielitz 2002).

Due to the basic character of the resource concept, however, the approach of resource protection will hardly be suitable to serve as the last barrier against resource exploitation. Also an ecocentric view recognizing intrinsic rights of nature would not result in a permanent priority of human interests (Bosselmann 1992, p. 272; Meyer-Abich 1984, p. 48). Even nonrenewable environmental goods may be utilized and consumed. This will always require an additional justifying reason. Altogether, the component of protection remains little pronounced. It is impossible to achieve a level of intensity similar to that associated with the protection of basic rights.[11] The orientation towards resources emphasizes, to a greater extent, resource management and thus, a sparing use of resources and resource efficiency,[12] which may be implemented above all from the angle of product responsibility. In addition, resource protection may serve as a starting point for other problem complexes such as land use (Wieneke 2006).

2.2 Proper Understanding of Resource Protection, Sparing Use of Resources and Resource Efficiency

One will notice that different terms are used in the environmental policy debate on this topic. The terms of resource protection/conservation, a sparing use of resources and resource efficiency are used as if they were more or less synonymous. At any rate, they are not clearly defined. This gives reason to scrutinize the terms and establish their interrelationships. Resource protection should aim at the actual protection of resources, namely, in the sense of resources to be worthy of protection as a component of pristine nature and as a potential to be used also by future generations.

[10] Thus, Angela Merkel demanded: "Resource consumption must be based on the capacity of ecosystems." (cf. Der Tagesspiegel 2011).

[11] Representative of all: Erbguth and Schlacke (2009a), § 4 marginal no. 27 ff., 31.

[12] Relativization of the right to protection by the concepts is emphasized by Kunig (cf. Kunig 2003).

In compliance with such determination of their meaning, a cascade-like relationship should be assumed to exist between the concepts. In this relationship, the protection of resources should have a priority position, followed by a sparing exploitation and management and, again in a subordinate position, by an efficient use of resources already in use. Such graduation is suggested because a sparing use of natural resources will also serve their protection; it will, however, remain second to conservation. Sparing use instead of conservation will have a bearing on the degree of protection (Kunig 2003).

To put it in other words, protection of a resource would mean conservation of the pristine resource (resource protection in a narrow sense). Sparing use would mean a cautious exploitation, and efficiency, the optimal and repeated use of the exploited resource whichever its use may be.[13]

It is true that resource protection cannot be implemented in an absolute way. Also, there are other issues that are likewise important. Nevertheless, the term of resource protection is basically suitable and more appropriate to characterize and guide the legal framework to be developed. In the interest of conceptual clarity, it would therefore be appropriate to speak of resource protection in a broad sense. In the further course, such prioritization could be specified by the obligation to use secondary raw materials and consider the opening and exploitation of old landfills prior to the utilization of pristine resources. This would mean an appropriate reaction to the fact that in the long run, resources are exhaustible and economy must rely on deposits of recyclable materials in waste (cf. Wendenburg et al. 2009, pp. 163, 165) and that the wastes from industrial production are the cheapest raw materials available.[14]

2.3 Relationship Between Resource Protection, Product Responsibility and Waste Management

The future design of resource protection, in a close interplay with product responsibility, counts among the most important fields of development of environmental law.[15]

So far, however, resource regulation has been considered, to a considerable extent, from the perspective of legislation on wastes. Initially, the impetus did not originate from the protection of natural resources but from the shortage of areas suitable for waste disposal in Germany (cf. Wendenburg et al. 2009, pp. 163, 164). According to this notion, the Closed Substance Cycle Waste Management Act adopted product responsibility as a complex of regulations in its own right in 1996: Pursuant to § 22

[13] In its § 1, the Closed Substance Cycle Waste Management Act uses the term of "Schonung der natürlichen Ressourcen", that is, sparing use of natural resources. Against the background of a concept understanding as outlined above, it is doubtful whether this means an appropriate implementation of the Waste Framework Directive, referring to "protection of resources" in Article 4 para 2 subpara 3.

[14] Friedmann (2008).

[15] Sachverständigenrat für Umweltfragen (SRU – German Advisory Council on the Environment) – SRU (2008), Thomé-Kozmiensky et al. (2007).

para 1, parties, who develop, manufacture, process and treat or sell products, carry product responsibility for compliance with the aims of closed substance cycle waste management. In order to comply with the aim of product responsibility, products must be designed, if at all possible, in such a way that waste production is reduced in the processes of their production and use and that environmentally compatible recycling and disposal of the wastes resulting from their use is ensured.

However, the understanding of product responsibility would be insufficient if it were focussed on waste management aspects only. Rather, it should be seen from the opposite perspective as a "transit station" between the poles of resource protection and coping with waste generation.[16] This means that there is a phase focussing on production but reaching far beyond in both directions (Schwegler and Schmidt 2008). Beyond waste law, corresponding regulations on product responsibility are found already in the existing legal system, for example, in legislation on genetic engineering, dangerous substances, pollution control, foods and other commodities, as well as medicinal products, and also in the contexts of contracts, liability law and criminal law (in detail: Kluth and Nojack 2003).

The shift in perspective (Smeddinck 2009, pp. 304 ff.) in the legal field of Resources–Product Responsibility–Wastes does not constitute an end in itself: The factual and conceptual approach is changed. Conceiving and implementing future environmental and legal policy instruments from a different starting point will result in perspectives and solutions different from those to be expected from developing and "improving" the outdated waste perspective. So far, this field is dominated by an approach based on regulatory policy, market and technology (cf. Wendenburg et al. 2009, pp. 163, 165, 170), diverting the interest from looking for other solutions and governance arrangements.

As far as product responsibility is concerned, it has become apparent that a further development will take place mainly for reasons of resource economy, that is, the manufacturer's own interest in the conservation of the resources exploited, and not as a result of official or regulatory requirements. In a tight financial situation, consumers will increasingly be interested in the potential uses. Ownership and responsibility may remain with the manufacturer. In this way, the chances of economic advantages becoming effective on both sides are better than those existing under conditions of a repeated change of ownership (Wendenburg 2007).

Ideally, the development of the legal field should be aimed at a partial codification comprising three books in the order, Resource Protection, Product Responsibility and Waste Management, and reflecting the actual process, that is, the use of resources. Material flow regulations could be integrated in each of the codes or recorded in a separate book. Currently, the subordinate position of product responsibility in the Closed Substance Cycle Waste Management Act does not comply with its central and above all, primordial importance. Similar to the suggestion made by Winter, that is, to introduce a General Environment Act instead of an Environmental Code (Winter 2007), one could think of creating a separate Federal Resource Protection Act.

[16] Fundamental references include Brandt and Röckseisen (2000), Führ (2000), Rehbinder (1995), and Groth and Knappmann-Korn (1993).

2.4 Current Considerations to Prepare Operationalization

A number of approaches have been considered regarding the operationalization of the topic of resource protection/resource efficiency: The need for defining clear objectives, measures and instruments to promote energy and resource efficiency both with regard to supply and demand has been emphasized. The strategy to accelerate the implementation of resource efficiency has been stated to be indispensable. Its development should be based on a great number of different components (Pfahl 2008, pp. 11, 14). Special regard is to be given to the great number of different actors and the fact that they were affected in different ways. In concrete terms, measures are to be designed for a sparing use of resources by reducing the consumption of such resources and the generation of wastes in general. At the same time, this is to achieve positive economic effects by cost savings and technological innovation. Specifically, it is necessary to identify efficiency potentials, boost existing instruments, enter into a dialogue with stakeholders, develop a communication strategy and create networks.[17]

In more detail:

- Identification of efficiency potentials: Actually existing potentials that would enable an increase in productivity are to be identified. Environmental exposure is to be reduced over the entire life cycle (including processing abroad) of products and materials involved.
- Onward development of existing instruments: From this angle, several approaches may be taken: There should be a systematic implementation of eco-design standards in product development.[18] It will be necessary to complete substance cycles, improve recycling, promote the development of innovative environmental technologies, reduce subsidies that promote resource consumption, perform a labelling of products, initiate market incentive programmes to increase sales of resource-efficient products and further develop the raw material indicator. The latter ensures a better consideration of the environmental and sustainability effects of raw material production, particularly that taking place abroad.
- Dialogue with stakeholders: Given the complex and dynamically developing relationships between the diverse economic sectors, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) will have a stake in inter-sectoral and resource dialogues.
- Developing communication strategy: This aspect addresses the topics of raising awareness and initiating public discussion of the issue of resource efficiency. This is important against the background of a lack of recognition of the value of materials and the associated chances by the public and small- and medium-size businesses.
- Creating networks: In order to promote innovation in environmental policy, the creation of networks is to be initiated. In this way, advantage could be taken

[17] On this issue and the following, cf. Pfahl (2008), pp. 11, 15; also cf. Fiebig-Bauer (2007), pp. 102 ff.

[18] Cf. Ecodesign Directive (2005/32/EC) with a limited scope.

of economic opportunities to the benefit of the environment and Germany as a business and research location. Accordingly, BMU organizes political conferences on the topic of resource efficiency.

A variety of regulating instruments have been listed in the synoptic view by Pfahl. Onward development of resource protection law has neither been addressed directly nor excluded.

3 Legal Policy: Innovations and Activities

More or less in parallel to the research projects described and inspired by the same environmental problems, but at different times, legal policy initiatives of resource protection have been launched. On the one hand, this contribution is to demonstrate that in some instances, the legal system has already taken account of the interest in resource protection (Sect. 3.1). On the other, it is intended to outline that there is a considerable need for action resulting from the new European Waste Framework Directive (Sect. 3.2).

3.1 Innovations in Legal Policy de lege lata

Above all in recent years, a few regulations to the benefit of resource protection have been put into practice. Even if in the individual case, also cross-sectoral programmes were implemented, the resulting regulatory links between regulations are not easy to understand.

The context of legislation on waste, for example, includes the Packaging Ordinance,[19] the End-of-life Vehicles Ordinance[20] and the Electrical and Electronic Equipment Act,[21] each with their implications on resource conservation.

According to § 1 para 1 sentence 1 of the Packaging Ordinance, it is the purpose of this regulation to avoid or reduce the effects of wastes from packagings on the environment. Primarily, packaging wastes should be avoided. Otherwise, reuse of packagings and recycling of materials and other forms of recovery are to be preferred to the disposal of packaging wastes.

The German End-of-life Vehicles Ordinance stipulates in § 8 para 1 that in order to promote the prevention of waste generation:

1. The utilization of hazardous materials in vehicles is to be restricted and to be reduced as much as possible even during the conceptualization of vehicles, in particular, in order to prevent their being released into the environment, make the recycling of materials easier and avoid the need for disposal of hazardous waste.

[19] Dated 21 August 1998 (BGBl I p. 2379), as last amended by the Act of 2 April 2008 (BGBl. I p. 531).

[20] Dated 21 June 2002 (BGBl I p. 2214), as last amended by the Act of 31 July 2009 (BGBl. I p. 2585).

[21] Dated 16 March 2005 (BGBl I p. 762), as last amended by the Act of 31 July 2009 (BGBl. I p. 2585).

2. Extensive consideration is to be given to the dismantling, reuse, recovery and, in particular, recycling of end-of-life vehicles and their materials and components when designing and producing new vehicles.
3. Greater use is to be made of recycled materials in the production of vehicles and other products.

The primary purpose of the Electrical and Electronic Equipment Act consists in the prevention of wastes from electrical and electronic equipment and beyond this, the reuse, material recycling and other forms of recovery of such wastes in order to reduce the quantity of waste to be disposed of and minimize the introduction of harmful substances from electrical and electronic equipment into wastes (§ 1 para 1 sentence 2).[22]

In the above cases, resource protection is included in a reflective way without being a target itself.

The "Meseberg decisions" triggered a great number of legal policy innovations with regard to energy efficiency[23]:

- Energy Saving Act[24]: Parties, who erect a building which according to its purpose has to be heated or cooled, are obliged to design and carry out thermal insulation, pursuant to the statutory instrument to be enacted under para 2, in such a way as to prevent avoidable energy losses during heating and cooling (§ 1 para 1).
- Energy-Using Products Act[25]: § 4 para 1 regulates the placing on the market of "energy-using products". According to this paragraph, an energy-using product covered by a legal regulation on implementation may only be placed on the market on the condition that it complies with the requirements for ecofriendly design and other prerequisites before being placed on the market and put into service as stipulated by the legal regulation on its implementation (…). Pursuant to § 2 para 3 No. 1, an implementing legal regulation constitutes an implementation measure adopted by the Commission of the European Communities as immediately binding Community legislation, in the sense of Article 15 of Directive 2005/32/EC establishing a framework for the setting of eco-design requirements for energy-using products.
- Smart metering: EU Directive 2009/72/EC concerning common rules for the internal market in electricity envisages that by 2020, 80% of all European consumers shall be equipped with electronic electricity metres. EU Directive 2006/32/EC on energy end-use efficiency and energy services had already obliged the Member States to develop a general framework for the measurement and verification of their energy use in order to improve compliance with the national energy-saving targets. The installation of electronic electricity metres will enable consumers to identify their actual consumption of energy together with the precise period of use. Having been given such information and thus

[22] Prelle (2007); a critical view: Roßnagel (2009), pp. 263 ff.; also cf. Wendenburg and Seitel (2009).

[23] In detail: Bosecke (2008).

[24] Dated 1 September 2005 (BGBl I p. 2684), as last amended by the Act of 28 March 2009 (BGBl. I p. 643).

[25] Dated 7 March 2008 (BGBl. I p. 258).

having developed a corresponding awareness, customers will be able to save 5–10% of their energy consumption. Furthermore, such additional information is to help consumers choose their supplier and decide between different supply options. In Germany, the installation of metres is a requirement for new and rehabilitated buildings as from 2010 onwards (cf. § 21 b para 3a Energy Industry Act[26]).

- Public procurement: In addition, the General Administrative Regulations under Article 86 of the Basic Law for the Procurement of Energy-Efficient Products and Services of 17 January 2008 were adopted. Thus, the traditional approach was supplemented which required the public sector to set a good example and, being an important consumer, use its market power in the interest of environmental protection.

3.2 *Implementation of the Waste Framework Directive*

In parallel to the considerations described above, another legal policy development has been initiated long ago: The European Waste Framework Directive (2008/98/EC) entered into force on 18 December 2008 and should be implemented in the Member States within 2 years. This Directive includes a number of topics aimed at resource management. The topics of extended producer responsibility, waste prevention programmes and establishment of recycling rates demonstrate this with particular clearness.

Extended producer responsibility: The status of the introduction of extended producer responsibility is explained in recital 27 of the Directive: It is one of the means to support the design and production of goods which take into full account and facilitate the efficient use of resources during their entire life cycle including periods of repair, reuse, disassembly and recycling, without compromising the free circulation of goods on the internal market. Since in Germany, product responsibility is already extensively regulated by the Closed Substance Cycle Waste Management Act, transposition into German national law is not expected to pose any problems.

- Waste prevention programmes: In order to improve the way in which waste prevention action is taken in the Member States and to facilitate the dissemination of accepted practices in this area, it is necessary to strengthen the provisions relating to the prevention of waste generation and to introduce a requirement for the Member States to develop waste prevention programmes concentrating on the key environmental impacts and taking into account the entire life cycle of products and materials. To this aim, waste prevention targets should be established. It is the purpose of such measures to break the link between economic growth and the environmental impacts associated with the generation of waste (cf. recital 40). The EU takes this challenge seriously.

[26] Dated 7 July 2005 (BGBl. I p. 1970).

This is emphasized by the deadline of 12 December 2013 for the Member States to establish waste prevention programmes. For the onward approach, detailed provisions are being taken (cf. Article 29) and more deadlines imposed (cf. Article 37 para 4 sentence 1 in connection with sentence 2).

In Germany, the notion of waste prevention was emphasized already in 1986 by the 4th amendment to the Waste Disposal Act by means of the new title "Gesetz über die Vermeidung und Entsorgung von Abfällen" (Act on avoidance and disposal of waste). Nevertheless, there are still uncertainties also in Germany as to how to tackle this task in a meaningful way.[27]

- Recycling rates for waste streams: The Directive also envisages a European recycling society with a high level of resource utilization efficiency. To this aim, targets for preparing wastes for reuse and recycling of wastes should be set (see recital 41, sentence 1). According to Article 2 para 2 member states are obliged to take the necessary measures for reuse and recycling of waste material (such as paper, metal, plastic and glass) from households and if possible from other origins (if the waste streams are similar to those from households) by 2020. The amount shall be increased to at least 50% of the overall waste by weight. For nonhazardous construction and demolition waste, the target rate is even 70%.

The legislative process to implement these and other provisions of the Waste Framework Directive in amendments of the Closed Substance Cycle Waste Management Act was started but is not yet completed.

4 Conclusion and Outlook

The topics highlighted above demonstrate the area of tension in which resource protection law has developed so far and will develop further in the future. A shift of the value of resources, starting with their worthiness of protection – as a component of pristine landscape – could result in an enhancement of the concern and a higher and more demanding level of all relevant legal requirements in the subsequent phases of resource management and use (cf. Meyer-Abich 1984, pp. 44 ff.). A more detailed elucidation of the combined complex of concepts for legal use still remains a desideratum. The relationship and the networking between the fields of resource protection, product responsibility and waste management and other relevant subjects have not yet been conclusively elucidated. In single cases, regulatory elements favouring resource protection were developed in a number of drafts for an Environmental Code. In addition to existing and new research projects initiated in particular by UBA, this may serve a further operationalization of the topic in the political-administrative sphere. In parallel, legal innovations referring to resource protection, mainly based on energy efficiency, have already been implemented in

[27] Cf. the current UFOPLAN project entitled "Developing the scientific and technical basis for the establishment of a national waste prevention programme".

recent years. The legislative process to incorporate the Waste Framework Directive into German national law, which devotes more attention than before to resource protection, will be concluded shortly.

Reasons speaking in favour of a partial legal codification of a federal resource protection law include that in this way, a general reference parameter claiming to constitute a general part or a fundamental law[28] would be created which the different existing[29] or future partial legal fields and approaches could be referred to.

At present, it is not yet possible to predict the future of resource protection law. It is, however, certain that it will continue to develop. Likewise, its standing will continue to grow.

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[28] Winter (2007), Smeddinck, (2007).

[29] Cf. Brandt and Röckseisen (2000), pp. 29 ff.

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Part II
Securing a Sustainable Supply of Raw Materials

Chapter 7
An International Metal Covenant: A Step Towards Global Sustainable Resource Management

Henning Wilts and Raimund Bleischwitz

1 Introduction

For a long time, the concept of closed substance cycle management has been seen in a local and national context only: The creation of local material cycles may virtually be considered as the paradigm of a recycling society. Such concept should be questioned for two reasons: Firstly, it is difficult to imagine that metals could be replaced by renewable raw materials produced locally on a sustainable basis. Insofar, countries poor in raw material resources such as Germany will have to deal with a sustainable use of metals which by necessity will require an international perspective. Secondly, international markets for used products are a reality so that domestic recycling will encounter considerable obstacles. This present chapter will address this issue, taking the subject of used vehicles as an example. Internationally scattered markets are characterized by insufficient recycling capacities. As a consequence, considerable material losses and negative environmental impacts have become evident.

This is why in the following an international management of metal markets is discussed. The authors' considerations start with a number of knowledge problems: As a rule, the buyer of a used product does not know which materials are contained in the product. At the same time, it may be assumed that the material losses observed today are to be attributed to a lack of management and that the development of appropriate mechanisms could well mobilize actors who are interested in the closing of material cycles. Such steering function could be assumed by an international metal covenant providing the basis for a cooperation of industry and governments. It has been the authors' intent to develop basic elements of such an agreement and to discuss critical aspects as well as possible consequences.

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2 Cooperation Agreements to Solve Knowledge Problems

The starting point of these considerations has been the thesis that knowledge problems and transaction costs are to be held responsible for the lacking completion of international cycles of materials contained in end-of-life products. On the one hand, recycling markets have failed to work properly because an asymmetrical distribution of information between recyclers and industry purchasing secondary raw materials has been impairing efficient agreements. On the other, the governments are lacking sufficient information that would be needed to correct the existing market failure in an optimal way by direct regulation.

Neither governments nor enterprises have the knowledge required to initiate and implement long-term changes towards sustainability. Rather, it is necessary to develop joint mechanisms, taking into account strategic interests and options for action (Bleischwitz 2005; de Bruijn and Tukker 2002; Grin et al. 2010). “Industrial transformation goes beyond the notion of eco-efficiency and beyond the domain of individual actors. It is about system innovation, both technological and institutional” (de Bruijn and Tukker 2002, p. 8). Regarding the problems considered in the present case study, the main focus will be on material flow innovations that may reduce material intensity. The concept of “responsible corporate governance” aims at a concentration of potential self-interests of industry and their merging by means of suitable incentives (Bleischwitz 2007).

The development of cooperative approaches to material flow innovations may also be substantiated from the waste management perspective. In this context, considerations are based on the fact that so far, recycling rates for certain substances contained in end-of-life vehicles (ELVs) have been too low because recycling activities meaningful both from the ecological and economic angle were omitted. Reasons include the costs for enterprises to obtain the required information on quality features of recycled products and materials in order to conclude contracts recognized as favourable for all parties involved. In contrast, the European ELV Directive (Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of-life vehicles) has encouraged cherry picking by single actors in recovery processes preceding the waste management stage. Such practice has been favouring marketable components and materials and aggravating a shift of the environmental policy problem due to the export of used cars. As a consequence, overcoming knowledge deficits becomes an independent regulatory objective.

In the context of asymmetric information, the operational rationality of maintaining established design and production processes should be pointed out. As a result of used car exports, enterprises may evade producer responsibility. This is attractive for them because it allows them to maintain existing production facilities and processes as well as supplier relationships. In a summarizing view, the consequences of imbalances in information have systemic dimensions in several respects:

- Under the prevailing conditions, high follow-up costs in the form of environmental damage, social costs and market distortion are generated on an international level.
- International follow-up costs result in distortions on the domestic market for material efficiency and resource conservation.

- The potential for future innovative paths of recovery and sustainable resource management is impaired.

Hence, the profile for a steering required against this background should aim at abolishing the present sharing of knowledge about international material flows along the product utilization chain involving industrial stakeholders in the fields of automobiles, metal and recycling and developing knowledge on sustainability potentials.

3 Used Car Exports and Material Losses as a Problem Field

Vehicle recycling harbours a considerable potential for material efficiency and resource conservation. The volume of end-of-life vehicles generated within the EU will increase from a present 10 to 14 million tons in 2015 (EEA 2008). End-of-life vehicles contain a great number of materials. Among these are material fractions including rare metals which already today may be recovered in a profitable way but also toxic substances posing considerable risks for humans and the environment. Insofar, the inseparable link between material efficiency which is profitable for individual enterprises and resource conservation which is required from the environmental angle is also illustrated by this field. If the promotion of metal recycling included only those options that are profitable for enterprises, the problem of negative environmental impacts due to harmful substances and disposal would remain unresolved on an international level. Insofar, a covenant in this field will have to deal with both, concentrating the interests of the industries involved and taking care of public matters. At the same time, deficits in product policy become evident: Such policy is too wide-meshed for the special cases of individual metals, and it has to comply with the principle of territoriality, which is deficient in the presence of internationally open markets.

In Germany, only a small share of deregistered vehicles is recovered inside the country. This is why innovative instruments should primarily aim at recycling standards in the countries of destination (Lucas and Wilts 2009). In 2008, not more than about 15% of the three million definitively deregistered vehicles were recovered in Germany (cf. Fig. 7.1). Vehicles exported from Germany to EU-10 countries are often purchased for reuse by third parties in non-EU countries. In 2008, Kazakhstan represented the quantitatively most important country of destination for used car exports from the EU.

For EU member states, it may be assumed that due to the implementation of the ELV Directive, high-quality recycling technologies will be used at least in the medium term. However, a major share of used cars will directly, or after another utilization phase in the EU-27 countries, end up in countries not committed to the ambitious recycling targets of the European ELV Directive. Even in large cities such as Moscow, a mere 10,000 out of 130,000 deregistered vehicles were recycled in 2009 (Lucas and Wilts 2011). At the same time, there has been a variety of illegal or tolerated practices to “dispose of” motor-vehicle bodies and parts in backyards, on roadsides, on secluded sites or in illegal dumps.

These lacking or insufficient international recycling infrastructures result in irretrievable losses of raw materials. Hence, there are systematic deficits in recording

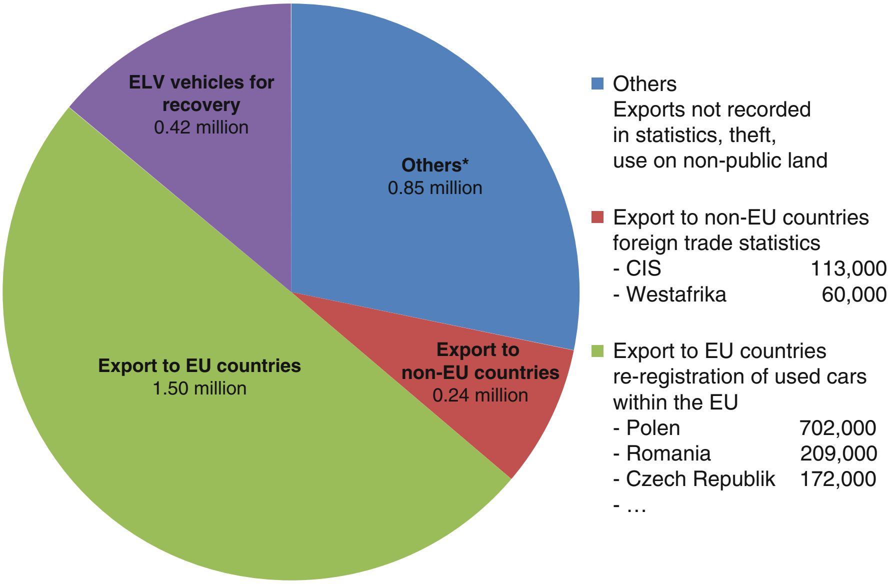

Fig. 7.1 Fate of vehicles definitively deregistered in Germany in 2008 (Source: Own illustration based on BMU/UBA 2010)

export flows of used vehicles and indications of probable law infringements. The resulting responsibility loopholes lead to considerable interruptions in the cause-effect chain: The ambitious objectives of the ELV Directive, that is, to achieve product design enhancements and ensure environmentally sound recovery after use on the basis of producer responsibility, are undermined by insufficient control of vehicle flows and enforcement deficits (SRU 2008, p. 732). Presently, the objectives and obligations of product responsibility stop at the borders of the EU member states. Consequently, the aim should be to achieve that (a) export is no longer used as a cost-effective option to evade product responsibility and (b) potentials for material efficiency and resource conservation may be opened up also on an international level. Therefore, enhanced incentives should be created for shifting producer responsibility towards material responsibility.

4 Considerations Regarding a Future International Covenant on Resource Efficiency in the Metal Sector

In the following, based on the deficits observed and the limits of direct regulation regarding the recycling of exported vehicles, a covenant is outlined to enhance material efficiency and resource conservation in this field of action. Covenants represent a combination of elements of direct governmental regulation and self-regulation by industry. On principle, covenants may be characterized by the following elements (Wilts et al. 2011):

- Industrial sectors commit themselves to achieving long-term goals.
- These goals are negotiated in cooperation with the responsible authorities of the public sector.
- In return, the public authorities commit themselves to creating appropriate framework conditions and to omitting further direct regulatory measures for the contract period.
- Covenants are concluded as private law contracts between all parties involved. Such contracts include both sanction mechanisms in case the stipulated goals are not achieved and options to adapt the terms and conditions in case of changing framework conditions.

The covenant's goal to be agreed upon should be to contribute to the completion of material cycles in the field of exported used cars. Depending on the type of material, such material cycles should be established on different spatial levels. While recycling standards are defined for steel car bodies in the countries of destination, enhanced recording and monitoring will provide for the return of certain resource-intensive fractions such as copper or platinum group metals (PGMs) on an international level. The covenant's approach is based on the existence of sufficient economic incentives for the recycling of such fractions, along with the establishment of appropriate framework conditions.

On principle, the covenant should agree upon a sufficiently long period warranting stable long-term framework conditions for the enterprises involved to ensure amortization of the necessary investments. The exact write-off period will have to take into account the specific situation of ELV disposal in the individual countries of destination, for example, in analogy to the transition periods for EU-acceding countries to implement the ELV Directive.

It is important that all obligations of the contracting parties are precisely and verifiably defined. In the context of this covenant, goals should be defined on three levels:

4.1 Completion of Industrial Material Cycles

In addition to the targets fixed by the ELV Directive regarding the recycling of a certain share by weight of an ELV, the covenant should define standards specific to groups of materials and intermediate targets for the completion of industrial material cycles. These should be based on the quantities currently used, establishing high-quality recycling and recovery procedures. The life-cycle approach should apply material flow concepts such as the Total Material Requirement. The number of potentially relevant materials includes copper and PGMs because both of these mean a decisive contribution to the profitability of ELV recycling. In addition, which applies in particular to copper, they require extensive dismantling of the vehicle, thus automatically creating incentives for a sorted recovery of other material groups. To this aim, material-specific recovery rates could be defined as medium-term targets. In the long run, however, it is intended to initiate self-supporting innovation processes providing effective incentives to exceed defined rates. Rates may definitely be suitable for directing innovation processes towards a sustainable development. However, they should be prevented from developing a life of their own as a target so that they might even become an obstacle to ecofriendly product design. In the context of the covenant, industrial partners would commit themselves to recovering a certain (to be negotiated) percentage of metal fractions contained in these vehicles which would also include the exported vehicles.

4.2 Recycling Standards

For the recycling industry in the countries of destination, such commitment by the automobile industry would ensure a defined input for treatment facilities in the sector of base metals. Such facilities should be constructed in these countries of destination for the exported vehicles, at least for the first stages of recovery. Regarding the recovery of ELVs, it has to be taken into account that although the recycling of materials will lead to considerable resource savings, the treatment procedure can be associated with substantial environmental impact potentials, for example, if oil and other operating liquids are directly discharged into sewer systems.

This is why the recycling industry should be committed to high environmental standards also in the countries of destination, including, for example, compliance with the requirements for treatment facilities according to the German ELV Ordinance (e.g. under § 5 para 3, a permission under building law, or the removal of operating liquids, cf. Berninger 2009, p. 495).

Of course, these and many other requirements have to be adapted to the conditions prevailing in the countries concerned. Among other facts, it has to be taken into account that so far, there is no established system of experts who could carry out such controls. Insofar it is required to also consider measures of capacity building and measures to establish basic institutions. In this respect, environmental dumping by evading elementary environmental standards should become unattractive at least in the medium term (e.g. when it comes to the reduction of harmful substances in ELV cars).

4.3 Enhanced Monitoring and Reporting

As a prerequisite for efficient resource management in the field of ELV recycling, the contracting parties should agree upon a monitoring system depicting the actual material flows in the ELV sector including exports within the EU. In order to record also privately exported vehicles, it would make sense to compare the foreign trade statistics with the databases of customs authorities and motor-vehicle registries in the countries of destination (in analogy to the EU database, REGINA). Many of the data required have already been recorded. However, networking and data exchange should be enhanced, while data protection has to be observed.

Above all, precise and binding reporting obligations for the contracting parties involved should be agreed upon in the covenant. This should, firstly, improve information exchange between manufacturers, recyclers and public sector authorities in order to identify possible efficiency potentials and promote innovation processes. Secondly, publication of the reports is also intended to exert pressure on individual stakeholders in the case of failure to sufficiently meet their obligations.

In addition to compulsory reporting, the covenant should also establish provisions facilitating the access to information for all contracting parties involved in order to ensure an improved adaptation of recycling to the quality requirements for the use of secondary raw materials. These could include, for example, subject-specific working groups or disclosure of certain manufacturing standards.

4.4 Sanctions

Past experience with regard to covenants has shown a lack of public control and insufficient provisions for discouraging free-rider behaviour of single stakeholders to constitute the critical points of the instrument (Bressers and de Bruijn 2005). As a matter of principle, a covenant should therefore include options to impose sanctions for non-compliance by means of civil action to enforce contract penalties.

In case of repeated failure to comply with the goals defined, there should be provisions to sanction the contracting parties concerned by means of economic penalties, if necessary. In case manufacturers fail to meet their obligations, a binding procedure for the settlement of disputes should have been introduced. The latter could define the options of a stringent direct regulation (e.g. with high recovery rates). A possible preliminary stage could, for example, consist in the option to exclude enterprises or industries from public research funding. Another measure to be considered could consist in a ban on such enterprises or trade associations to participate in the development of binding standards.

5 Impact Assessment: Benefits of an International Metal Covenant

As far as we know, no international covenant between several states and industrial sectors has been concluded so far. This is why concrete practical experience is still missing. Also in Germany, no concrete covenants have been established so far. However, conclusions may be drawn both from the discussion on sectoral agreements in international climate policy and the experience with national environmental agreements, above all in the Netherlands. The Dutch Target Group Policy encompassing more than 100 sectoral agreements concluded since 1989 has been part of a long-term (2020) oriented national environmental policy plan. In a summarizing view, the results of the Target Group Policy have met with a predominantly positive response both by public authorities and industry and also by environmental governance research (Elzen et al. 2004). The success factor of such approaches towards a transition management consists mainly in an enhanced cooperation between different industrial sectors (Kemp 2010).

5.1 Recovery of Raw Materials: A Scenario

Both the course and results of a negotiated solution are difficult to predict. This is why in the following, a scenario is developed which is based on the principles of sustainable resource management and on the notion of material responsibility and intended to promote optimal and appropriate mining, production and use of raw materials for the benefit of society while safeguarding environmental objectives (Minsch et al. 2000).

Within this scenario, a covenant is to be agreed upon between Germany and the ten most important countries of destination of used car exports (Kazakhstan, Guinea, Russia, Belarus, Serbia, Benin, Bosnia-Herzegovina, Tadzhikistan, Angola and Nigeria). The covenant should comprise agreements on the copper and PGM fractions: While PGM recycling, mainly from catalytic converters, constitutes a profitable business already today, the recycling of copper, for example, from wiring harnesses, requires a preceding extensive dismantling of the vehicle. For an estimate of the potential of this instrument, the entire range of EU exports (passenger cars, both diesel and petrol driven vehicles) is to be taken into account since, as a matter of course, it is assumed that not only German ELVs will be recycled in the countries of destination. Based on evaluation of the 2007 EU foreign trade statistics, calculations resulted in a total quantity of 8,029,000 vehicles for all ten countries of destination.

With regard to PGMs, the covenant is mainly aimed at a reduction of transaction costs in the cross-national recycling value chains. By means of improving the flow of information, it is intended to enhance the existing system and recover secondary raw materials in a technically optimized way. At the end of the utilization phase, above all the catalytic converters are disassembled, collected and transferred to a high-quality treatment facility by means of international logistics, in Germany and Europe, respectively. Each catalytic converter contains between 1 and 15 g of PGMs. This value may vary considerably depending on the type of car (diesel or petrol, cubic capacity, age) and usage behaviour (dissipative losses on operation). In Eastern Europe, the incentive for systematic collection has been on the increase along with the share of ELVs equipped with a catalytic converter. Nevertheless, Hagelüken and Buchert (2010) have estimated that on a global level, only about 50% of the PGMs used is recovered so far.

In the context of this scenario, it is assumed that an increase in high-quality recovery to at least 75% could be achieved by the development of appropriate redistribution systems in the countries of destination. In this way, an additional quantity of about 7.5 tons of PGMs could be recovered in the contracting states. Assuming a 50:50 ratio of platinum and palladium used in a catalytic converter, this amount is currently worth about 19 million €. These initially low revenues hardly require any investment since presently, the existing integrated smelters still have sufficient capacities (Johnson 2010, p. 23).

For the fraction of copper, it shall be assumed in addition that the covenant will not only envisage measures that may be profitably implemented in the short term but on an intermediate and long-term basis may contribute to enhancing competitiveness by way of learning and innovation processes. A starting point for such processes may consist in the recovery of copper contained in ELVs: So far, copper has not been recovered separately in the countries of destination considered and therefore, becomes subject to dissipative losses during the shredding process. Currently, a quantity of about 22-kg copper is spent per new vehicle. By 2025, however, a continuous increase to 40 kg is to be expected due to an increasing use of electronic functions in the car (Lucas et al. 2007).

For this scenario, it may be assumed that in the future, the 75% copper recovery rate currently achieved in Germany will be reached on an international level for 50% of vehicles. By 2016, this share is envisaged to increase to 95% (according to the total rate of 95% stipulated by the ELV Directive). On this basis and taking into account increasing total quantities, quantities used and quantities recovered, the additional quantity of copper recycled in 2030 from EU used car imports would amount to about 200,000 tons worth 840 million € per year (assuming a long-term price of 4,000 € per ton, with the current value being even 7,000 € per ton (figure refers to March 2011)).

5.2 Development of Recycling Capacities in Emerging Countries

The instrument of an international covenant provides a chance for promoting the decoupling of economic growth from resource use not only in Europe but on a global level. By means of agreements regarding the targets, codes of practice and capacity building, the industrial sectors involved are provided incentives to intensify knowledge and technology transfer to the countries of export destination where in many cases, appropriate facilities and infrastructures for recycling are still completely missing. "In order to improve the technical and environmental standards in less developed countries, an increase of know-how, in connection with technology transfer, if required, is urgently needed" (UBA 2009).

For the recycling industry to be involved in the covenant, the export of technologies constitutes an enormous market potential. Presumably, the market for environmental technologies for dismantling, shredding or sorting will triple by the year 2020. Presently, the international market share of German enterprises in this field of business corresponds to about 25% (BMU 2009).

6 Conclusion

The sectoral approach will allow enterprises to coordinate their shares in the targets negotiated that can be assumed according to their individual adjustment costs. In analogy to the approach of an emission trading scheme, equalization payments may be agreed upon on an intra-sectoral basis to be paid by enterprises making only small contributions to reaching the set targets. Similar approaches could apply on the intersectoral level for negotiations between recyclers and car manufacturers as well as the resource-based industries.

Taking into account the entire value chain may result in the creation of a considerably greater resource efficiency potential. To this aim, however, it is required to agree upon allocation rules for the equalization of costs incurred and benefits generated. Nevertheless, it has to be stated in a summarizing view that it is impossible for a single policy instrument to appropriately cover the entire range of problem structures, objectives, types of stakeholders, resources etc. Instead, a balanced mixture of policies will be required which is suitable to overcome the variety of obstacles, taking into account innovation phases and cope with the future global challenges of sustainable resource management.

Hence, in the short run, an international metal covenant could provide a means to benefit from a tense situation on raw material markets. In a medium-term perspective, it could constitute an expandable component of global resource management.

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Chapter 8
The Austrian Minerals Plan

Leopold Weber

1 Starting Situation

On the occasion of an amendment of the Mineral Resources Act in 2001, the Austrian National Council entrusted the Minister of Economy with preparing an Austrian Minerals Plan documenting the deposits of the required mineral resources in a reasonable period. Based on these deposit maps, a countrywide plan of resource extraction forming the basis for future operating schedules for extraction was in relation to the respective demand to be drawn up together with the Federal provinces and municipalities. The works were started with the target to look for a joint solution between Federal Government and Federal provinces for safeguarding all mineral resources in the long term based on regional planning.

Even if in a free market economy companies are basically responsible for the supply of economy with mineral resources, it is the task of the public administration to provide the respective basic conditions in the framework of an up-to-date minerals policy wherever this will exceed the tasks of the companies. An up-to-date minerals policy involves, inter alia, legislative, fiscal and regional planning measures within the triangle of profitability, environmental protection and social compatibility. The minerals policy should aim at providing the basis for a sufficient supply of economy with cheap minerals, safeguarding of mineral deposits based on regional planning in the long term to reach a respective legal and planning security for companies.

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2 Safeguarding of Mineral Resources and Regional Planning

Also if a minerals policy is a task of the Federal Government, at least the implementation on the level of regional planning falls to the Federal provinces. A specific feature of Austrian regional planning is that it is to be considered as an annexed subject and that is why a region is planned by several regional corporate bodies. The superior regional planning by the Federal Government and the Federal provinces basically *on equal level* has to be respected by the local regional planning. No inessential conflict potentials, notably with the regional planning of municipalities, result from this. Hereby, a solution of this problem is not seen in a *compulsory execution* of a governmental regional planning by the Federal provinces but rather in a joint consensual solution with the Federal provinces.

Each Austrian Federal state has its own regional planning act. In most of these regional planning acts of the Federal provinces, it is at least pointed to the fact that mineral resources are to be accordingly considered and plans complicating or even hindering the usability of a mineral deposit may not be implemented. However, the actual and active implementation of the plan varies from Federal state to Federal state. It reaches from a *positive form* as so-called gravel master plans up to negative planning, i.e. an extraction of minerals is basically possible there where it is not explicitly prohibited. On the other hand, in other Federal provinces, resource safeguarding measures are not envisaged. Though advantages may be recognized in a positive as well as in a negative planning, it was the declared aim of the Austrian Minerals Plan to prepare together with each Federal state an optimum *tailor-made* solution.

All Federal provinces agreed on an area-wide and objective registration of all mineral deposits as a decision-making basis for further actions. Here, the implementation of regional planning should take the specific ideas of the Federal provinces into consideration. Whereas, e.g. in most of the Federal provinces, the planning regions were orientated towards political districts in Tirol, there was suggested to use *supply areas* as a basis owing to its strong spatial structuring by valley inhabitants. The fact that in some Federal provinces dredging though not being explicitly prohibited is, however, actually not desired was also considered. These and many other aspects were considered accordingly.

3 Evaluation of Mineral Deposits

Mineral deposits may be only safeguarded if sufficient information on their type, quantity and quality are available. Together with the Geological Survey, type-specific, innovative methods of evaluation were prepared for surface-near mineral deposits. The Technical Committee for Deposit Research of the Austrian Mining Association developed an own method of evaluation for (deeply situated) deposits of ores, industrial minerals and energy resources (with the exception of crude oil and natural gas).

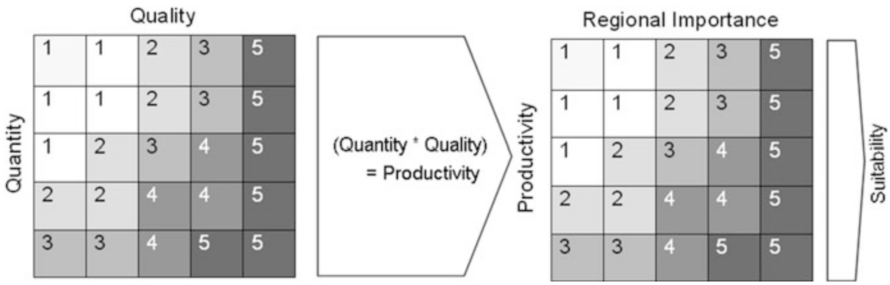

Fig. 8.1 Evaluation matrices for the determination of suitable zones

3.1 Example of Construction Resources (Loose Rocks)

The Geological Survey compiled geological information on loose rock in a special map (*lithological map*) as an essential basis for decision-making. In contrast to a *classical* geological map representing the individual units according to their age in such a lithological map, the usability of the different lithological units is of immediate importance. Already the preparation of such a lithological map as a basis for evaluation is an innovative approach to an objective identification of areas of mineral resources (Weber et al. 2009).

In a further step, the loose rock deposits were arranged always in five classes according to their quality and quantity and based on a matrix a *geological potential* was determined from them. Parallel to this operation, the regional importance of the deposits for the supply of the surrounding areas was classified because a large gravel deposit in the plain around a large city has the same importance as a small deposit for the local supply of distant valley inhabitants. Finally, five suitable classes represented as a basis for further processing in digital maps result from the further matrix-based cutting of the *geological potential* (see above) according to the *regional importance* of the deposits (Fig. 8.1).

The best suitable areas (suitable zones 1–3) were used for further processing. Areas where already now extraction is legally prohibited (e.g. settlement areas, transport routes and national parks) have been digitally cut out (scenario 1).

In a further step also, areas where an extraction of mineral resources is only possible under specific conditions (e.g. natural parks, Natura 2,000 areas, preferential zones of water management and areas 1,600 m above sea level) have been cut out. The remaining areas of mineral resources were represented in digital maps (scenario 2).

A careful examination of each individual area for its effective possibility of use proved to be an indispensable and important intermediate step. In the case of further conflicts having been recognized (e.g. high-tension power lines and ski runs), the respective areas were eliminated *by hand* (Methods see Figs. 8.2 and 8.3).

General information on Figs. 8.4, 8.5, and 8.6: As the results of the evaluation are treated confidentially, this situation has been consciously omitted (Fig. 8.7).

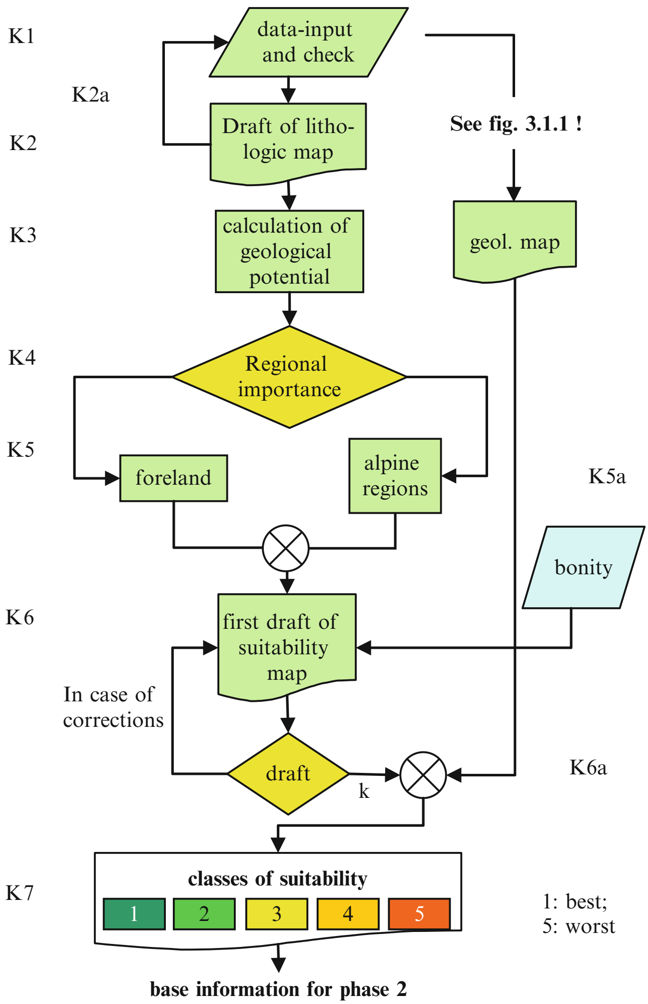

Fig. 8.2 Flow diagram for the assessment of loose rock (sand and gravel), phase 1

3.2 Example of Construction Resources (Hard Rocks)

In the case of solid rock deposits (construction resources as well as high-quality carbonates), a special method of area demarcation was applied. First of all, a circular area (r = 700 m) was buffered around the centre of a potential deposit, and this area was examined for conflicts. Subsequently, the residual area was examined for its geological conditions, the possibilities of extraction were checked, and the volumes resulting from it were modelled. Deposits with reserves for extraction > 100 (assumption 300,000 tons per year) were preferred. Basically, it was checked whether an

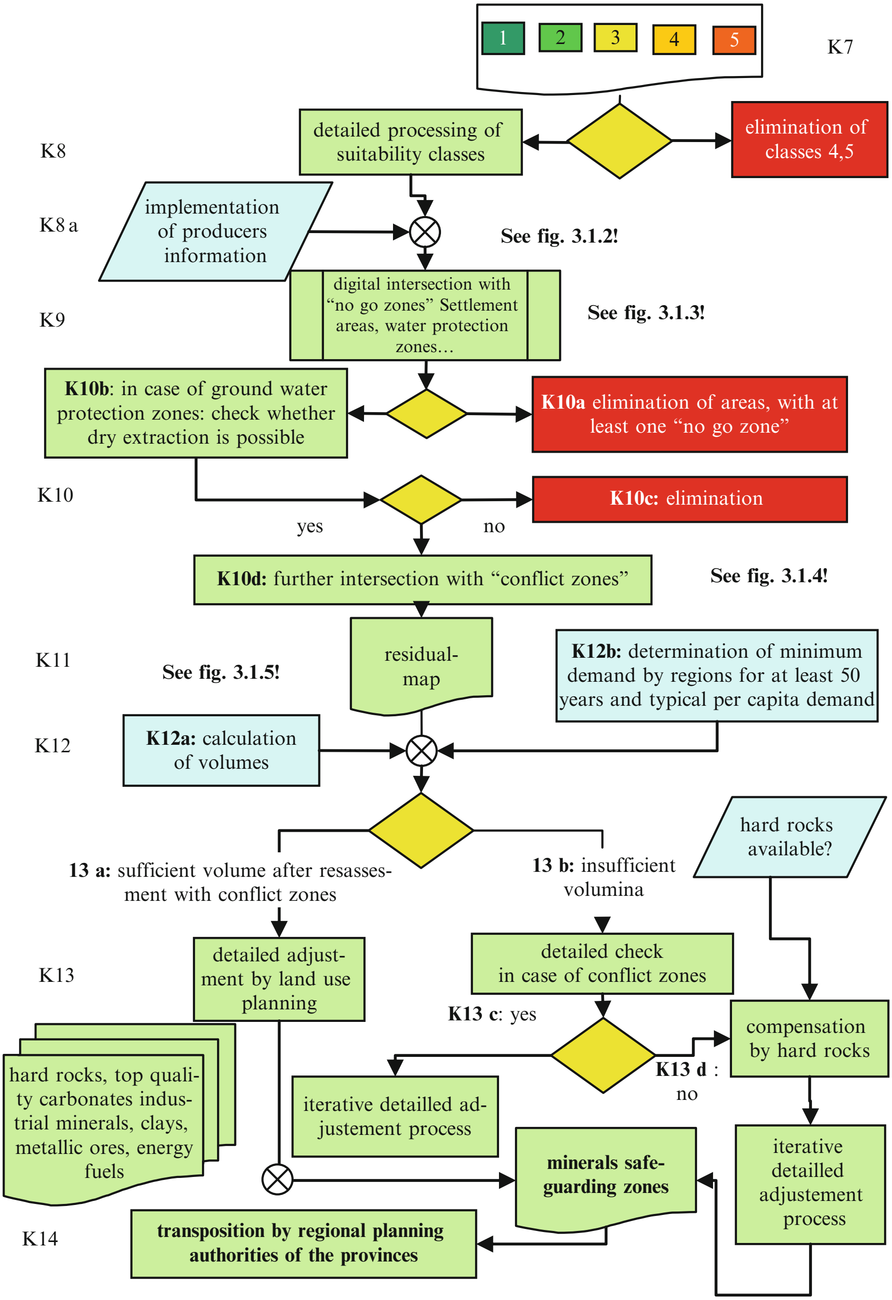

Fig. 8.3 Flow diagram for the elimination of conflicts in loose rock (sand and gravel), phase 2

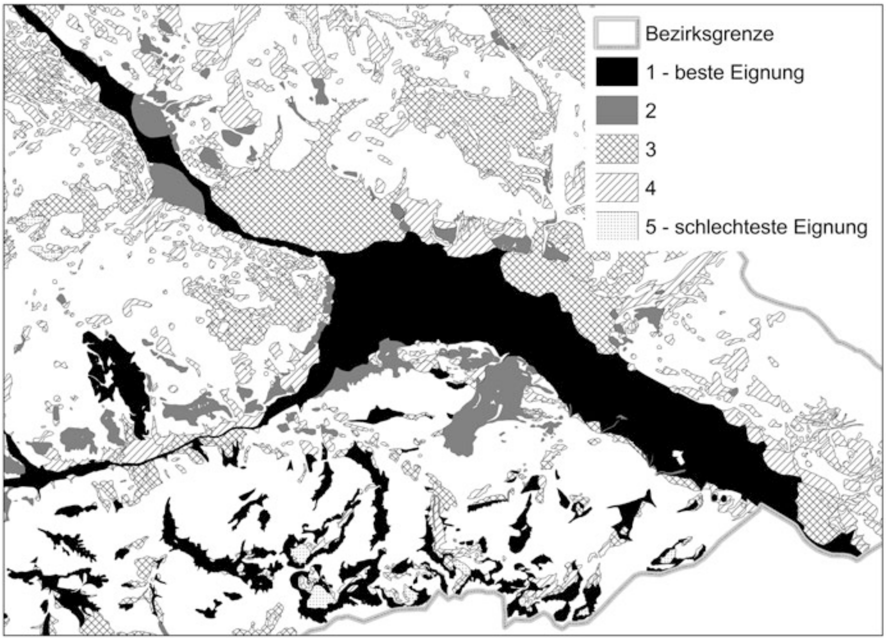

Fig. 8.4 Loose rock; spread of the suitable zones 1–5

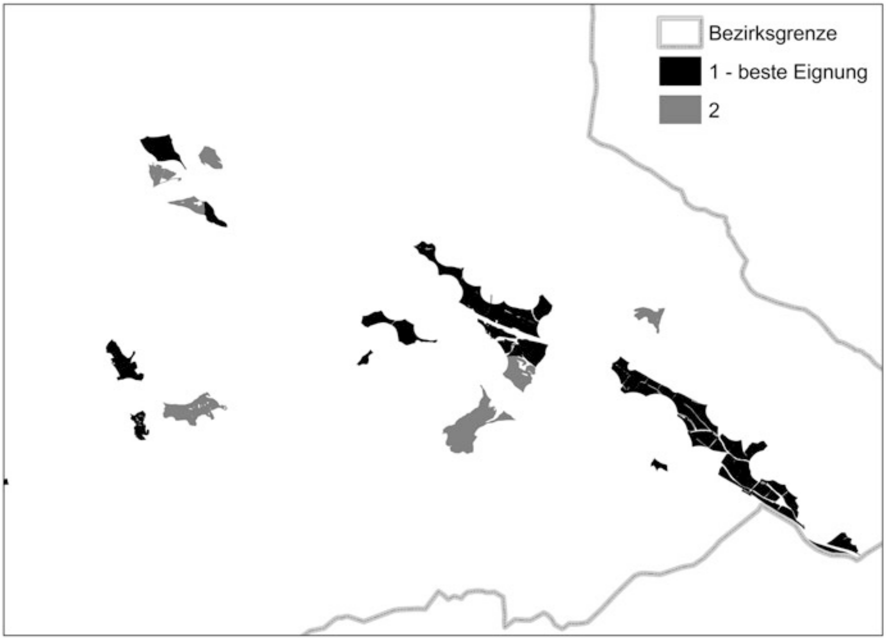

Fig. 8.5 Loose rock; spread of the suitable zones 1–3, minus *no-go* zones (scenario 1)

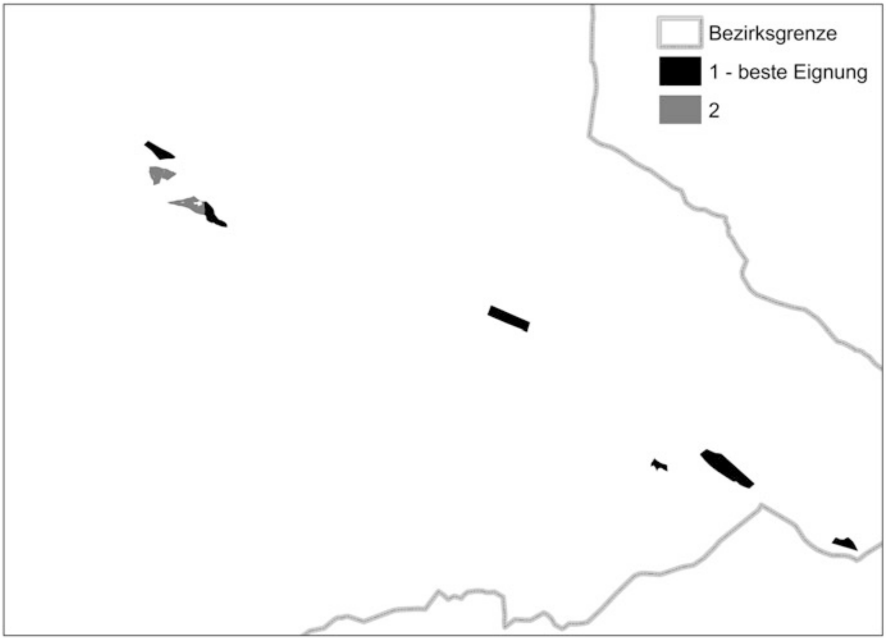

Fig. 8.6 Loose rock; spread of the suitable zones 1–3, minus *no-go* zones and conflict zones (scenario 2)

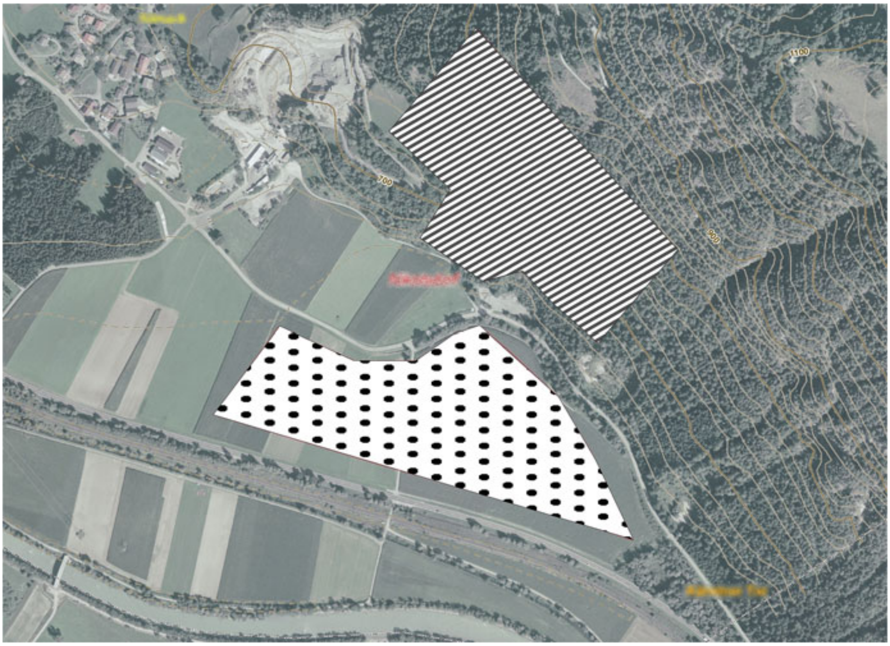

Fig. 8.7 Fine adjustment of a safeguarding area for loose rock in the framework of regional planning (*dotted*; *centre* of the figure) or for solid rock (*hatched*; *upper* third of the figure)

Table 8.1 Comparison of conflict-free quantities of construction resources with the demand for them in a supply region

Supply region	Sands, gravels suitability 1 in mill. m³ (1)		Sands, gravels suitability 2 in mill. m³ (2)		Solid rock (3)	Available quantity in mill. m³ (1)+(2)+(3)	Minimum demand (50 a)
	Total	Dry	Total	Dry			
xxx	36.6	36.6	8.8	8.8	55.43	Approx. 100	17.5

environmentally compatible (low-emission) extraction by means of an open pit with visual barrier with haulage shaft and excavation tunnel will be possible.

3.2.1 Determination of the (Regional) Minimum Demand

In contrast to expensive mineral resources such as ores or energy resources, construction resources may be transported (locally to regionally) only over short distances. An optimum solution will be only given if the distance between producer and consumer will not be more than approx. 30 km and reserves will be held available for at least 50 years. For this reason, it was tried to assess the respective minimum demand for each planning region. The demand for mineral resources varies strongly regionally as well as temporarily between about 5 m^3 and more than 20 m^3 pro capita and year. Also demographic forecasts and planned infrastructural projects were included in the assessment.

Table 8.1 shows that about 45 mill. m^3 of gravel sands are available in this planning region. Further 55 mill. m^3 of solid rock may be provided. Such rock will be required notably for flood control (*river building blocks*) in this supply region. Thereof results a volume of building resources extractable conflict-free of about 100 mill. m^3. Considering the loss of extraction (distances to real estates, traffic areas, slopes etc.), sufficient quantities of sands and gravel and solid rock are left so that a sufficient (geological) availability of resources in this planning region is given.

130% of the demand for loose rock and 108% of the demand for solid rock could be supplied from conflict-free areas for the whole Federal province in a planning period of 50 years. It is remarkable that these areas of mineral resources occupy only 0.142% of the whole area of the country.

3.2.2 Examination of the Future Demand

In a further step, the volumes of conflict-free areas of mineral resources were determined by means of GIS, and these quantities were compared with the minimum demand assessed. However, in this connection, attention should be drawn to the fact that the building industry does not only need loose rock but also solid rock. For the time being, about 60% of the demand for building resources is covered from loose rock deposits, the remaining quantity of approx. 40% from solid rock

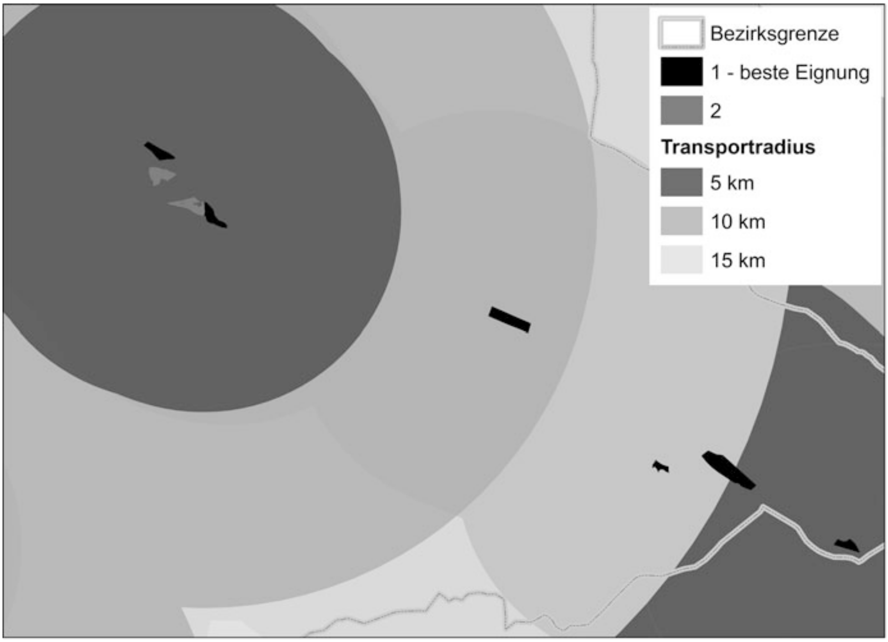

Fig. 8.8 Examination of the coverage of supply with loose rock of suitability 1 and 2 in the event of transport distances totalling 5, 10 or 15 km

deposits (Nötstaller 2003). In the medium to long term, however, a trend reversal is to be expected.

Only in exceptional cases it was possible to cover the minimum demand by a conflict-free best suitable potential of mineral resources (suitability 1). Where this was not possible, conflict-free areas of less suitable categories were used. Only in areas where this was not sufficient to meet the minimum demand it was tried to fall back on conflict areas with the smallest spatial resistances. Thereby, attention was paid to keeping a balanced relationship between loose and solid rock.

3.2.3 Examination as Far as the Supply Is Ensured

Statistically considered, each second ton-kilometre of transported goods belongs to mineral resources (Nötstaller 2003). A reduction of the transport distances by approx. 10% would result in a reduction of the CO_2 load by more than 1.6 mill. t a year.

To examine whether an area-wide supply will be possible within the planning region given, smaller transport distances transport radii of 5, 10 or 15 km were arranged around the deposits. Figure 8.8 shows that it will be possible to cover the demand of the whole (settled) supply region without causing problems. Owing to a lacking settlement (high mountain region), it will not be necessary to ensure the supply of the regions in the north of the supply region.

3.3 Ores, Industrial Minerals and Energy Resources

Deposits of ores, industrial minerals and energy resources are *worth being safeguarded* if they are used or may be used economically at present or have been used in the past, and still remaining (geological) reserves have been shown by former mining activities, the extraction of which will be highly probable in future owing to their quality and quantity.

Deposits of ores, industrial minerals and energy resources are *partly worth being safeguarded* which – with regard to their extraction or processing – for the time being, are not economically usable but which with a sufficient probability may be expected to be extracted in the mean to long term in the event of the prices of mineral resources rising and/or new extraction methods being developed.

After carrying out further investigations, it will be always possible in both cases to classify the deposit higher in the category *worth being safeguarded*. The assessment of partly worth being safeguarded was made by an *expert judgement* by members of the Technical Committee for Deposit Research of the scientific-technical association *Austrian Mining Association* covering the special fields in science of mining (mining and mine economics), science of processing and science of geosciences. A gradual procedure was adopted also for this group of mineral resources: an expert team eliminated preliminarily from the deposit file (interactive resource information system) with about 3,500 entry deposits which for qualitative and/or quantitative reasons do not come into consideration for being possibly used (*dropping of ballast*).

3.4 Methods of Assessment

The remaining deposits were evaluated as regards their quantity (size of deposits), quality (content of valuable substances) or bonity (position, geometry, regularity), rock conditions, mine water conditions, processability etc.; deposits which the expert team did not consider for a future extraction owing to their quantity, quality and bonity have been eliminated. Deposits for the future extraction of which will be possible due to their quantity, quality and bonity were examined if owing to their location, an extraction by open pit or underground mining will come into consideration. In the case of surface-near deposits (extractable by open-pit mining), the contours of the safeguarding area correspond to the contours of the deposits. As regards deeply situated deposits (extractable by underground mining), see below (Weber 2007).

3.4.1 Determination of the Area Required for Safeguarding Areas of Ore and Industrial Mineral Deposits

The area required for a resource safeguarding area depends on the type of the mineral deposit. The area required for deep-lying mineral deposits extractable by underground mining may be possibly restricted to the area required only for

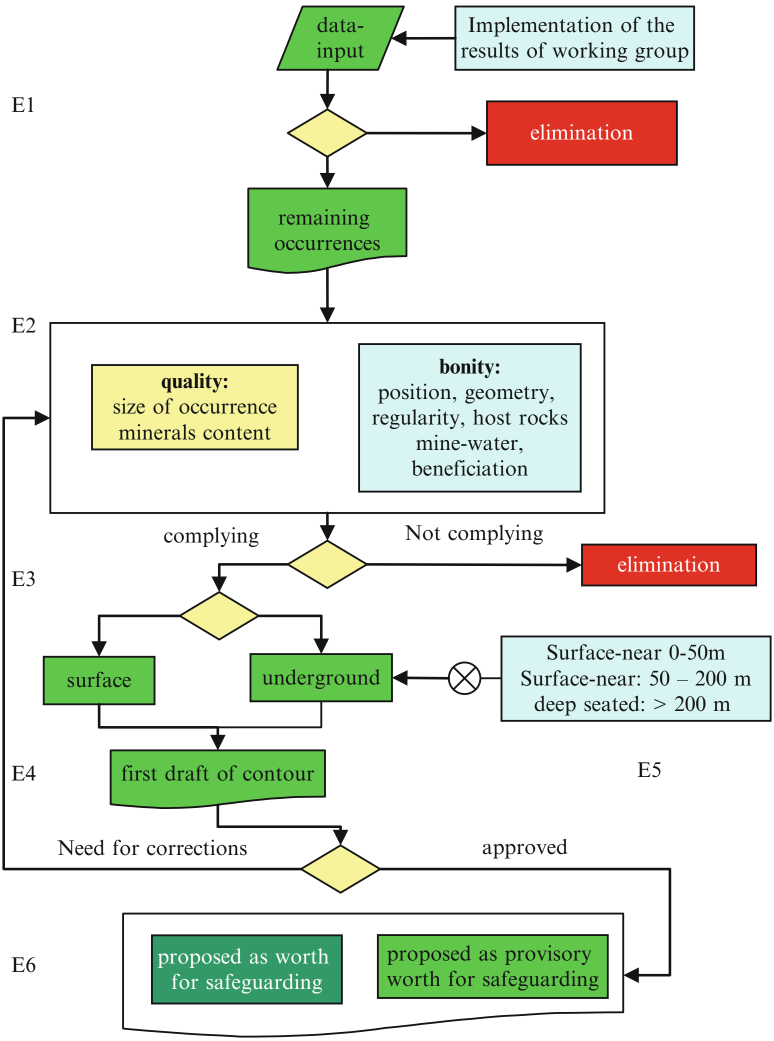

Fig. 8.9 Flow diagram for the assessment of ores, industrial minerals and energy resources; phase 1

open-pit mining. The contours of the mineral deposits are taken as basis for surface-near mineral deposits (e.g. building resources). Finally, the resource area was drawn in outline and its worthiness of being safeguarded (worth of being safeguarded/provisory safeguarded) was explained as basis for the elimination of conflicts in phase 2. Similarly, as in the case of loose rock by means of GIS cutting in connection with all possible conflict potentials (water, building land, traffic routes, nature conservation, forest etc.) was carried out (methods: see Figs. 8.9 and 8.10).

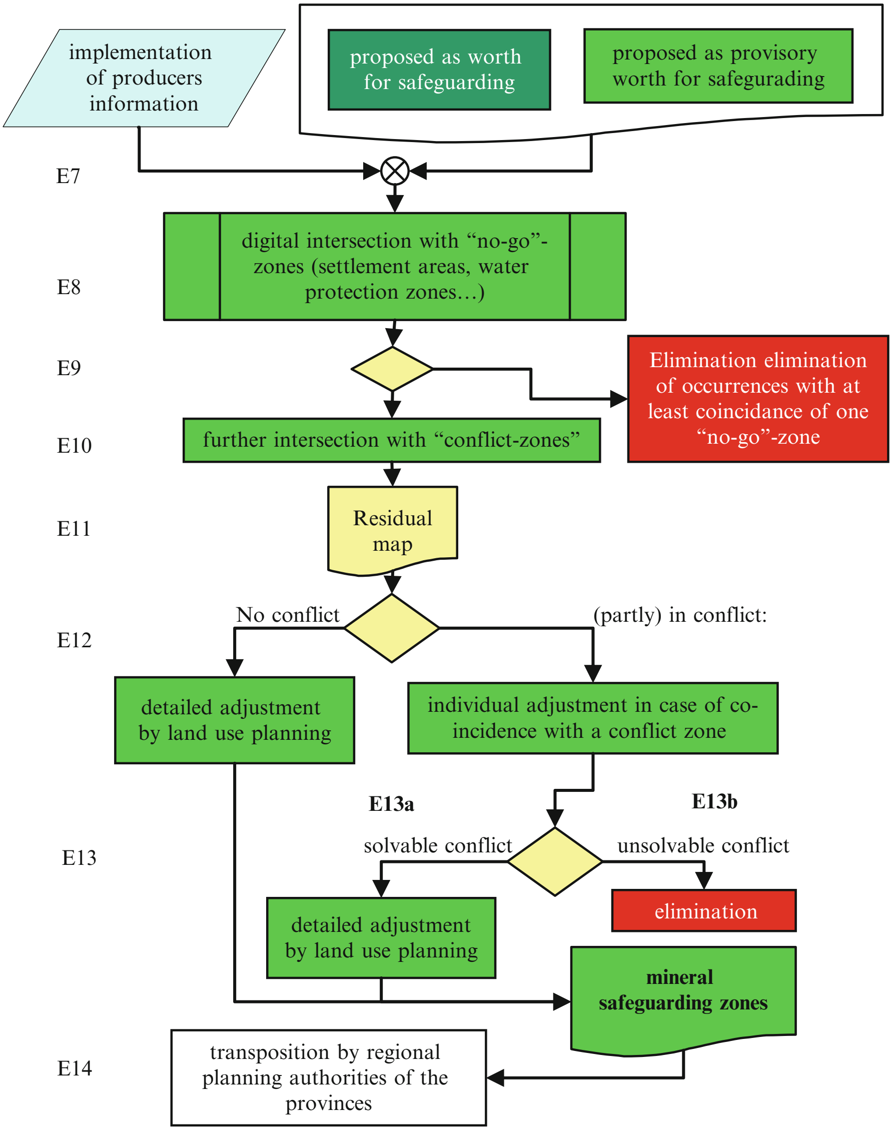

Fig. 8.10 Flow diagram for the elimination of conflict in deposits of ores, industrial minerals and energy resources, phase 2

Deposits for Extraction in Open-Pit Mining

The area to be safeguarded at deposits on the surface comprises basically the whole area wherein all probability extractions will be made considering open-pit mine slopes and the respective infrastructure including stockpiling, dumps and tailing ponds. Typical values for the general inclination of open-pit mine slopes in loose rock are approx. 30–45° and in solid rock 45–60°.

Deposits for Extraction in Underground Mining

The safeguarding area for surface-near, shallow and deep-situated deposits comprises basically areas for the infrastructure belonging to mining including stockpiling, dumps and tailing ponds and areas required for access and future extraction.

In the case of shallow-lying deposits (0–50 m), it shall be proceeded on the fact that the influenced zone extends to the surface and as a result besides subsidence, in particular, goaf phenomena may appear on the surface. The safeguarding area for shallow-lying deposits comprises, in particular, such areas of the surface where in all probability according to the present and foreseeable state of the art, bigger harmful impacts (e.g. goafs, surface subsidence) may occur if the deposit will be extracted. This impact area forms part of the safeguarding area and results from the projection of the boundaries of the whole prospective extraction area on the surface given a preliminarily assumed critical angle of approx. 60–70° in solid rock and of approx. 45° in loose rock. The deposit shape is irrelevant for fixing the safeguarding area.

In the case of surface-near deposits (50–200 m), it shall be proceeded on the fact that the influenced zone may extend to the surface and as a result besides subsidences, in particular, break phenomena may appear on the surface. The safeguarding area for surface-near deposits comprises, in particular, such areas of the surface where in all probability according to the present and foreseeable state of the art, bigger impacts may not be completely excluded if the deposit will be extracted. This impact area forms part of the safeguarding area and results from the projection of the boundaries of the whole prospective extraction area on the surface given a critical angle of approx. 60–70°. The deposit shape is irrelevant for fixing the safeguarding area.

In deposits in the deeper underground (>200), it shall be proceeded on the fact that depending on rock conditions and the extraction technology, extensive subsidence phenomena will appear on the surface which, however, may as a rule be tolerated. That is why the safeguarding area for deposits lying deeper than 200 m comprises only the infrastructure belonging to mining including stockpiling, dumps and tailings ponds and areas required for the access and future extraction (Weber 2007).

So far, a number of potential mineral areas have been countrywide identified as worth being safeguarded or provisory worth being safeguarded. Among them, there are deposits of steel-refining metals such as tungsten and manganese; nonferrous metals such as antimony, lead, zinc, copper, polymetallic ores and precious metals; industrial minerals such as baryte, bentonite, diabase, diatomite, haematite, feldspar, vein quartz, gypsum, graphite, kaolin, magnesite, oil shale, salt, talc and leucophyllite; and energy resources such as brown coal and hard coal.

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Part III
Sustainable Production and Consumption

Chapter 9
Materials Efficiency in Product Design and Manufacturing

Mario Schneider, Volker Härtwig, Julia Kaltschew, Yvonne Langer, and Kristin Prietzel

1 Introduction

Data published by the Federal Statistical Office have revealed that in the manufacturing industry, material costs constitute by far the greatest cost pool (44.3%), that is, more than twice the 18% share of labour costs. In contrast, energy costs account for a mere 1.8% of the total costs. These figures show that savings in the field of materials have a particularly great influence on the cost structure. Hence, the companies' return on sales may increase considerably by opening up a corresponding potential for savings.

Figure 9.1 shows the cost structure of the manufacturing industry in 2007. The figures published by the Federal Statistical Office refer to enterprise data acquired 2 years ago. A review of the annual development of cost structures in the 2001–2007 period shows material costs to have been continuously on the increase by about 1%, which was paralleled by a decrease in labour costs. Figure 9.2 illustrates the dynamics of the development of these two cost types.

When dividing the material costs by the labour costs, the resulting quotient was almost 2 for 2001. In the further course, until 2007, the quotient rose to almost 2.5. This fact demonstrates again the increasing importance of material costs. Hence, savings in the field of materials are considerably more effective than those in the field of labour. Even a minor decrease in the per cent share of material costs may result in a clear decrease of production costs and thus, an increase in the competitiveness of enterprises. This is why a higher efficiency of production processes is indispensable. In order to help enterprises in identifying their saving potential and increase their competitiveness, the German Materials Efficiency Agency (Deutsche Materialeffizienzagentur – demea) was founded by the Federal Ministry of Economics and Technology.

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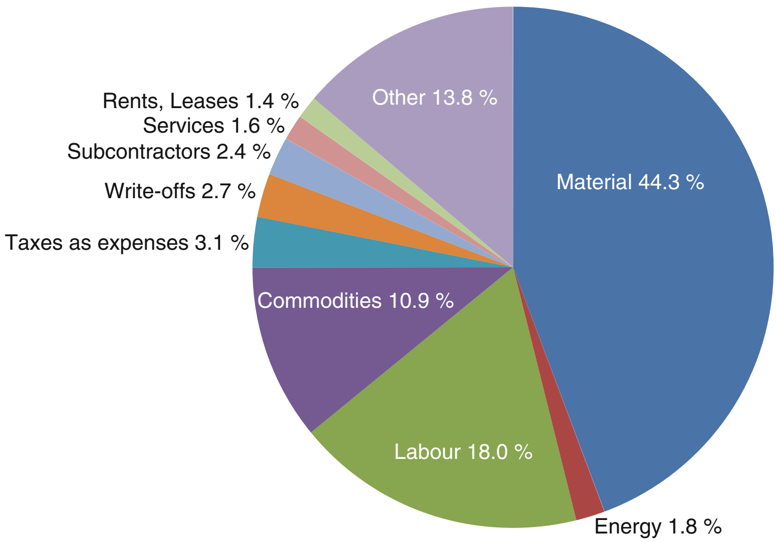

Fig. 9.1 Cost structure in the manufacturing industry in 2007 (Source: Federal Statistical Office 2009)

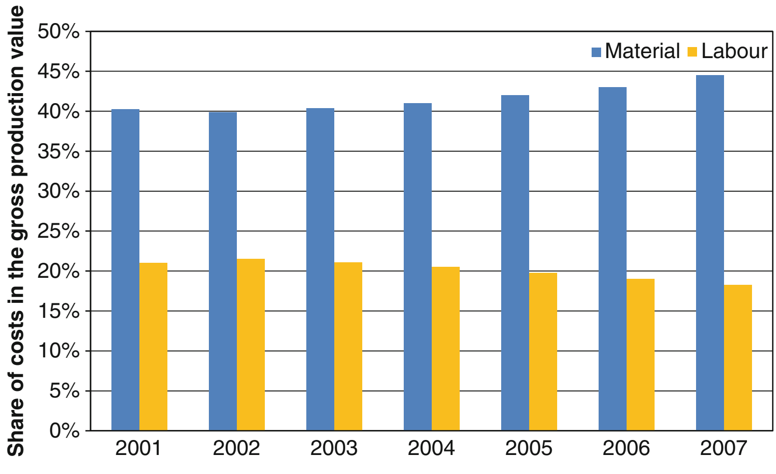

Fig. 9.2 Development of material and personnel costs (Source: Federal Statistical Office 2003–2009)

Evaluation of the previous consulting projects under the Materials Efficiency Impulse Programme has demonstrated that on average, 2.4% of material costs could be saved each year. This corresponds to an average saving potential of more than 200,000 €. In addition, it was demonstrated that 50% of the potential resources could be opened up by means of investments of less than 10,000 €. Another 20%

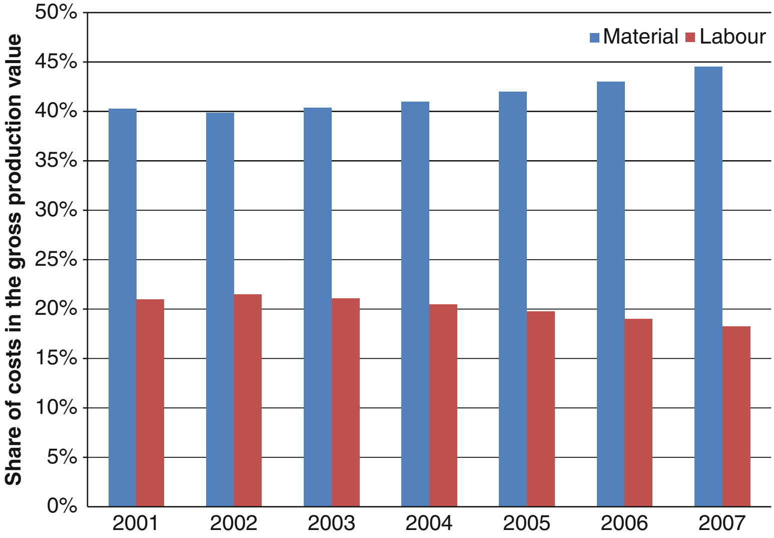

Fig. 9.2 (continued)

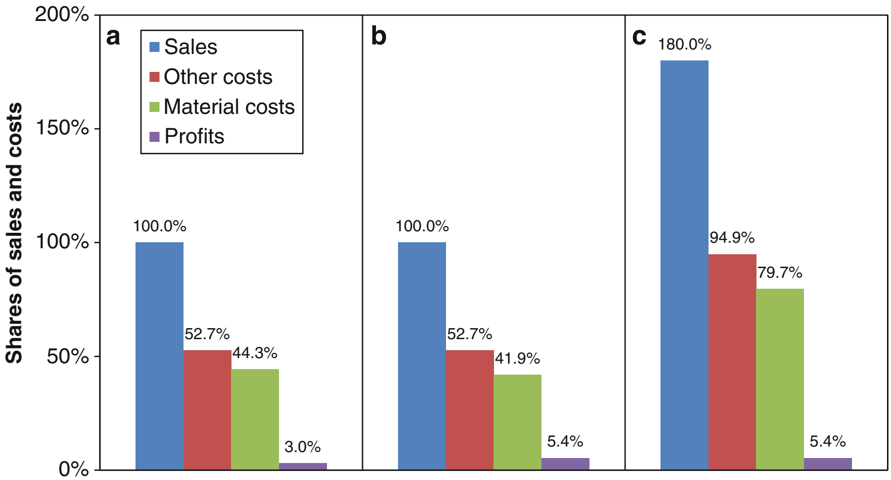

Fig. 9.3 Effects of material savings at the business management level. (**a**) Initial situation, (**b**) Material savings of 2.4%, (**c**) Sales increase by 80%

required investments below 50,000 €. The effect of material savings at the business management level is shown in Fig. 9.3.

In the initial situation shown in Fig. 9.3a, an enterprise having annual sales of 100% incurs material costs of 44.3% of the sales volume, based on publications of the Federal Statistical Office, and assumed profits of 3%. Other costs account for 52.7%. A reduction of material costs by 2.4% as shown in Fig. 9.3b may result in a direct increase in profits to 5.4%. For comparison, Fig. 9.3c shows a comparative calculation of the increase in sales required for the enterprise to achieve an increase in profits corresponding to that achieved by reducing material costs by 2.4%. The result would be an increase of turnover by 80%. This would mean a considerable financial expenditure for the enterprise and would be most difficult to achieve in saturated markets. In contrast, a reduction of material costs may be achieved already by making a minor investment and is very profitable, according to the calculation shown above.

2 Approaches to Reducing Material Costs

In the following, concrete approaches are described that would help to reduce material costs over the product's life cycle. All examples discussed here originate from consulting projects carried out in the context of the Materials Efficiency Impulse Programme, that is, from operational practice.

Adoption of these proposals will not only result in positive effects on material consumption. Material means a consumption of energy, labour and capital. Experience has shown that the saving effects achieved for the latter are in the same order of magnitude as those for pure material costs.

Strikingly, it is often the simple approach that brings about major improvements. The main problem appears to consist in the complexity, that is, the great number of factors to be considered. This indicates how important it is for manufacturing companies to rely on external expertise in order to enhance their materials efficiency.

2.1 Cost Transparency

Cost transparency is a fundamental prerequisite for identifying and developing saving potentials. If an enterprise has "only an electricity metre and a water metre" and the purchasing department places its orders at defined intervals while knowledge is lacking on which materials and media are consumed at the different production stages, it is very difficult to identify wasting of resources and to remedy the situation. In practice, particularly in the case of small enterprises, it takes consultants several days to obtain an initial overview of consumption levels. Therefore, cost transparency is indispensable where new products and production facilities are involved.

2.2 Information

Information is another essential element. Where are certain materials stored? Are there any leftovers that may be used? Have the materials already been assigned to other production processes? Which qualities are (in fact) required? Are there similar components used in other products? These exemplary queries demonstrate the importance of the relevant information being available, if possible, at every workplace in the establishment. Regrettably, in many enterprises, such questions are not asked at all nor are they always easy to answer.

2.3 Documentation

Important information (e.g. agreements with customers on changes to the product design or to procedural steps in production) should be documented in a clear and comprehensible way. Such approach should be natural; however, we are far from this being operational practice everywhere. Staff in production areas should be guided by means of clearly structured work instructions containing unequivocal dosage specifications in common dimensions (kg, m^2 or m^3).

2.4 Motivation and Training of Staff

Staff members in construction, production and production planning departments have a decisive influence on the efficient handling of materials. It is important to raise their awareness for materials efficiency and to motivate and train them accordingly. As a rule, a sustainable increase in efficiency may only be achieved if these staff members are involved in continuous improvement processes (CIP). Their minds are filled with knowledge about the production processes, existing cases of wasting of materials and approaches to improvements.

2.5 Product Construction

It has been uncontested that the most important effects can be expected from product construction (keyword: lightweight construction). In many cases, components are oversized or even dispensable. Which material thickness is required? Which types of stress is the product exposed to during use? Is it necessary to use solid material or is hollow material sufficient? Is it possible to separate load-bearing elements from functional ones and to optimize the entire system? Is it possible to reduce the diversity of components?

Optimization of product construction is often associated with an enhancement of performance characteristics (e.g. reduction of weight resulting in energy savings when the product is in motion).

2.6 Diversity of Components and Materials

A great diversity of components and materials will involve the risk of inefficiency because all components and materials have to be included in planning and held available. Constructive changes that may occur in any product life cycle could result in the necessity of having to dispose of components or materials directly from existing stock.

2.7 Selection and Substitution of Materials

The question of materials is an interesting issue not only with regard to new products but also to existing ones. Metal or plastics? Shall a product component be planed from solid wood, or is it possible to mould it as a wood-plastic composite (WPC)? Is it possible to use recycled material (e.g. plastic waste)? Which variant will result in the lowest scrap rate as well as material and energy consumption?

2.8 Processing

Also the selection of the type of processing may have a decisive influence on materials efficiency, although technological restrictions have to be taken into account in the individual case. Chip-removing processes should be avoided, whenever possible, because they involve considerable material losses. In the case of metals, for example, bar stock material may serve to produce blanks very similar to the target structure that need only minor processing by turning or milling. In the case of wood products, wood-plastic composites, as mentioned above, constitute an alternative that is worth considering. In many cases, injection-moulded plastic components offer the advantage that production wastes can be ground and recycled for another use in the material flow. For special metallic components, procedures such as powder injection moulding (PIM) may be used where the target structure is produced from powder with almost no loss of material. However, the procedures mentioned may require considerable technological expenditure and be cost-effective only where great numbers of pieces are produced. Other important aspects will include energy consumption and process reliability as well as scrap rates.

Likewise, a considerable saving potential is present where cutting processes take place. For example, laser technology may permit to produce sections thinner than those made by using the “thick” saw blades, or very thin sheet steel may be cut without deformation. These are only a few examples to demonstrate the existing potential and at the same time, the technological complexity of the subject.

2.9 Selection of Suitable Tools

Also the selection of tools is very important. Inferior tools or those showing excessive wear will increase the scrap rate and decrease efficiency. What is the thickness required for a saw blade? A saw blade that is too thick will result in an unnecessarily high material loss.

2.10 Specifications and Tolerances

It is important to define specifications and fix tolerances in a reasonable manner. Unnecessarily high requirements will result in too many components being sorted out in quality testing that might have been well suited for use.

2.11 Organization of Manufacturing

In businesses that have "developed organically", many transport as well as storage and retrieval operations take place that are actually unnecessary. They involve the risk of damage or mistakes and increase the scrap rate. At the earliest possible opportunity, manufacturing should be reorganized to develop a continuous flow production where the material flow through the factory follows a continuous and straight path, avoiding interim storage and other "efficiency guzzlers".

2.12 Workplace Design

Workplaces should be designed in a way that provides for an efficient handling and processing of and preventing damage to materials and components. Other requirements to be met include safe workpiece holders, good quality tools, clear arrangement and ergonomic seating positions. Fatigue will lead to an increased production of scrap. Safety, tidiness and cleanliness will increase materials efficiency.

2.13 Warehousing

It is often reported that stored materials or components are not found and have to be reordered or reproduced out of necessity. This is why transparent and efficient warehousing is indispensable. "Private stocks" of employees whose contents are unknown and therefore cannot be taken into account in material planning should be avoided. Proper storage will prevent corrosion, decay or other spoilage of materials. Attention should be paid to the admissible storage period. These suggestions may seem trivial. Nevertheless, the demea consultants very often meet with negligence of this type. On principle, as little material as necessary should be stored. Many materials are disposed of directly from the store because products are no longer marketable or components can no longer be used for assembling since they have been replaced by newer versions. Lean stocks will increase materials efficiency and reduce capital commitment.

2.14 Production Planning

Disposal of materials directly from the store is a direct late consequence of insufficient production planning. If possible, semi-finished products should be ordered and manufactured only on the basis of concrete orders and/or reliable sales forecasts. Stocks kept for fear of shortage should be reduced as much as possible.

2.15 Pooling of Orders

In many cases, pooling of orders in manufacturing planning is meaningful to achieve an optimal utilization of material stock in bar or sheet form. This is by no means a trivial issue because it is not supported by a great number of planning programmes, or the organization of manufacturing establishments fails to take it into account.

2.16 Quantitative Scrap Optimization and Nesting

Meanwhile, "simple scrap optimization" can be found in almost every enterprise. Nevertheless, there are special features that are not yet mastered by all of them. In the case of sheet materials, for example, good parts may be placed in punching zones. If, nevertheless, a sheet is not completely utilized even if orders are pooled, more parts may be punched from that sheet where experience has shown that these are frequently needed.

2.17 Diversity of Parts and Components

The production of frequently needed parts from residual lengths or areas of material will succeed much better if the diversity of parts and components is as low as possible. A reduction of diversity will involve considerable advantages since it will reduce the stockpiling required and thus, also the risk of storing materials which will never be needed again and will have to be scrapped years later, not to mention a reduced capital commitment.

2.18 Length-Optimized Purchasing

Another important measure to increase materials efficiency may consist in purchasing length-optimized material. As a rule, bar stock, beam and sheet materials are available in different lengths or areas. Unfavourable basic dimensions may result in a dramatic increase in scrap rates (in spite of optimization). However, length-optimized purchasing will require a high information transparency and good communication between the production and purchasing departments.

2.19 Batch Sizes, Start-Up Wastes and Set-Up Periods

Similar positive effects may be produced by smaller batch sizes, less start-up wastes and shorter set-up periods, with the latter being a precondition for smaller batch sizes.

2.20 Qualitative Scrap Optimization

For materials with variable surface qualities (e.g. leather), qualitative scrap optimization may constitute an effective means. The areas of the material having the best surface quality are used for conspicuous positions, while those of inferior quality are used for less visible parts such as bottom or rear sides.

2.21 Inspection of Incoming Material and Batch Tracing

As a prerequisite of this, however, a qualitative scrap optimization is required so that the relevant aspects are identified early enough prior to production, if possible in the context of an inspection of incoming material. The latter is highly recommended, in general. However, it is omitted in many cases. It is rather pointless to perform production processes using materials that do not comply with qualitative requirements. In case deficiencies are identified later on, also batch tracing is recommended.

2.22 Labelling of Materials and Components

All materials and components used in the production process should be labelled in such a way as to enable unequivocal identification. The risk of mistaking components and materials will increase the scrap rate and reduce materials efficiency.

2.23 Recycling of Scrap, Wastes and Remainders and Sorted Collection

Scrap, production wastes and remainders should be returned to the production process. Of course, the existing options will strongly depend on the respective industrial sector and the materials used. They will, in part, involve the supplier (e.g. for metal filings). At any rate, sorted collection is required.

2.24 Recording of Leftovers

The recording of leftovers is another important prerequisite. If the existence of such materials is unknown, they cannot be included in the planning and will remain unused. Leftovers include both delivered materials and parts that were produced in addition on the basis of experience, that is, the scrap rates recorded, and not needed eventually.

2.25 Continuous Quality Control

Continuous quality control is very important. Identification of a deficiency should be immediately followed by an adequate reaction. If deficiencies are identified late, for example, during the final inspection, or detected by the customer, lots of material, working hours and possibly energy may have been wasted.

2.26 Tool Monitoring and Maintenance

If the quality of production procedures depends on the condition of the tools used, regular monitoring and maintenance and, if needed, re-engineering of the latter should be performed. The prescribed maintenance dates have to be kept.

2.27 Cleaning Processes

Experience has shown that cleaning processes offer a high potential for improvements. Often, the cleaning of products is not seen as being within the scope of core competence of the manufacturing companies so that there is no targeted onward development of such processes.

2.28 Dosage of Cleaning Agents Including Water

Frequently, the dosing of cleaning agents and water is in need of improvement. There is neither knowledge nor documentation of the optimal dosage. For water, a wide range of combinations of pressures, nozzle shapes and droplet sizes are available.

2.29 Water Recirculation and Treatment

Also water used for cleaning may be recirculated. There is no need for using fresh well water at every cleaning stage. Often, contaminants may be removed by physical or chemical filtration. Valuable materials may be recycled from sludges. There is also a wide range of processes available for water treatment. Only rarely, the best ones are employed.

3 Practical Examples from Different Industries

Concrete projects carried out in the context of the Materials Efficiency Impulse Programme have demonstrated the success of the approaches to increasing materials efficiency described above. The examples presented refer to different industries and enterprises of different sizes. Thus, it is demonstrated that material savings are an important aspect when enhancing competitiveness both in industry and trade.

3.1 Metal Processing

In an enterprise in Baden-Württemberg producing metal parts such as screw nuts, cam lobes and discs, high scrap rates and a high wear of tools were observed during metal cutting. A fundamental solution to the problem was found by using preformed blanks instead of solid material (Fig. 9.4). In this way, the material wastes produced were reduced by 50%. Also the tool wear was reduced owing to the lower cutting

Fig. 9.4 Using preformed blanks instead of solid material

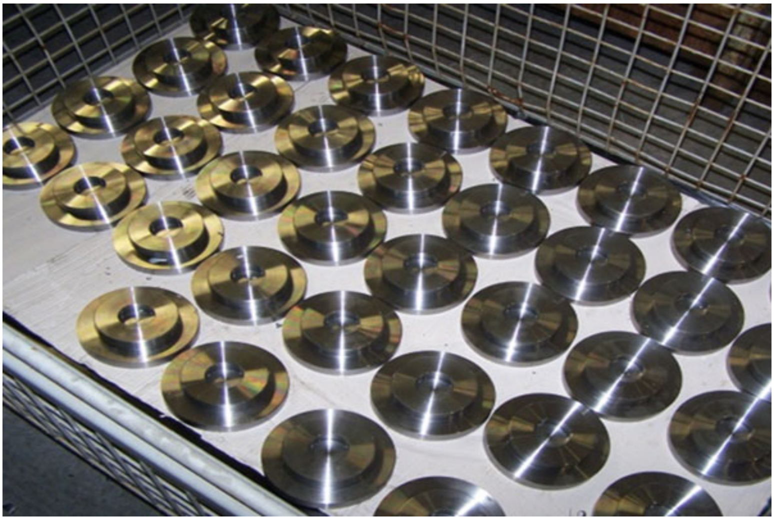

Fig. 9.5 Optimizing casting allowances

forces acting upon the tools as a whole. This resulted in an annual material saving potential of 2,370,000 € and as a consequence, an increase in the returns on sales by 13.7%. In addition, the enterprise's efficiency was improved by a reduction of the processing period indirectly resulting in a higher production capacity.

High metal cutting wastes, associated with a relatively high scrap rate, were also observed in a Bavarian enterprise. A change in casting allowances and the introduction of automated dimensional inspection after turning will result in a reduction of the amount of cutting wastes for essential parts by 45% and thus, also in a reduction of tool wear. Eventually, it will be possible to save 5.9% of the material used, resulting in annual material savings worth 115,000 €. The processing period decreased by 35% in this case (Fig. 9.5).

3.2 Electrical and Electronics Industries

A Bavarian manufacturer of electric motors produced high quantities of residual materials on reels. The company lost valuable material because residual pieces of copper were not recorded after sawing and therefore, could not be considered in planning. In addition, the company originally had two bar stock material stores. When they merged later on, even more material could be saved. The effects that may be achieved are impressive. Now, more than 99% of the raw copper material is used in production. Altogether, 4% of the materials can be saved, corresponding to annual savings in an amount of six-digit figures (Fig. 9.6).

Fig. 9.6 Centralized bar stock

3.3 Processing of Plastic Materials

In a Thuringian company dealing in injection moulding technology, material-saving potentials identified for granular material and finished products amounted to a total of 195,000 € per year. The most important measures included tool optimization, direct recycling of the sprue and improvement of the communication between production and toolmaking and appropriate storage. Likewise, training of the setters for setting the parameters after mould exchange and of production staff for competent quality assessment of injection-moulded parts contributed to material savings. Eventually, the company's scrap rate could be reduced by 50%.

In a plastic processing company in Mecklenburg-Vorpommern producing large-volume containers, two essential causes of high material consumption were identified. Firstly, wall thickness of the products was too high and secondly, the process involved an unnecessary input of new goods. As appropriate measures to increase materials efficiency, wall thicknesses were optimized, and polyethylene was substituted by recycled material. This resulted in annual savings of polyethylene in the amount of 270,000 €.

For the logistics of paints and lacquers, a firm of packers in North Rhine-Westphalia achieved considerable savings. The most essential sources of loss consisted in error-prone packing patterns, improper transport and mistakes in load security and handling. Optimization of the packing of pallets and of process flows

Fig. 9.7 Error-prone vs. optimized packing patterns

as well as instruction of the staff resulted in a clear reduction of damage occurring during storage and transport. As a result, this segment has recorded a saving potential of 100,000 € and thus, an increase in the rate of returns by 15% (Fig. 9.7).

3.4 Wood Processing

In Lower Saxony, an enterprise making windows and doors experienced losses of 38 and 32% of the material used in the fabrication of entrance doors and windows, respectively, due to insufficient material quality and purchases of squared timber without length optimization. By improving the inspection of incoming material and the storage of timber blanks, reducing material routes and implementing a number of measures at individual workplace, an annual saving potential in the amount of 142,000 € was identified. This included fittings, accessories and paints. Scrap rates could be reduced by 40% (Fig. 9.8).

3.5 Furniture Manufacturing

A manufacturer of upholstery furniture in Bavaria focussed on the leather and fabric cuts when searching for material-saving potentials. Savings could essentially be achieved by means of optimizing the pattern and nesting processes. Additional material savings and prevention of extra work were achieved by inspection of the

Fig. 9.8 Optimized workplace organization and improved storage of timber blanks

bar code labelling of leather hides, by using screens with automatic sorting plan displays to facilitate sorting and by a detailed analysis during separation. Furthermore, also warehousing was optimized with regard to excess age, discoloration or the risk of a stock-out. In this way, annual material savings amounting to 243,000 € could be identified.

3.6 Surface Coating

In an enterprise in North Rhine-Westphalia specializing in high-quality surface finishing, an annual saving potential amounting to 90,000 € was identified with regard to paints and solvents. These savings resulted from an improved application technology, automated cleaning of paint sprayers, modification of glossy paints and enhanced recovery of solvents in purging processes.

3.7 Food Production

Material savings amounting to 398,000 € could be identified for a food manufacturer. Major saving potentials were found above all for potatoes as a raw material but also for a number of ingredients and films, folding boxes and cartons. Measures recommended to achieve this goal included the minimization of down times of production as well as of materials remaining from opened packages and of residues, optimization of material flows in the establishment and extension of storage capacities. Material savings were also achieved by an optimization of batch sizes.

3.8 Breweries

A brewery in North Rhine-Westphalia could save considerable expenditure on raw and finished material by measures taken in a number of functional areas. These included the brewhouse, cooling plant, bottle cellar, steam generation and feed water cycle. Savings could be achieved above all by means of enhancing process stability. Concrete measures included water and chemicals savings in strip lubrication, the use of industrial water for filling and filter sterilization, an increase of carbon dioxide recovery and the prevention of beer losses due to overfilling. In this way, annual savings of malt, water, chemicals, carbon dioxide and beer worth 219,000 € were achieved.

3.9 Services

A laundry business in Brandenburg sought ways to reduce their material and water costs. Appropriate measures identified included chemical savings in the continuous batch washer (tunnel washer) and washer-extractor, salt savings by reducing the consumption of water and steam, and water savings by loading of higher quantities, recycling and reduction of vapour losses. The annual savings achievable may amount to 180,000 €.

3.10 Textile Finishing

A manufacturer of textile floor coverings in North Rhine-Westphalia demonstrated that there were considerable saving potentials with regard to material costs. Savings could be affected essentially by means of improving the precision in the dimensioning of dyeing ratios and, depending on the product involved, omitting of rinsing or prewashing. In this way, the business may save 262,000 € per year.

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Part IV
Further Development of a Sound Waste Management

Chapter 10
Strategies to Increase Resource Efficiency

Martin Faulstich, Markus Köglmeier, Anna Leipprand, and Mario Mocker

1 Introduction

Undoubtedly, a sparing use of natural resources and an increase in resource efficiency are the most important issues to be tackled in the future. On the one hand, the production, processing, use and disposal of materials are associated with considerable environmental impacts resulting from excavation residues, pollution, production wastes and the emission of greenhouse gases. Mining of raw materials and processing often require huge amounts of water and energy. These activities as

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well as the transport infrastructure involve a massive interference with ecosystems (SRU 2005). On the other hand, a major part of natural resources is exhaustible and nonrenewable. For some raw materials, for example, crude oil, it is even possible to predict the time when the quantities that can be economically obtained under the prevailing conditions will become exhausted[1] (BGR 2009). Deposits of other important raw materials, for example, a number of metals, are often concentrated in a few countries, which may result in dependency and market distortion. In addition to dependency on such regional conditions, there are also oligopolistic market structures where large shares of the world's resources of specific raw materials are in the hands of a small number of companies (Bardt 2008).

Also, there is a rather uneven distribution of the per capita consumption of resources on the global level. The average consumption of a European or US inhabitant is five to ten times higher than the specific consumption per inhabitant in India or Africa (SERI 2010). The demand for resources will continue to increase due to the global population growth and rising standards of living. Altogether, the probability of conflicts arising from attempts to gain access to resources will increase.

Three problem areas, that is, environmental pollution, security of supply in the face of scarce resources and distributive justice, which are closely interconnected, have been dominating the current discussion. However, this has also brought to light the existing great variety of conflicting interests. An obvious strategy to solve these problems consists in a more sparing and more efficient management of resources. A reduction of consumption may mitigate conflicts, improve resource-to-production ratios to ensure a longer lifetime of existing reserves and reduce negative environmental impacts. To maintain the existing standard of living in the industrial countries and to raise it in the emerging and developing countries, an increase in the efficiency of using natural resources is therefore of decisive importance.

In Germany and in Europe, politics have recognized the situation and developed strategies and measures to promote a sustainable and efficient use of natural resources. These are macroeconomic approaches aiming at an increase of the added value while at the same time the consumption of resources is reduced. In addition, on the microeconomic level, there are also good reasons to increase material efficiency and, thus, to reduce costs (product or production with reduced material input).

In order to identify the most efficient approaches to a sparing use of resources, a model concept based on the value chain was developed (Faulstich et al. 2009). In this way, the strong influence that can be taken on the demand side is visualized. For this reason, the political strategies used in Germany and Europe are briefly explained, and possible instruments of control are discussed.

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[1] See also Andreas Breitenfellner's article "Economic growth and resource use" (Chap. 4).

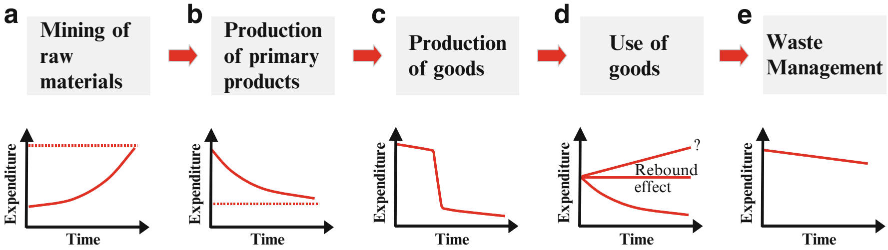

Fig. 10.1 Schematic representation of the stages of the value chain together with the respective framework conditions for an increase in efficiency

2 Anthropogenic Material Flow Chains

2.1 Model for Resource Efficiency Improvement Potentials

The vision for the future should consist in an economy that comes as close to a closed-loop system as possible, transferring only a limited quantity of materials back and forth between use and processing/recovery while simultaneously reducing losses to the maximum extent possible. In order to achieve this objective, our societies and economies have to provide for a visibly more efficient use of resources. Against this background, a model concept was developed illustrating the essential links of the value chain and their efficiency potentials (Faulstich et al. 2009). In this context, the term efficiency initially refers to the cost/benefit relationship in rather general terms.

The consecutive stages of the value chain are shown in schematic form in Fig. 10.1. The mining of raw materials is followed by the production of primary products, which in turn are used to produce goods and also provide the material basis for services. In this process, the behaviour of users and demand have a decisive influence on the type and extent of production and, thus, also on the upstream and downstream stages of the chain. Wastes or goods no longer required are disposed of. Under the current conditions in Germany, this includes material recycling and thermal utilization and also disposal by incineration or landfill. At all levels of the value chain, the specific expenditure necessary for the provision of the respective service is limited by different framework conditions. In the following sections, these conditions are described and discussed in more detail.

To simplify matters, the specific expenditure is described in qualitative terms only, and its dynamic course is outlined. There is a great number and diversity of resources used at the individual stages of the value chain. For a quantitative consideration, it would therefore be necessary to develop a weighted assessment standard for the different categories first. In this respect, there is still a considerable need for methodical research.

2.2 Mining of Raw Materials

Figure 10.1a illustrates, in a fairly simplifying way, the conditions for the production of raw materials from natural sources, as referred to a single deposit. In principle, there are chances for improving efficiency. However, it has to be assumed that in the course of time, the specific expenditure will increase continuously. Reasons for this may include decreasing concentrations of utilizable material, an increase in the share of impurities, higher quantities of excavated material requiring disposal or the necessity of mining at ever deeper levels below ground. For these considerations, it is initially irrelevant whether the expenditure is quantified in physical or monetary units. The broken boundary line in Fig. 10.1a represents the maximum of acceptable expenditure. Above this limit further mining would no longer be economically profitable or technically feasible, and the respective deposit would be considered as exhausted.

2.3 Production of Primary Products

General aspects of the production of primary products are outlined in a similar way in Fig. 10.1b. Normally, a continuous decrease of the specific expenditure is achieved by a steady improvement of processes and methods. However, with regard to material input, there are natural limits in the stoichiometry of the decisive reaction equations and in the thermodynamic equilibria (broken line in Fig. 10.1b). In a technically optimized production, only incremental improvements within these limits are possible. Thus, a noticeable increase in efficiency could be achieved only by substitution with other materials.

2.4 Production of Goods

The production of goods offers a vast potential to increase material efficiency. At this stage of the value chain, it is possible to achieve not only incremental improvement and optimization but also efficiency “leaps” (Fig. 10.1c). Many measures of this kind are associated with cost savings for the producers. As a result, also economic potentials are opened up, and the competitiveness of manufacturers is improved. For example, it is possible to increase material efficiency by means of optimizing the construction or the design of products and/or optimizing production processes (reduction of cutting scrap, in-house recycling) (Simon 2009). Wherever possible, materials should be used that are obtained from less scarce and ecologically unproblematic or renewable resources. However, radical improvements can be expected in particular from innovations that lead to a new design of products and processes and provide for certain functionalities of products in a resource-saving way. A good example of this is given by combining the different functionalities of “print”, “copy”, “scan” and “fax” to be performed by a single (4 in 1) machine.

2.5 *Use of Goods*

The way goods are used has a particular influence on the upstream and downstream stages of the value chain. Mining and processing of resources are induced by the need for goods and services. At the same time, though, goods no longer required are directly handed over to the regime of waste management. In this respect, there is still a great potential for savings in today's affluent industrial societies. Efficient strategies to prevent waste generation must, however, be considered from the side of the consumer and address the patterns of demand. Such approaches are described in detail later.

Nevertheless, future developments of patterns of consumption and use may also induce a constant or even increasing use of material, a phenomenon referred to as rebound effect. This effect describes the fact that percentage savings at one point in the system are in part or completely counterbalanced by a growth of the total production or an increase in consumption at another point and therefore do not result in a reduction of the absolute consumption. Hence, positive effects from savings at the stage of the production of goods or from changes in the behaviour of consumers may become reduced or even neutralized due to the rebound effect. If no countermeasures are taken, improvements of efficiency may even lead to increased consumption. Such conditions are illustrated by the different developments over time shown in Fig. 10.1d.

2.6 *Waste Management*

The long-term fate of materials in the system after having been used is the domain of waste management. This sector is increasingly developing towards modern material flow management. Already at present, it makes significant contributions to resource and climate protection. Nevertheless, valuable materials are still disposed of together with nonreusable wastes. Depending on the waste treatment procedure applied, such valuable materials accumulate, for example, in bottom and fly ash from waste incineration, and thus are not available for immediate reuse.

If such residues are disposed of by landfill, there is a clear-cut distinction between these and the emission into different environmental compartments, which is to be considered as material discharge, because in principle, the deposited material is available for recovery and thus may serve as a source of raw material. It is true that for wastes with a low concentration of valuable materials and possibly contaminated wastes, the absolute expenditure may be initially higher as compared to the mining of raw materials. Nevertheless, a reduction of the specific expenditure may be assumed to take place (Fig. 10.1e). On the one hand, there is a steady improvement of conditions due to increasing efficiency in waste treatment technologies. On the other, also the elimination of ecologically problematic substances from the goods produced, which has been demanded by the concept of

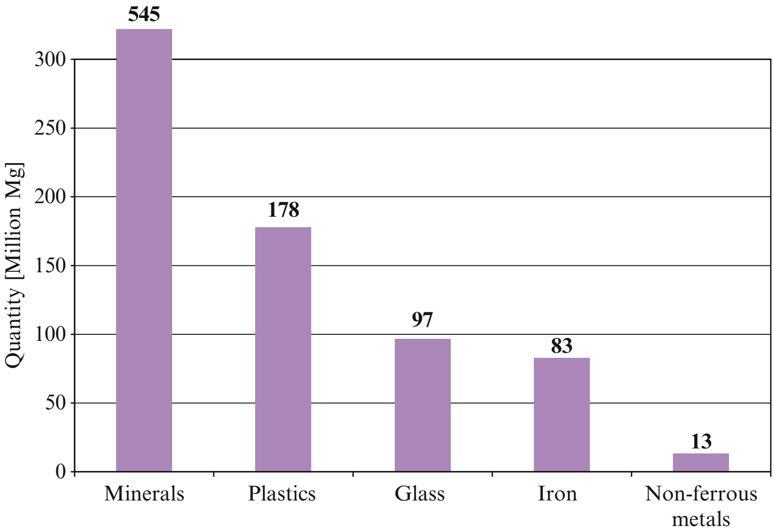

Fig. 10.2 Quantitative estimates of individual groups of materials contained in German landfills

a substance-related environmental policy, will contribute to a reduction of expenditure (SRU 2005).

The landfill mining should be considered as an essential part of a strategy for which the term of "urban mining" has become established (e.g. Obernosterer et al. 2000; Weber-Blaschke et al. 2007). This means that the entire anthropogenic stock of materials is considered and used as a potential resource adding to and completing conventional mining. First estimates based on literature data have shown that in the German waste management sector, a total of about 2.5 billion Mg (megagrams = metric tons/tonnes) of municipal solid waste, demolition debris and commercial waste was disposed of in landfills since 1975. Of these, municipal solid waste accounted for about 960 million Mg (Bilitewski 2000; Görner and Hübner 2002; UBA 2006). Such data served as a basis for approximate calculations regarding the quantities of the individual groups of materials deposited. For this purpose, waste analyses from different periods were used. The results of a fist rough estimate are shown in Fig. 10.2 (Mocker et al. 2009). Due to the fact that there had not been a quantitative recording of wastes before 1975, the resulting amounts should rather be considered as a lower limit. In a similar way, it can be estimated that in the past, as an order of magnitude, much more than an amount of ten million Mg of sewage sludge (dry matter) was disposed of in landfills, corresponding to a deposit of more than one million Mg of phosphate (expressed as P_2O_5).

However, resource saving does not constitute the only advantage of material recovery in the sense of a closed-cycle management. In most cases, the use of

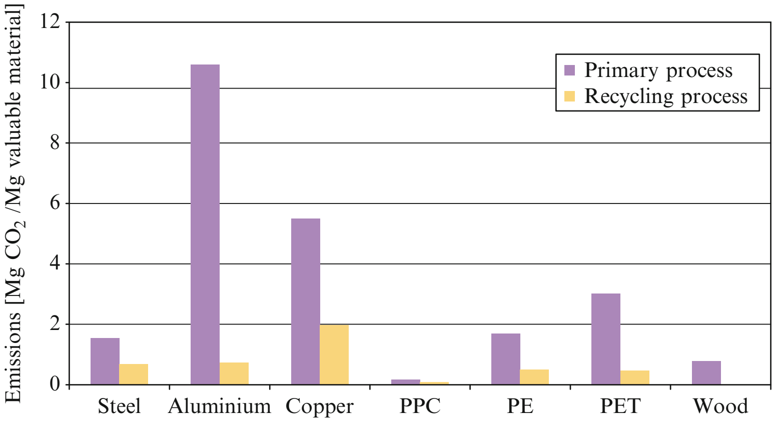

Fig. 10.3 Comparison of CO_2 emission from primary and recycling processes (*PPC* paper, paperboard, cardboard, *PE* polyethylene, *PET* polyethylene terephthalate)

recycled materials causes considerably less environmental pollution than their production from natural resources. This context is illustrated in Fig. 10.3, taking CO_2 emission as an example (UMSICHT 2008).

2.7 Conclusions

Due to the tendency of increasing quantities of excavation residues and on account of the original purpose of raw material supply, the mining of raw materials hardly provides any approaches for a noticeable reduction of material input. In the production of primary products, increases of efficiency are possible within the limits set by stoichiometry/thermodynamics. However, in many cases, due to largely optimized processes in a highly developed society, such improvements will remain limited to incremental ranges.

In contrast, considerable potentials may be opened up by means of efficiency leaps in the value chain of goods and services or by targeted changes in behaviour patterns in the fields of consumption and demand. Instruments of control that may be used are described in the following chapter.

As such instruments become effective and produce noticeable changes, also the vision of a genuine closed-cycle economy becomes more tangible where the majority of material movements take place between the production of primary products and goods. To achieve this, an integration of waste management in a comprehensive resource policy is indispensable. This would mean a reversal of material flows *from* the landfill *to* the production of primary products and goods, which in this way could contribute to the protection of natural resources and provide an additional source of raw materials. When the urban raw material deposits will have dwindled like natural resources, if not earlier, the majority of material movements will take place between the production of primary products and goods only. A supply of the energy required for recovery processes from renewable sources would mean an approach to a level close to the ideal of sustainability regarding the use of resources.

3 Political Strategies and Options for Action

3.1 Strategies and Objectives on the Global, European and National Levels

Negative environmental impacts from the use of resources become evident on different levels, ranging from a devastating destruction of the local environment in mining regions to global climate change due to the combustion of fossil energy sources. Also the problem of security of supply cannot be resolved on a national level due to the dynamic development of geostrategic conditions and uneven distribution of raw material deposits. This is why in a globalized world with complex material flows and trade relations, resource consumption and negative environmental impacts have eventually to be controlled by politics on the international level. While for the field of climate protection, political and institutional structures already exist on the international level, global resource management is still in its early stages.

The EU Strategy on the sustainable use of natural resources (European Commission 2005) has formulated the overall objective of reducing the negative environmental impacts generated by the use of resources under conditions of a growing economy. This is to be achieved by decoupling on two levels, namely, decoupling of resource use from economic growth, on the one hand (*dematerialization*) and a reduction of the negative environmental impacts of resource use, on the other, for example, by means of a replacement of materials (*transmaterialization*).

Also in the context of the European Raw Materials Initiative, a reduction of the consumption of primary raw materials in the EU is an essential objective (European Commission 2008). In order to reduce the dependency on critical raw material imports, it is envisaged to particularly promote resource efficiency, recycling, substitution and the use of renewable resources.

The basic objective of the German resource policy has been formulated in the National Strategy on Sustainable Development (Bundesregierung 2002, 2008). According to this strategy, the resource productivity of the German national economy is to be doubled as compared to the base year of 1994.

In the long term, the improvements in energy and raw material productivity should be guided by the “Factor 4” vision (Bundesregierung 2002). The “Factor 4” formula stands for the idea to double the distributable wealth while simultaneously halving resource use (Weizsäcker et al. 1997). The recently published update entitled “Factor 5” has envisaged an increase of resource productivity by 80%, particularly in the sectors with the highest consumption of energy, water and raw materials and the highest levels of greenhouse gas emission (Weizsäcker et al. 2009). In its 2008 Resource Efficiency Strategy, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit – BMU) has advocated to go beyond the objective of the Strategy of Sustainable Development in the long term and to envisage a reduction of the absolute material input (BMU 2008a).

Both on the European and national levels, there are other strategic documents emphasizing the topic of the security of supply, namely, the "Elements of a raw materials strategy of the German Federal Government" which were developed in cooperation with the Federation of German Industries (Bundesverband der Deutschen Industrie – BDI) and adopted in March 2007, and the Raw Materials Initiative of the European Commission (Bundesregierung 2007; European Commission 2008). Both documents place particular importance on securing access to non-European raw material resources and reducing barriers to trade. It is a particular objective of the EU Raw Materials Initiative to increase the use of domestic raw material potentials. Other components of these strategies include a reduction of the consumption of primary resources in the EU, an increase of resource efficiency, the use of secondary raw materials and an increase of the share of recycled materials. However, these play a less prominent role.

3.2 Product Design and Consumer Behaviour

Resource policy is aimed at the starting point of the value chain, that is, the point at which resources enter the economic system. However, as shown in Chap. 2, there are certain later stages in the value chain where corresponding measures may be expected to be particularly efficient. Insofar, resource policy has to be based on a life-cycle perspective and eventually achieves an integration of the resource perspective in many fields of politics. A possibility to reduce the consumption of material-intensive goods and services consists in extending the lifetime of products and increasing the intensity of their use. This makes sense in particular if the production phase occupies a high share in the life-cycle balance, and it will modify the requirements for the design and production process. Manufacturers may increase the life spans of their products, for example, by choosing more wear-resistant components or shifting wear and tear to less expensive components that are easy to replace. Already during the construction process, more attention should be paid to features facilitating disassembling at a later date and to components that may be replaced and recycled individually (modular construction). Such mode of construction forms the basis for durable products that are open to innovation: Material-intensive components for which hardly any innovations are expected (e.g. casings, drum and stand weights of a washing machine) are used as long as possible, whereas other components can quickly be adapted to technological progress (e.g. motors, control and operating elements).

Another attractive approach consists in the motto "Using instead of owning", which is put into practice, for example, by means of leasing systems. The original idea of leasing was that the manufacturers remain the owners of the goods. As a result, repairability and recyclability become valuable product characteristics for the manufacturers. Of course, an increase in the intensity of use is also achieved if the lessor does not produce the products himself. Some examples include car sharing in urban agglomerations, the collective purchase of high-quality and durable tools in housing or residents' communities and, increasingly, also the rental of expensive winter sports equipment.

In many cases, however, the useful life and durability of products do not only depend on innovative technical properties. Often it is decisive whether the product has a modern, aesthetic or stylish appearance. In this respect, trends and moral concepts play an important role. Timeless design classics such as works by the Bauhaus artists illustrate that certain designs maintain their attractiveness even for decades. For example, the Barcelona chair designed in 1929 by Mies van der Rohe can still be seen today in the customer areas of many banks.

Although such solution concepts have been published already some time ago (Börlin and Stahel 1987; Stahel 1989; Faulstich and Schenkel 1993), no significant transformation towards a leasing society has been observed so far. It seems that durable products and leasing or sharing concepts are not, or only to a quite limited extent, promoted by current economic incentives. Therefore, economic system reforms will be required in order to support a resource-saving closed-cycle management. It will presumably be impossible for such reforms to result from the currently prevailing concept of economy, which is focussed on short-term returns.

Decoupling of economic performance and consumption of resources could as well be achieved by consumers asking for other less material-intensive goods or services. Services such as visiting a restaurant or the hairdresser cannot generally be considered as less resource-intensive than material goods because also the provision of such services is often based on the use of goods and energy. Nevertheless, the results of a study published by the European Commission have suggested that improvements of the environmental situation by a factor of two could be achieved by a shift of demand from resource-intensive categories such as foods, transport and clothes towards health and education (Tukker et al. 2006). Such calculations already take into account a limited elasticity of demand, for example, in the food sector. A prerequisite, however, will consist in broad-based information campaigns on such relationships and transparent labelling systems enabling consumers to critically control their consumption of resources. Such control could resemble the methods for calculation of personal CO_2 emissions.

3.3 Instruments of Political Control

In the following, a number of selected instruments to control resource policy are presented and discussed.

3.3.1 Product Responsibility

So far, it has been impossible to significantly reduce the material flows within our national economy. For a sustainable reduction of resource input and thus of the quantity of wastes generated, measures must be taken at the production level and have to take into account the entire life cycle of a product. The principle of product responsibility may build a bridge between production and disposal and contribute in a decisive way to a sparing use of resources and prevention of waste.

A comprehensive and effective implementation of product responsibility may give important impulses: The expected effects include a reduction of material input and thus also of waste streams, improved recyclability and repairability of products, a longer useful life and new utilization concepts such as leasing or sharing. Also positive macroeconomic effects may be achieved, for example, with regard to employment.

3.3.2 Material Responsibility

As compared to the theoretical effects of product responsibility described above, the success of the legal regulations implemented so far has turned out to be rather modest. Up to the present, the potential of product responsibility has not yet been successfully utilized to change production and consumption patterns. The causes of this situation include, firstly, the design of the legal provisions proper. Secondly, there are economic framework conditions counteracting the incentives of product responsibility or diminishing their effectiveness. At present, product responsibility is reduced to cost responsibility for an environmentally safe waste disposal and partial recycling. In addition, even such limited product responsibility is undermined by masses of used cars and waste electrical equipment being exported (SRU 2008). Therefore, a discussion is required as to which instruments would be suitable to comprehensively promote and effectively implement product responsibility.

3.3.3 Natural Resource Taxes

The design of the tax system may decisively influence the behaviour of producers and consumers. Environmental taxes on raw materials serve the internalization of external effects and eventually a reduction of consumption. Given the fact that in the last decades, labour productivity has increased much more than material and energy productivity (BMU 2008a), a further development of the ecological tax reform appears to be meaningful since it would reduce the cost of labour and simultaneously create incentives to save material. Experts have continued to consider ecological reforms of the tax system as a central instrument for resolving the conflict between consumption of natural resources and increase of prosperity (Ekins 2000; Müller-Fürstenberger and Stephan 2009). In addition, monetary instruments could produce far-reaching innovative effects if they are designed in an appropriate way, that is, if the tax rates are high enough (SRU 2008).

However, onward development of the environmental tax reform has been counteracted by widespread reservations among the population and the resistance by national economic stakeholders fearing competitive disadvantages from the introduction of national taxes. Global resource taxes or usage fees for raw materials traded on international markets would avoid international distortions of competition. However, they are presently being discussed at best as a long-term perspective (Bleischwitz and Bringezu 2009).

3.3.4 Product-Related Regulation

Regulatory instruments of product policy may specifically address individual industries and product groups and assist the development of their efficiency potentials (SRU 2008). Regulations taking into account the product and its life cycle offer a number of advantages for control. They refer to the stage at which product characteristics and process chains are designed. Such regulations may trigger a competition of innovations at this level, that is, among the producers of the final product. As they create the demand for precursor products, such producers act as potential gatekeepers of material flows and therefore may initiate improvements along the entire value chain. The burden of the innovation process is predominantly borne by the upstream producers, a fact which in turn facilitates demanding control activities at the level of the processing enterprises and their purchase departments.

Altogether, regulatory control at a detailed level, that is, relating to individual products, has become an important component of innovation-oriented environmental policy. However, this component has to become effective in the context of economic trend control, that is, control at a more general economic level, by way of the price mechanism. Tax incentives and product-related targets should act in concert, thus avoiding conflicting messages to producers and consumers.

3.3.5 Public Procurement

It is meaningful and necessary that market-based and regulatory solutions are completed by a procurement policy which is guided by environmental principles. Public procurement accounts for about 16 and 13% of the gross domestic product (GDP) of the EU and Germany, respectively. If this enormous official buying power is taken advantage of by means of a stringent ecological approach to the procurement of goods and services, the public sector may contribute considerably to the spread of environmental innovations.

In Germany, however, the potential of public procurement has not yet been exhausted to its full extent. The essential obstacles include, among others, the higher costs of “green” products, uncertainties regarding the legal admissibility and a lack of information (SRU 2008).

3.3.6 Information and Labelling

It is the purpose of information on the environmental impact of products, for example, by means of product labelling, to put consumers in a position to make their purchase decisions on the basis of their preferences for eco-friendly products (if available). The resulting increase in demand is supposed to offer direct incentives for enterprises to enhance the eco-balance of their products.

All over the world, experts are working on methods to inform about the climate and resources' balance of products. Ecological footprints or ecological rucksacks are images helping to communicate and illustrate the consumption of environmental resources. Similar to nutrition claims, also the consumption of resources could be shown in product labelling and expressed as percentage of sustainable per capita consumption (Hinterberger 2009).

There is no doubt that eco-labelling has a certain potential and should be welcomed at any rate as a contribution to transparency and consumer information. In Chap. 3, a brief reference has been made to the requirement to develop, at a preliminary stage, appropriate evaluation standards for resource consumption. Nevertheless, the effectiveness of this potential is presumably limited for a number of reasons: Firstly, for prospective buyers, the eco-balance of products is only one aspect among many others and may be secondary to other factors (e.g. price, promotion campaigns, fashion trends). Secondly, surveys indicate that people tend to overestimate their behaviour regarding environmental compatibility and sustainability and that ecologically sensitive purchase decisions are predominantly associated with a personal benefit (e.g. healthy food from organic farming, long-term financial advantage from the use of energy-efficient appliances). In addition, consumers feel increasingly overwhelmed by the great number of labellings (BMU 2008b).

4 Conclusion and Outlook

Given the strongly increasing demand for resources and consumer products, incremental improvements of energy and resource efficiency such as increases in efficiency in power plant construction or automotive engineering are no longer sufficient. It is likewise important to define the term of sustainable lifestyles, which is quoted so often: Do we spend our incomes on more and more material goods or on more education, culture and health? Do we prefer quality or quantity? Do we buy products or do we buy the use or service of a product? And how long and intensively can goods be used? The big challenge to be faced is setting the course in a way to promote the development of sustainable lifestyles. This requires an open-minded attitude towards "radical" innovations and new system solutions but also the willingness to consider in-depth social and economic relationships. To the extent that such instruments take effect and provide for tangible changes, also the vision of a genuine closed-cycle economy will materialize.

The recent financial uncertainty may have clouded the awareness of climate and environmental risks for a short period of time. It is urgently required that the current way towards a possible new recovery is also used for shaping the transition to a resource- and energy-efficient and low-carbon economy. A sustainable industrial society of the future will largely be based on secondary raw materials in the field of metals and minerals, on renewable raw materials regarding hydrocarbons and on renewable energies.

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Chapter 11
Developing Waste Management into an Element of Resource-Efficient Material Flow Management

Michael Angrick

> Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist. Kenneth E. Boulding (economist)

Waste management has become a major sector. Between 1993 and 2005, some 20 billion € was invested in Germany in new plant technology and in securing and modernising landfills due to the requirements of the Technical Instructions on Waste from Human Settlements and the Waste Storage Ordinance alone. These investments resulted in 11,000–15,000 additional jobs. According to the Duales System Deutschland, since 1991 German business has made investments totalling over 20 billion € and created around 17,000 jobs for the Green Dot system. 170 installations exist today for the sorting of lightweight packaging alone.

High recovery rates and increasing automation have affected the way large parts of the waste management sector view themselves. Today, recovery-oriented waste management sees itself primarily as a manager of raw materials and only in the second instance as a disposer. The waste management sector will contribute to conserving resources to the same extent to which conventional disposal develops into resource-saving material flow management and pursues recovery strategies such as the "2020 target", which is explained below.

It has been the Federal Environment Agency's goal for many years that by 2020 at the latest, municipal waste from households should be recovered on such a scale that it is possible to cease landfilling for the sake of climate protection and sustainability ("2020 target"). Since June 2005 the Waste Storage Ordinance has prohibited landfill of municipal waste which has not been pretreated. It is now important to focus on improving the utilisation of recoverable materials contained in waste by optimising recycling and energy recovery while taking strict requirements for protection of

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environmental media into account. A study commissioned by the Federal Environment Agency shows that a virtually complete recovery of municipal waste can be achieved by using a range of measures. This strategy can be broadened to include other types of waste and is then termed “resource-saving waste management”.

This includes highly efficient incineration with utilisation of the waste heat for production of electricity and heat, treatment of the slag from incineration and high-quality recycling of sorted plastics, ferrous and non-ferrous metal fractions and other resources contained in waste. Finally, incineration fly ash can be used as stowage material in mine backfilling to serve as a long-term pollutant sink where this is in compliance with physical building requirements. Suitable waste management systems for the parties responsible for waste management should be chosen according to economic aspects, the existence of long-term contractual commitments and the development potential of existing waste management infrastructures.

The Federal Environment Agency has shown that the consumption of mineral resources for residential buildings, which in 2000 amounted to 150 million tonnes per year, can be cut by half by 2025 – with a concomitant reduction of the environmental impacts associated with their extraction – through increased selective demolition of buildings and greater utilisation of fractions of concrete, steel, etc., in construction. Our goal must be to increase the selective demolition of buildings and improve the treatment of construction and demolition waste in order to increase the rate of recycling of these wastes from 70 today to 80% by 2012. The UBA is investigating these resource-relevant flows of waste and material, thereby helping to tap this as yet unexploited resource conservation potential.

The Federal Environment Agency uses the term “sustainable waste management” when the concept also includes other aspects such as demographic change or issues to do with waste charges, resource conservation and essential public services with coherent work packages.

1 Scarce Resources: Using Wastes as Raw Material Stocks

The German federal government’s target of doubling resource productivity by 2020 compared to 1994 and the European goal, formulated by the European Commission, of developing a “recycling society” draw increased attention to further waste streams (mineral waste) and materials which will only reach waste management in years to come.

Scarcity of energy resources has accompanied the growing scarcity of industrial raw materials, particularly metal resources, for several years now. The reason for the current shortage of raw materials on markets is the growing demand of large and growing economies such as China and India. As a result, prices for crude oil and scrap rose by 100% and more between 2003 and 2008.

The measures of a strategic resource policy include not only increasing resource productivity but also diversifying resource supply sources – and recycling contributes to such a diversification. Recycling of scrap steel, for example, is well established both nationally and internationally. Functioning scrap markets (with defined scrap-steel qualities) exist along with a functioning infrastructure for collection, return and recycling. Around 44% of all German steel (around 20 million t/a) is produced from scrap steel.

As the demand for industrial raw materials grows, so do the anthropogenic stocks of raw materials currently in use and – with a time lag – their stocks in landfills and the environment. Copper is a good example for the previous description: Global anthropogenic stocks of copper in long-lived technical goods, buildings and infrastructure such landfills have built up to now be as large as the remaining natural reserves that are exploitable with current technologies and cost-effectively – in the face of a demand for copper that remains unsated.

In order to be able to continue to reliably cover the demand for copper in the future as well as use it efficiently, it will be necessary to rely more heavily on concepts for the use of anthropogenic material stocks, which are known by the term "urban mining". Towns and municipalities will presumably be important raw material suppliers of tomorrow. Even today, the extraction of raw materials from existing buildings through selective dismantling or demolition and recovery of materials such as copper is an important resource issue.

It is not known, however, how large the anthropogenic copper stock in Germany actually is and how it is spatially distributed. How much metal is "stored" in, for example, commercial buildings and infrastructures and how dynamic the change in those quantities is, that is, how fast they reach the waste sector, are questions that have not yet been sufficiently explored. Also missing are sound building and demolition forecasts which provide information on the contribution which metals used in construction could make to future supply of raw materials. The same is true for resource-relevant minerals such as phosphorus. German agriculture imports some 150,000 tonnes of phosphorus per year in the form of P-containing mineral fertilisers. Phosphate production is associated with considerable emissions harmful to the environment. Our goal must be to recover phosphates from wastewater, sewage sludge and meat and bone meal in the future. The target is to reduce the import of raw phosphates by one-third by 2020 compared to current levels through the establishment of recovery methods.

"Urban mining" also means the need for towns and municipalities to identify and harness further resource conservation potential. Current recycling rates are as high as 88% for paper and glass waste, about 82% for tinplate and 72% for aluminium. On the other hand, recovery of commercial waste similar to household waste, residual waste and even separately collected biowaste or lightweight packaging is often suboptimal. For example, the energy contained in biowaste is lost if no prior fermentation takes place, and the current forms of disposal withdraw recoverable materials contained in residual waste (no less than 15–20% of this waste) from material or mechanical recycling. Likewise, sorting of the waste collected via the Green Dot system is far from capturing all recoverable fractions. Policymakers have responded to this by currently considering the introduction of a "bin for recoverable materials".

A continued rise, or stagnation at a high level, of raw material prices could make ideas that previously seemed utopian economically attractive in the future. One is the dismantling of municipal waste landfills – our geologically youngest raw material repositories – to recycle or recover energy from the recoverable materials they hold. This is referred to as “waste mining”. First estimates by German scientists indicate that about 26 million tonnes of ferrous scrap, 850,000 tonnes of copper scrap and 500,000 tonnes of aluminium scrap are stored at German landfills alone. This is equivalent to, respectively, 125, 140 and 50% of annual consumption of these materials in Germany. In addition to this, these landfills contain materials which through thermal recovery could make a substantial contribution to covering primary energy requirements.

2 From Waste Management to Management of Material Flows

Experts have talked about the need to move away from managing waste towards managing material flows for decades (Bringezu 1996). The call for waste prevention and waste reduction became official in Germany in 1975, when the German government announced its waste management programme whose order of priority was “prevent, reduce, recover” (BMI 1975). Even then it was clear that prevention, reduction and recovery, if rigorously implemented, would have a considerable impact on the type and number of products and on the way they are manufactured and distributed Schenkel Faulstich.

3 Waste Management

Article 1 of the Closed Substance Cycles and Waste Management Act (Kreislaufwirtschafts- und Abfallgesetz, KrW-/AbfG 1994) states: “The purpose of this Act is to promote closed substance cycle waste management (Kreislaufwirtschaft) in order to conserve natural resources and ensure environmentally compatible disposal of waste.”

Major successes have been achieved in waste management since the 1970s in many respects. There have been advances in landfill technology, more waste is being recycled, and since 2005 untreated waste may no longer be landfilled. Despite this, waste management cannot call itself sustainable. While the above-mentioned Act of 1994 lays down in law the principles of sustainable, resource-saving material management, most notably the priority for waste prevention and recovery over disposal, the extent to which this tallies with reality is limited. Waste prevention, which is to be given priority, is not happening – it is a myth. Waste volumes have in most cases merely been shifted from disposal to recovery. In some areas, a moderate decoupling of waste volumes from gross domestic product can be seen.

However, the decrease in total waste volumes by 14% between 1996 and 2005 was due mainly to a decline in the volumes of construction waste induced by cyclical change in building activity. A decoupling of waste volumes from economic growth did not take place.

The reason that it has not been possible to reduce our economy's material flows is that the consumption of raw materials cannot be controlled via waste management and waste legislation. Waste management and waste legislation necessarily address the end of the value-added chain and are therefore in principle ill-equipped to put in place a comprehensive resource management. Attempts to use waste legislation to this end overburden this instrument. Resource consumption by an industrialised country such as Germany can only be reduced through measures focussed on production, product design and product use. This requires other approaches which address the phases that precede waste management (German Council of Environmental Advisors (SRU 2008)).

On 17 June 2008, the European Parliament approved the amendment to the Waste Framework Directive. One key element of the new directive is a five-stage waste hierarchy:

- Prevention and reduction
- Reuse
- Recycling
- Other recovery operations
- Safe and environmentally sound disposal

Here too, waste prevention occupies the highest position. The aim is to strengthen waste prevention as the first and foremost objective of modern waste policy.

This takes us to a key question: What is waste prevention? How can we achieve it? Is it even possible to prevent waste?

Let us first look at the terms. Waste prevention is certainly the most enigmatic one. We take this to be measures to prevent the generation of waste. Waste prevention does not directly operate in waste management. Waste law therefore incorporates it only as a principle, not as a statutory obligation. Waste prevention must start above all with a change in production and consumption patterns. In production, waste prevention – that is to say, the production-integrated reduction, multiple use and recovery of the input materials – is frequently associated with financial savings and is therefore in many cases in the manufacturers' own best interest. For example, waste from steel production is predominantly recovered and only in part disposed of at landfill sites today. Recovery problems exist in the following areas: For an annual 1.2 million tonnes of slag from steel works and 200,000–300,000 tonnes of refractory material from furnaces, there is currently no economically feasible recycling method. There are two plants for recycling of sludge from the treatment of blast furnace gas (the only worldwide), but their capacity is not sufficient for the quantities arising.

Recovery comprises measures aimed at using waste that has already been generated as a material or for energy recovery. The goal of both waste prevention and waste recovery is to reduce the quantities of waste to be disposed of. In the industrial sector, a strict line between prevention and recovery can only be drawn when defining hierarchical system boundaries and reference units that serve as basis for the assessment (e.g. of the plant, area of production, sector, economy).

Man manufactures products using energy and raw materials. The harnessing of natural forces (energy) and natural resources (raw materials) is a basic prerequisite for value-added material. Every economic activity involves at the same time production, consumption and the generation of waste. Economic activity as an entity comprising production, distribution and consumption always also generates waste. In the estimation of the American economist Georgescu-Roegen, modern industrial production means transforming precious raw materials into useless goods (Georgescu-Roegen 1974). A discussion of the controversies surrounding this issue (raw material means raw material for a product since only as such is it of value) at this point would go beyond the scope of this contribution.

The capitalist economy is dependent on the rapid process of raw materials becoming products and then waste. Without this process of constant devaluation of products into waste, our economic system could not function (Schenkel).

So, the best kind of waste is one that does not arise in the first place.

In the 1980s and 1990s, many municipalities in Germany undertook large efforts to familiarise the population with waste prevention measures. This essentially took the form of hints for certain consumer behaviour which only rarely helped to actually prevent waste. Many subsequent efforts likewise failed to produce the desired result (Kopytziok 2007).

That waste prevention is necessary is beyond dispute. However, there are certain facts that must be realised before evaluating possible prevention strategies.

In the case of waste from everyday life, it is mostly the products themselves which arise as waste after use or consumption. Each of these goods may sooner or later be declared as waste based on subjective or objective judgement. Waste is a phenomenon of its holder’s particular scale of values. There is nothing that could not be both valuable material and waste at the same time. We must realise that the industrialised society ultimately produces nothing but waste, whether immediately in the case of the yoghurt cup or after many decades in the case of industrial machinery (Schenkel).

4 Waste Prevention Strategies

Waste prevention strategies must address the fundamental link between production, consumption and waste generation. These are strategies that address the diversity of material flows, imports and exports; the acceleration of material throughputs; and the development of industrial structures in the face of changing prices for raw materials and strategies that consider the exchange of materials between developed and developing countries and the divergence between labour costs and raw material costs. Waste management thus becomes raw material management, with major implications for trade and development policies.

Reuse is when the form of the product and its function are largely retained. The term used when the function is no longer the same is “further use”. This type of use is still at a high-quality level.

Recovery breaks down the form of the product, resulting in a loss of value. If the production process is the same as for the original product, this is a reuse; if not, we refer to this as “further use”.

Material recovery is joined by thermal recovery (the Waste Framework Directive provides for a clear hierarchy!).

According to this, only reuse delivers waste prevention in the true sense of the word; this is the case for reusable packaging, for example.

Reprocessing of sorted waste from production processes for reuse for the same purpose results in materials of largely equivalent quality. This so-called in-plant recycling is considered a waste prevention measure by some authors, because the generated waste does not appear in the external balance. They seem to disregard the fact that any reprocessing, however meaningful, again requires energy and material, even if only in the form of the reprocessing equipment.

So, if even in-plant recycling does not really prevent waste, further use, material recycling and conventional recycling can do so still less. For one thing, there is scarcely a substance that can be recycled an infinite number of times; for another, every new cycle causes additional pollution and requires energy whose transformation in turn entails problems. Recycling has natural limits. Although matter cannot get lost or be destroyed, all processes involve losses in various ways (e.g. by abrasion, wear and tear). That is why processes tend to take linear paths, from substance source to substance sink, instead of forming a closed loop (Schenkel). It would be more justified to refer to this as flow-through management than as closed-cycle management (Angrick 2008).

Entropy in closed systems will always increase. High-order states (products) are transformed into lower-order states (wastes) through material dispersal; reversing this process requires input of energy.

Recycling processes inevitably lead, with each cycle, to an accumulation of the pollutants that all products inherently contain. Functional requirements for products likewise impose limitations on recycling. Wastes should, of course, be reused or used further, but it is an illusion to think that this solves the waste problem (Schenkel).

Waste can only be prevented if the specific input of material and energy is reduced. The generation of production waste is highest in the abstraction of raw materials and decreases with increasing sophistication of the manufacture of the actual product. The logical step, therefore, is to reduce waste quantities in the extraction of raw materials. German/European industry has “practised” this for years, because not only raw material extraction but also in many cases the manufacture of the primary (semi-finished) product takes place abroad. This makes our waste statistics look more eco-friendly. It is uncertain how much a reduction of material and energy consumption in the manufacture of products actually reduces waste quantities. For example, growing miniaturisation may cause the proportion of composite materials to increase, with the result that such goods often cannot be consigned to recycling. Miniaturisation has also meant that goods can often be made available in larger numbers to a larger number of consumers. Today's industrialised society is inundated with devices that are small and light but actually quite unnecessary (e.g. mobile phones, digital cameras, MP3 players). The rebound effect does its part to increase resource consumption (Angrick 2002).

Also, the systemic imperative of economic growth – a core problem of our civilisation – often thwarts possible waste reductions.

A change would be possible only if manufacturers were involved in the responsibility for their products even after they have left their works. This idea, referred to as product responsibility – "producer's responsibility" would be a more appropriate term – is elaborated in the German Closed Substance Cycle and Waste Management Act (Kreislaufwirtschafts- und Abfallgesetz, KrW-/AbfG 1994). According to this act, product responsibility comprises development, manufacture and use as well as the disposal phase, that is to say, the entire lifecycle of a product. Product responsibility demands a reorientation towards ecological design and towards reducing material streams in the manufacture and use of products (Fricke 2007).

The most important measure within the concept of product responsibility is the obligation for manufacturers to accept returned goods. This notion is intended to motivate manufacturers to design their goods in such a way that they are easy to disassemble, their constituents are known and safe, and attention is paid to ensuring a certain durability of the product, since this can reduce costs.

5 Summary and Outlook

Still, all this does nothing to prevent waste. Since everything must grow, ever more products are launched on the market. Even reused product packaging and the like are destined to end up as waste. Even if products are easy to disassemble and even if they are designed to have a longer useful life, they always remain new goods on their way to becoming waste. That is why the concept of waste prevention is a myth, an unachievable goal (Angrick 2008a).

No matter how one looks at it, preventing waste means preventing the devaluation of a raw material into a product! This in turn means that one must abstain from buying products. An approach of this kind means above all to revaluate the values common to industrialised societies and to find other indicators of economic success. Product longevity instead of frequent product changes driven by fashion or technical progress, use instead of ownership, and growth in resource-efficient goods and services instead of growth based on raw material consumption would be the yardsticks against which sustainable progress is measured (Schenkel and Reiche 1992). Significant progress would be likely only if leasing were markedly extended. For example, if the automobile industry leased out all of its vehicles instead of selling them, its endeavours to develop recycling-friendly vehicles would be much more visible.

It is clear that waste prevention does not work through recycling or any form of reuse or further use but that instead only prohibitions on products would bring a chance of success. For instance, there should have been a "Tamagotchi Prohibition Ordinance". Instead, the world is being inundated with unnecessary electronic scrap whose generation could have been avoided. But the question that immediately arises is who is to decide which products should be distributed and which should not? Even if it is obvious that we need to put an end to this quantitative growth, that such economic growth cannot work and is bound to collapse sooner or later. That is why sustainable growth is an oxymoron (Baum 2010). That is why we need to change course and this includes changing our consumption habits.

Therefore, consumers need access to transparent information. We need product labelling which tells us what "ecological rucksacks" the product is carrying, so that we can make informed choices and act in a truly sustainable manner.

We are still far from experiencing resource emergencies, and the economic dogma to which we have submitted ourselves still holds. It is not until we notice that we have "created rubbish" by having exploited finite natural resources over the last 200 years without regard to coming generations that we will realise that a reversal constitutes the "ultima ratio". We need this last insight in the form of new models of progress, a new, generatively sound way of managing the economy. This was acknowledged as early as the 1992 conference in Rio de Janeiro. The United Nations millennium goals also include a clear call for a "reversal of the loss of environmental resources".

Up until now, production and consumption processes typically have had a linear structure. This means that in the beginning the function of the biosphere as a source is utilised by extracting resources, while after use and consumption, that is, at the end of the process, the biosphere's function as a sink is utilised by releasing emissions (wastes too are emissions!) (Paech 2005). Waste in material terms is defined to be materials, articles and residues which are no longer useful to their holder. The transition from being of value to not being of value usually occurs subjectively, depending on the economic values and use opportunities of individuals or society. Since the boundary between commodity and waste depends on subjective judgements and is therefore variable, defining the term "waste" exactly is inherently difficult. When procuring raw materials and products is difficult and resource intensive, waste materials are treated carefully, repaired, collected, reused or recycled. This has been so throughout the history of humankind through to the age of industrialisation and especially in times of need and war. It still holds true today in poor and developing countries. As long as man only used natural products, waste management posed no problem. Nature does not know any waste but breaks down organic material and reuses it as nutrient and growth medium in a (nearly) perfect cycle. Since the age of industrialisation and mass production and the associated growth in population and prosperity, the quantities of anthropogenic waste have risen drastically in both of the sectors that are the main waste generators:

- Production (production waste)
- Consumption (spent products)

Up to now, the decision as to which types of waste, and how much of them, should be generated in production processes has depended mainly on economic factors – firstly, on the costs for the raw materials to be processed as compared to the costs for reuse or other use and, secondly, on waste disposal costs.

Low prices for raw materials and, in the past, low costs for waste disposal have favoured the generation of large waste volumes and impeded the development of recycling concepts. The picture is similar for the majority of goods. Cheap mass production and high labour costs for maintenance and repair have spurred the trend towards throwaway articles. As a consequence, industrialised countries in particular have seen a dramatic increase in waste volumes whose management is causing increasing problems.

The move from waste management towards material flow management will not happen automatically. It means in the long term that the current waste legislation must be replaced or absorbed by a law governing materials.

But above all it means that we must have the courage to stop defining ourselves through what we consume and adopt truly sustainable lifestyles.

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Part V
Taking into Account the Whole Life Cycle: Three Examples

Chapter 12
Resource-Conserving Use of the Stock of Residential Buildings to Reduce Absolute Demand in the "Construction and Housing" Area of Need

Julia Verlinden

1 Significance of the "Construction and Housing" Area of Need

The buildings sector in Germany is responsible for great flows of energy and materials. Not only the construction process and the use of buildings are of relevance but also upstream raw material extraction as well as the manufacture and transport of building materials and the demolition of buildings.[1] These measures give rise to "substantial adverse effects on the environment in the form of raw materials, land and energy use, air and water pollution, noise and waste as well as microclimatic and landscape changes" (Jörissen et al. 2005, pp. 42–43, *original in German*).[2]

The construction sector in Germany is one of the most material intensive economic sectors. About 95% of gravel, sand and stone quarried in Germany are utilised in the construction industry (BGR 2010, p. 76).

Annual mining of about 550 million tonnes of non-metal, mineral raw materials for the construction industry[3] causes progressive devastation of the landscape in the order of 1,440 ha per year (or 3.9 ha per day) (BGR 2010, p. 48, cf. also Penn-Bressel 2013, p. 6).

[1] The following Chap. 13 by Keßler/Knappe deals in greater detail with this topic.

[2] In addition, the multiplicity of building products as well as their ecobalances and effects on human health introduce further relevant aspects into the debate.

[3] Non-metal, mineral raw materials include sand, gravel, clay, limestone, natural stone and gypsum. Around 5.5 million tonnes of construction steel are also of relevance to the German balance.

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In boom year 1999, land use merely for housing development amounted to 49.9 ha per day, with an additional 7.3 ha per day for traffic infrastructure. These figures decreased in 2009 on demographic and economic reasons to 17.4 and 2.6 ha, respectively. The largest part of such construction activities was on "greenfield sites", while the rest took place on brownfield sites or by means of redensification (cf. Penn-Bressel 2013; UBA 2003, pp. 59–61)

The great ecological, economic and societal relevance of the construction and housing area thus become clear. This was also emphasised in the final report of the Enquete Commission of the German Bundestag of 1998:

> There is hardly a comparable field in which the complex web of relationships […] is so strongly pronounced as the topic of "construction and housing". […] The most varied ways of life are reflected in the type of housing. […] Cities, buildings and open spaces form the spatial shell for everyday life, for society and for the culture of the people who live in them. […] This shell is altered through constructional work, which is the means of adapting the environment of people to their individual needs, […] In the area of "construction and housing" interactions between environmental impact and life-styles, social structures and needs as well as working and consumption habits become apparent (Deutsche Bundestag 1998, p. 126, *original in German*).

2 Resource Potentials of Using Existing Buildings Instead of Constructing New Ones: Scientific Findings

Many products bear a heavy "ecological rucksack". In the production and processing of raw materials, different environmental media are affected, and in the manufacture and transport of products to customers, many times the amount of raw materials is utilised than can be seen in the finished product.[4] Extension of the useful life of products therefore generally leads to improved resource efficiency[5]: The fewer the products that are manufactured and thus consign existing still-functioning products to rubbish tips, or the more old products that are recycled, the less the number of ecological rucksacks that arise. Only with few products, whose technological development leads within a short period to large gains in efficiency (during the use phase), can the use of raw materials and energy be justified and, as a result, the speedy replacement of existing products be ecologically sound.[6] This strategic approach of extension of useful life is obviously logical, yet not always easily

[4] For example, around 1.6 kg of resources are expended in the manufacture of a CD (UBA 2010b, p. 3).

[5] It is therefore more resource-conserving, for example, to use mobile phones for several years, rather than to acquire a new phone with every new service contract (cf. Tagesschau 2011).

[6] Life Cycle Assessments show that a modern, efficient refrigerator of the energy efficiency class A++ justifies replacement and recycling of a 10-year old, still-functioning appliance (cf. Rüdenauer und Gensch 2007, pp. 4–5).

Table 12.1 Potential reduction of environmental impact in the "construction and housing" area of need for 2025 as a percentage change compared to the base year 2000 (UBA 2004, p. 130)

	Reference scenario (%)	Sustainability scenario (%)
Additional land use	–14	–84
Raw mineral materials	–9	–33
CO_2 emissions	–19	–52

realisable, since it contradicts common consumer behaviour in certain consumption areas.[7] In the area of construction and housing, too, there are significant resource-conserving potentials in reduced new construction:

> A consistent sustainability strategy […] cannot solely depend on the promotion of increases in efficiency; it must also bring about a change in consumption habits. Since the most resource-intensive areas of life in western societies are housing, food and mobility, behaviours in these three consumption areas should become sufficient[8] (Stengel 2011; p. 26, *original in German*).

Here, it is important to draw a distinction between individual needs (or wants) themselves and their material manifestation in the form of demand for specific products or services (the latter are also termed needs).

As a rule, and as an alternative to construction of new buildings, the need for housing can be satisfied much more resource efficiency through the use of existing buildings. A study commissioned by the German Federal Environment Agency (UBA) calculated, with the aid of a materials flow model (BASiS-2.0) developed by the contractors, different scenarios for Germany in the field of construction and housing up to the year 2025. A "reference scenario"[9] was compared with a "sustainability scenario" (UBA 2004). According to the reference scenario, additional land use as a result of further urban expansion would scarcely be reduced. Mineral raw material consumption would barely decrease, and neither would existing potentials for reduction of CO_2 in the area of construction and housing be exploited. In the sustainability scenario, on the other hand, clear savings in additional land use, raw materials and CO_2 emissions would be possible by 2025, compared to the figures for 2000, as shown in Table 12.1.

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[7] Ecological efficiency of a product and the social effects of its manufacture often play no relevant role, or just a secondary role, in the purchasing decisions of consumers. Technical equipment or clothing, for example, is more frequently replaced than is necessary. Product novelties, new functions and, in particular, social trends supposedly arouse new consumer needs. "Consumerism feeds on recognition structures and the concept of the good life: a belief and lifestyle that characterise western societies, which are manifested in the notion that identity, status, happiness, purpose and social integration are coupled with the consumption of goods and options. This consumerism, which is not bound to individual consumer goods, is diametrically opposed to the sufficiency strategy" (Stengel 2011, p. 27, original in German).

[8] For a definition of sufficiency (and distinction from efficiency and consistency) see Sect. 3.

[9] For the reference scenario, existing trends were extrapolated. It largely represents a "business-as-usual trend" in the construction and housing area (UBA 2004, pp. 130–131).

These relevant savings in land, raw materials, energy and CO_2 emissions[10] can be achieved by the year 2025 under the following conditions (assumptions in the scenarios): Instead of 8.85 million new housing units between 2000 and 2025 (Reference Scenario), only 6.85 million (about 23% fewer) new housing units are constructed, which are to be found to a large extent in core cities and suburban areas rather than in rural areas. Moreover, in the period under consideration, fewer housing units are demolished (only 0.95 million instead of 2.45 million in the Reference Scenario); the share of multiple dwelling units increases and more old housing units are combined (UBA 2004, p. 93).[11] At the same time, both scenarios assume an identical population development (stagnation up to 2025) and identical housing need. Here, reference is made to figures from the Federal Office for Building and Regional Planning and the Leibniz Institute of Ecological Urban and Regional Development (BBR/IÖR 2001), according to which in the year 2025, there will be "a considerably larger housing stock" in Germany (UBA 2004, p. 98, *original in German*). The population will then, however, not be larger than in the year 2000, and according to current forecasts would be even smaller (Federal Statistical Office Germany 2010a).[12]

The greater proportion of buildings that will be required in the future already exists. An Enquete Commission of the German Bundestag assumed in 1998 that 75% of building stock in Germany that will be used in 2020 already exists. For Europe, it is estimated at least 80% of buildings required in 2050 already exist (Cramer 2010, p. 32). Here, however, the spatial distribution of supply and demand must also be taken into account. What is important is "intelligent management of the building stock […] that is directed, on the one hand, at meeting the wishes of present users, and on the other hand at developing construction concepts that can be flexibly adapted to the needs of future generations" (Jörissen et al. 2005, p. 43, *original in German*).

[10] Here, the total of annual carbon dioxide emissions has been calculated from the construction, maintenance, modernisation and heating of residential buildings as well as from the construction and maintenance of traffic infrastructure, including upstream emissions (UBA 2004, p. 130).

[11] By contrast, In 2009, 18 million residential buildings and almost 40.2 million housing units existed in Germany; that was 1.2 million more residential buildings and 1.8 million more housing units than in the year 2000 (Destatis 2010a, pp. 6–13). Moreover, between the beginning of 2001 and the end of 2009 around 430,000 flats were demolished; since 2004, the trend in the annual decrease is noticeably declining (Destatis 2010a, p. 16). According to the Sustainability Scenario, in 2025 there would, on balance, be 5.9 million more housing units than in the year 2000 (Reference Scenario: 6.4 million more housing units than in 2000). The trend in recent years has moved, on balance, not only with regard to the total number of flats but also regarding the decline, in the direction of the Sustainability Scenario.

[12] At the same time, it has to be considered "that a declining population development will not alone give rise to a trend reversal in settlement development. It would be a fallacy to expect that the growth in land use for settlements and traffic infrastructure would itself grind to a halt with declining population figures" The ageing of society and the associated growth in demand for living space per person must therefore be included in the forecast (Siedentop 2010, p. 239, original in German). Moreover, the expected increase in the number of households is also relevant (Statistische Ämter des Bundes und der Länder 2007, p. 30).

In summary, the results of the scenario research project indicate that satisfaction of the demand for housing space in Germany through concentration of construction activities on redevelopment and modernisation of housing stock, with about 23% less new construction than in the Reference Scenario and further planning conditions, can lead to marked savings in land, raw materials and CO_2 emissions. This development would thus contribute to fulfil the commitments of the German federal government under the Kyoto Protocol and would also be supportive of objectives in the federal government's sustainability strategy, such as the doubling of raw material productivity by 2020 (compared to 1994) (Press and Information Office of the Federal Government 2008, p. 41) or a reduction in the daily increase in land use for housing and traffic from 120 ha per day in 1993–1996 to 30 ha in 2020[13] (Press and Information Office of the Federal Government 2008, p. 45).[14]

Even with optimisation of the use of housing stock, there will still be regions in Germany in which a surplus of buildings exists, and this situation will be further aggravated through the ageing of society and migration into the centres. "In the New Länder [the federal states of the former GDR] alone, there are about 1.1 million vacant dwellings due to demographic change" (Press and Information Office of the Federal Government 2008, p. 108). Here, raw materials from the demolition of buildings can be recycled and building products reused. More on the opportunities and challenges of the use of anthropogenic stock as a raw material source can be found in the following Chap. 13 from Keßler/Knappe.

Due to changing general conditions, new challenges also arise for the building materials industry. Irrespective of the scenario, fewer materials will be needed in future in the construction sector in Germany (in the "Reference Scenario" almost one-tenth, and in the Sustainability Scenario one-third less than in the year 2000). Those companies, whose focus has up to now been on the distribution of bulk building materials, will now increasingly have to look around for new business fields. On the other hand, the building craft can expect an increase in demand. Building conversions and modernisation, in particular, are manpower intensive and thus help to secure jobs.

[13] New daily land use therefore decreases solely on "greenfield sites" from about 31 ha per day in the area of construction and housing in the year 2000 to about 27 ha per day by the year 2025 in the Reference Scenario, but only to about 5 ha per day in the Sustainability Scenario. "The Sustainability Scenario thus indicates for the "housing" need a perspective for the decoupling of growth in living space and "Greenfield" land use (UBA (Umweltbundesamt) 2004, p. 105, original in German; cf. also UBA 2003). In fact, land use for housing construction decreased up to 2009 to 20 ha (including traffic infrastructure), of which the greater share (about 15 ha) was supposedly on greenfield sites (cf. above).

[14] On the relationship between resource protection as well as raw material and energy efficiency and the reduction in land use, see also Penn-Bressel 2013.

3 Suggestion for a Strategic Hierarchy in the "Construction and Housing" Area of Need

In order to strategically orientate political decisions, in different fields of action of environment policy, there are "objective and action hierarchies", in part aggressively represented, and in part "intuitively considered". The "waste hierarchy", for example, is an explicit element of the EU Waste Directive (2008/98/EC) and was expanded from the initial three to five stages:

The following waste hierarchy shall apply as a priority order in waste prevention and management legislation and policy:

(a) prevention,
(b) preparing for re-use,
(c) recycling,
(d) other recovery, for example energy recovery and
(e) disposal. (European Parliament and the Council 2008, Article 4)

While the waste hierarchy concentrates on the end of the resource chain, there is also the possibility, however, to orientate policy decisions on the basis of such a hierarchy in a whole consumption area or in an "area of need". In the area of mobility, a three-stage policy objective hierarchy ("triad") is therefore being discussed: (1) avoid traffic, (2) shift traffic and (3) calm and shape traffic in an environment-compatible manner (cf., e.g. SRU 2005, p. 121).[15]

Similar to the terminological distinction between "mobility" and "traffic", a distinction can also be made in the construction and housing area between housing as an actual need[16] (analogous to the need for mobility) and construction as a relevant general condition for meeting this need (analogous to traffic). At the same time, construction or mobility is itself only rarely an explicit personal need. Yet the objectives of "satisfying needs for housing and mobility" can be achieved in each case with the aid of different measures. In the process, the expenditure of resources can be high or low. Sustainability (not only, but especially on the demand side) can, for example, be expedited by efficiency, consistency and sufficiency strategies.[17] These varied strategies can also supplement each other. The variety of means of satisfying human needs is displayed in Table 12.2.

[15] The German Advisory Council on the Environment (SRU), which has advised the federal government since 1971, points to the fact that precise environmental objectives should actually be in the focus of attention, and that although the triad of strategies represents "important elements", "objective and means" should not be confused (SRU 2005, p. 121).

[16] The housing need is closely connected with basic physical needs such as sleep, warmth and safety, and also comprises relevant aspects of extended human needs such as private sphere, status, independence, individuality as well as room for freedom of personal development and creativity.

[17] Efficiency is improved by input/output ratio. Sufficiency is the reduction of action that harms the environment. Consistency is an alternative form of economic management, for example, substitution (cf. Kleinhückelkotten 2005, pp. 53–55).

Table 12.2 Differentiation of need and means, own representation

Need	Different aspects and means of satisfying needs
Mobility (mobility, in order to be able to participate in social activities, such as employment, culture, meeting friends and family, education, shopping and visiting the doctor)	Choice of means of transport: bus, rail, car, aircraft or by foot Frequently or seldom out and about (e.g. combining journeys) Covering short or long distances to reach a destination (small cinema locally/large cinemas in the city, etc.)
Housing (private safe haven, longer-term centre of one's life, cultivation of relationships, feeling at home)	Conversion, extension, *construction*, modernisation of buildings, relocation: Size: more or less living space Location and residential environment: city centre/suburbs/village and respective infrastructure Legal status: rental or ownership Dwelling standard Total costs: e.g. rent exclusive of heating and service charges plus energy costs Varied building materials (e.g. no risks to health, from renewable raw materials, recycled building materials, etc.)

An example is the need for "light" can be met in different ways. During the day, the sun makes a huge contribution; additionally, or at night, light can be made available with electricity. In the latter case, varied levels of effort can be involved, yet the result is the same. *How* the electricity is produced that lights the lamp – whether with coal, atomic power, water or wind – is irrelevant for satisfaction of the human need for "light", but of considerable importance for the environment.

How the needs for housing and mobility can be met with less construction and less traffic is therefore a key challenge of sustainability policy. What is more, the term "construction" is understood to cover all construction activities; that is, not only the building of new residential buildings but also rebuilding, extensions, maintenance and repair, reconstruction as well as the construction and maintenance of relevant housing infrastructure (construction of roads as well as supply lines for electricity, gas, water, telecommunications, etc.)

From the point of view of regional and environmental planning, there are clear objectives concerning sustainable settlement policy. "Internal development" should enjoy priority over "external development",[18] and "old" over "new". This means that instead of designating new built use zones on greenfield sites, brownfield sites in settlement centres should at first be utilised, and inner development and land

[18] This has been a "kind of principle" of sustainable spatial and urban development policy in Germany since the 1980s (Siedentop 2010, p. 235). It is also meaningful in terms of traffic policy considerations (shorter distances), and is urgently required concerning demographic change and the high infrastructure costs that are to be expected as a consequence (Siedentop 2010, p. 237).

recycling take place.[19] The second objective relates to the building itself: The further efficient use of existing buildings should have priority over the construction of new buildings.

Policy for the construction and housing area of need is not clearly demarcated from other areas of environment policy relevance; in fact, strategies from energy, raw material, social and construction policy merge. Traffic, land use and cultural policy also touch on concepts for sustainable construction and housing. Investigations of materials flow in the construction and housing area show that the greatest input of *materials* is incurred in the *construction* of a building, while the greater proportion of *energy* demand arises during a building's *use*. It is therefore particularly resource conserving when the energy systems of existing buildings are modernised, and these buildings are then further used for as long a period as possible. Instead of demolition and construction of new buildings, these existing buildings should be heat insulated in accordance with the latest, highly efficient construction standards and converted to supply with renewable energy:

> A building is the sum of wide-ranging resources: raw materials, manpower and experience. Demolition of an intact building simply because it no longer corresponds to contemporary taste is misguided on the grounds of sustainability. […] As a rule, it is environmentally more compatible and more economic to develop and improve an existing building than to demolish and replace it with a new building. (Cramer 2010, p. 32, *original in German*)

Since besides the durability and site specificity of its products, the construction sector is characterised by the huge number of actors, who "share responsibility for the product 'building'" (Jörissen et al. 2005, p. 43, *original in German*), it is advisable to pursue common strategies. An example of this is the "*Leitfaden nachhaltiges Bauen*" (Guide to sustainable construction), whose guidelines are obligatory for federal government buildings (BMVBS 2011).

Relevant aspects of a comprehensive strategic policy approach for the construction and housing area are displayed in Fig. 12.1. Here, not only are planning decisions involved that relate as a whole to the building as a product for satisfaction of a need but also building materials and products that should be employed as a matter of priority. Here, too, "avoidance of resource-intensive construction activities" is basically prioritised.

From these different expectations for resource conservation in the area of construction and housing a number of demands on policymakers arise for the setting of a framework for promotion of sustainable construction that is not a risk to human health. This can include various regulatory, fiscal, planning, informational and other policy measures, not only at the federal level but also at the state and municipal level. Such a hierarchy can be a useful strategic tool for policymaking, particularly when decision-makers at different levels and in varied policy areas (horizontal and vertical) have agreed on basic orientation.

[19] On measures for optimised land use cf. Penn-Bressel 2013.

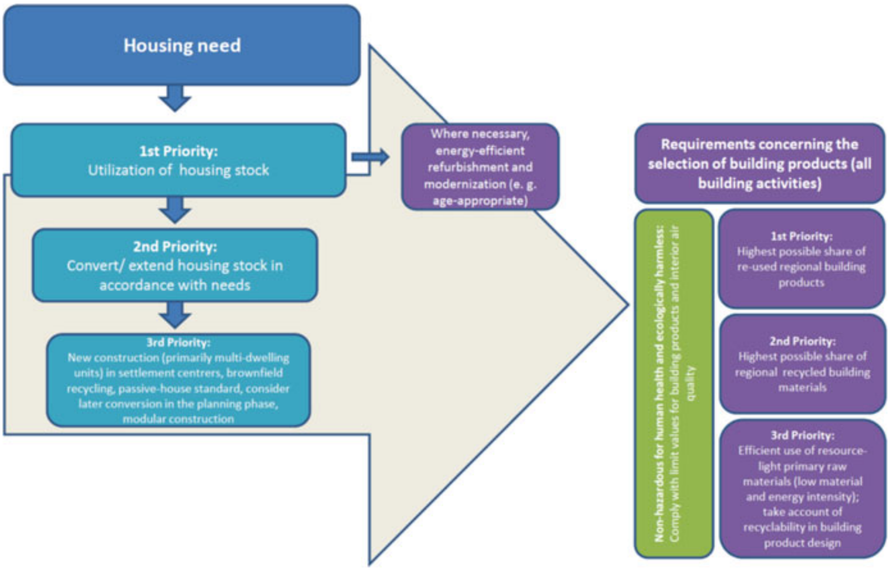

Fig. 12.1 Hierarchy in the construction and housing area of need, own representation

4 Political Approaches to a Framework for Support of Sustainable Use of Existing Housing Stock

Two key objectives can be identified for sustainable use of existing housing stock:

- Reduction of still high energy consumption in many buildings in the course of their use through intensification of energy-efficient refurbishment as well as optimisation[20] of existing buildings for which such refurbishment is no longer worthwhile.
- Reduction of high direct and indirect demand for land and raw materials through avoidance of new construction on greenfield sites; instead of this, utilisation of existing buildings were available and the setting of an adequate policy framework.

4.1 Reduce Energy Demand in Existing Buildings

For the first of the above two points, the German federal government has already implemented a number of policy measures. These important initial steps in the right direction have up to now not brought the expected results, and extremely high

[20] Extensive energy-efficient refurbishment is in some cases not worthwhile, as a building will only still be used (e.g. because of the demographic development) for a few years. Technical optimisation of existing heating systems or optimised heat management could, for instance, bring about a meaningful increase in efficiency with acceptable effort.

potentials still exist. The rate of energy-efficient refurbishment of residential buildings still lies markedly below the desired 2.5% per year.

The subsidy schemes of the state-owned banking group "KfW Bankengruppe" (KfW 2010) are regarded as useful. The KfW offers not only loans at favourable terms but also subsidy schemes. Both are also financially beneficial for the state. KfW calculated for the year 2009 that every subsidised euro in building refurbishment programmes triggers an average capital investment of nine euros, and that in the year in question a total of 300,000 jobs were thereby secured (Irsch 2010, p. 10). Of the invested money, a substantial portion flows back to the government through revenue sources such as income tax and value-added tax. The KfW building refurbishment programmes are therefore not a budgetary burden in Germany, but rather produced a noticeable revenue plus in the years 2005–2007 of – conservatively estimated – 30 to 100% *additional* to refinancing of the programme itself (Kuckshinrichs et al. 2009, pp. 56–57).

Information services, such as those provided by the German Energy Agency (*Deutsche Energieagentur*, *dena*), or state-promoted energy consulting services, which provide recommendations concerning energy-efficient refurbishment, can also be useful for attainment of the objective (dena 2010).

The Energy Saving Ordinance (Bundesregierung 2009) is the result of German implementation of the European Energy Performance in Buildings Directive (EPBD) (European Parliament and the Council 2003) and contains minimum energy standards in the case of refurbishment and retrofitting obligations (e.g. roofs, which are so far not insulated or replacement of old and inefficient boilers) as well as transparency for tenants and purchasers concerning the energy efficiency of a building in the form of building certificates.

4.2 Adapt Housing Stock to Needs, Avoid New Construction

As to the second objective, "avoidance of new construction on greenfield sites" has to be further specified. To begin with, thorough analysis of societal, spatial planning and economic parameters is necessary, in order to identify relevant "levers" and ultimately to develop meaningful measures.

4.2.1 Parameters: Trend in Population Development and the Housing Market

Since residential buildings are of long duration and site-specific products, the respective *regional* housing situation is relevant. In this respect, there are great differences between eastern and western Germany, as well as between different agglomerations and in rural areas. Here, supply and demand as well as forecast vacancies differ due to varied population development. Even when nationwide, 8% of flats in the year 2006 were vacant, the regional distribution differed greatly (Destatis 1998–2006).

Construction activities take place in individual regions to a varied extent, and in some regions are still necessary in order to meet local demand, for the population grows contrary to the nationwide trend, for example, in Bavaria until around 2020, and in Hamburg until about 2030 (Destatis 2010b). While the number of households (parallel to the declining population) in the "old" federal states (formerly the BRD) and Berlin will *increase* until around 2025, in the "new" federal states (formerly the GDR) not only will the population decline but also the number of households (Statistische Ämter des Bundes und der Länder 2011, p. 33).

In "growth regions" it is difficult to avoid new construction. Necessary new construction should, however, be as resource conserving as possible on land in town centres, using resource-conserving building materials. Corresponding urban planning should also concentrate on multiple dwelling units, which utilise, relatively, less land and raw materials than detached or terrace houses.

In most regions of Germany, however, the housing stock is theoretically adequate, and further new construction would put the housing market very much under pressure. The high level of new construction work until the end of the 1990s is a key reason for the present below-cost selling or letting of many objects in eastern Germany (Schätzl 2007, p. 102). Further new construction would therefore be counterproductive for regional housing markets, which already suffer from high numbers of vacancies. In this respect, one must be able to convince property owners in such regions that avoidance of new construction will lead in the medium to long-term to improved levels of occupancy in their properties. This group of stakeholders should be won over as allies, in order to adapt housing stock in such regions to new needs with sustainable modernisation.

4.2.2 Parameters: Financial Impact on Municipalities of Designation of Building Land[21]

As in numerous other areas of environment and sustainability policy, the market has failed in the case of land use, since external costs are insufficiently internalised. This problem was the subject of a research project commissioned by the Federal Environment Agency, which came to the conclusion that there was a "costs paradox in the development of land", which was described as follows: "actors involved in property development attempt to minimise their individual costs. However, their decisions combine to produce a cost-intensive settlement structure at the regional level" (UBA 2009b, p. 13).

In concrete terms, the fact is that municipalities develop their infrastructure and designate new development areas in order to attract new inhabitants and the settlement of industry and trade in competition with other municipalities, "hoping for additional taxes and deliberately neglecting all future costs for necessary supplemental infrastructure" (Penn-Bressel 2013); for such expansion of municipalities

[21] cf. on this topic also Penn-Bressel 2013.

and cities as well as their infrastructures leads to increasingly high financial burdens on public budgets. At the end of the day, these "non-transparent costs" lead to "inefficient settlement structures as the result of a multitude of individual decisions with no overall planning". In the research project, five basic patterns were identified in varied decision-making contexts, which come into consideration as "levers" (UBA 2009b, pp. 15–17).

Basic communicative, informative and monitoring approaches to mitigation of non-transparency of costs are particularly relevant suggested solutions. Precise tools have already been developed, "enabling local governments to assess future costs and benefits of public investments (including taxes and fees, but also maintenance costs of public infrastructures) for many years in advance. These calculations, done properly, might temper a bit the hopes of extra gains by attracting new taxpayers"[22] (Penn-Bressel 2013).

4.2.3 Parameters: Varied Housing Needs of Different Population Groups

Planners and architects must orientate themselves, similar to policymakers, to new challenges and must also incorporate information on *qualitative* social developments into their respective disciplines in order to develop sustainable concepts. Focus solely on "quantitative population dynamics" inadequately encompasses the complexity of challenges and solution approaches. It is proposed, for example, that the "concept of lifestyle" be more strongly considered, in order to be able to meet the key challenges of "shrinking cities and regional disparities" (Kirschbaum und Schuster 2008, pp. 438–439, *original in German*):

> For […] despite declining population figures there is a housing shortage, […] a relative one that is related to the mismatching of user wishes and architecture. […] This can concern both high-cost housing and social housing. That not all wishes can be realized is obvious. It is much more a question of recognizing wishes beyond status and of implementing selective demands of residents in terms of lifestyle. (Kirschbaum und Schuster 2008, pp. 438–439, *original in German*)

Some social trends (population development as well as favoured styles of living and construction measures) can be controlled, at least in part, through changes in general conditions by means of policy instruments. This way, the "out into the country" and "into the periphery" movements of recent decades were promoted in Germany by inter alia, a tax allowance for commuters travelling between home and place of employment.[23]

[22] http://www.folgekostenrechner.was-kostet-mein-baugebiet.de

[23] Penn-Bressel (2013) deals in greater detail with long-term regional population development and consequential construction measures for residential buildings in Germany in the course of recent decades and in the future.

As a whole, decision-making and behavioural processes are complex, yet understanding the needs that lead to people moving out of cities and building new houses helps in the setting of a policy framework. In the process, different population groups are the focus of attention. Some are increasingly drawn into the countryside, while others consciously seek cultural diversity and good infrastructure in city centres. The motives can vary in individual cases. The image of a "single-family home in the village" has to be examined. In turn, from such insights, the deficiencies of housing stock in city centres can de deduced, which supposedly make them unattractive, in order to initiate investment in housing stock.

Which needs are specifically relevant and the cause of new construction activities? For regional housing offers obviously do not correspond with demand; or available information on existing offers is insufficient. Needs vary in different social milieus and population groups as well as in different periods of life. Here, the expectations of people who decide for a new house in the countryside have to be ascertained. The extent to which these needs might also be satisfied in a "used" property or in a newly constructed building in the city centre must then be clarified.

Insofar as such needs and trends are known, policy measures can be directed at offering suitable living space from existing housing stock. More about the measures later.

Empirical Results

In 1996, the housing needs of different lifestyle groups were investigated in a representative survey. The following features were named as important/quite important: basement, balcony, car parking space, cable/satellite TV, comfortable bathroom, open-plan kitchen-living room and a "room for everyone". At the same time, not only did demands and wishes differ between eastern and western Germany, but also among different lifestyle types (Schneider 1999, pp. 129–146). In 1996, the most frequently named "dream house" of all population groups was a one- or two-family house; the approval ratings fluctuated, however, between 39 and 73%, depending on lifestyle group (Schneider 1999, pp. 165–174). There was a similar result concerning the desired residential area. As a whole, more than a quarter of those surveyed would like to live in the countryside, more than half wanted to live in a small, medium-sized city or in the area surrounding a large city, while several lifestyle types showed a clearer preference for a large city (Schneider 1999, pp. 189–207).

In 2005, in another investigation, students at the University of Kassel were surveyed.[24] The result was that a large proportion of those questioned preferred

(continued)

[24] Here, 474 questionnaires were evaluated. Random sample: age spectrum from 19 to 48 years, average age 24.0 years, 68% women and 32% men (Kirschbaum and Schuster 2008, p. 201).

(continued)

a single-family house as form of habitation, while all other possibilities trailed behind (Kirschbaum und Schuster 2008, p. 208). "The strongly associated term 'flooded with light' is named as an important feature of a flat or house". Further wishes are several stories, high ceilings and rooms that allow adaptation to changing needs (Kirschbaum und Schuster 2008, p. 213, *original in German*). In addition, more than 90% of those surveyed stated "that for them private open space [such as balcony, patio or garden] is very important" (Kirschbaum und Schuster 2008, p. 214, *original in German*). In the residential environment, "nature (as much greenery as possible) and social contacts – that is, active neighbourly relations" as well as good transport connections and infrastructure are regarded as relevant. "Freedom from car traffic and seclusion, on the other hand, are not important features of the residential environment" (Kirschbaum und Schuster 2008, p. 214, *original in German*).

In a survey commissioned by the Wüstenrot Foundation and published in 2008, families mentioned, above all, the following wishes concerning their residential environment: safe roads, safety for small children and the possibility for them to play without supervision, green areas and open spaces in the residential environment, availability of schools, childcare and doctors, clean, quiet and assessable residential environment as well as access to local public transport (Wüstenrot-Stiftung 2008, pp. 113–114). Families, in particular, possess a "high location orientation" and "the approval ratings on the city as residential location are higher than those of other groups". From this, "a sufficiently large potential for improvement of living conditions and the residential environment for families can be deduced" (empirica 2009, p. 26, *original in German*).

For certain population groups, improvement of information appears to be wise, as correction of the image of existing buildings and housing in the city does.

Other needs can be considered in urban and spatial planning, for example, cleanliness, quietness, little traffic, good services and shopping infrastructure in city districts, green spaces and playgrounds.

Still further needs can only be met through specific capital investment in buildings, for example, certain flat sizes, balcony, kitchen and/or bathroom modernisation, quietness and improvement of the private sphere (sound insulation from neighbouring flats and traffic).

Certain trends in population development – for example, into agglomerations or from east to west – originate in individual groups, partly due to compelled occupational mobility. Social trends, in this case, result not only from personal needs and policy frameworks but also from economic rationalities. Investigations have shown that it is not always the explicit wish of people to build on greenfield sites, but rather often a financial decision. Investigations of "migration motives" show "that there is no basic disinclination towards the city as housing location and living environment. A […] large proportion of migrated households would have been happy to stay in the city" (empirica 2009, p. 26, *original in German*). In fact, "the demand to combine ones own provision for old age, considerable housing needs and, at the same time, increasing consumption needs of the growing household and necessary provision for the education of children can hardly be fulfilled" (empirica 2009, pp. 17–18, *original in German*). If affordable housing available for owner occupation or to rent in cities, families would be happy to remain there. They move to surrounding areas because there they can afford appropriate housing (whose acquisition is still socially desirable and, in terms of provision for old age, also regarded as economically expedient)[25]:

> A lack of rented flats suitable for families can additionally reinforce this preference for home ownership. However, cities […] have up to now hardly been in the position to mobilize a corresponding offer. Appropriate housing stock for owner-occupiers remains scarce, and as a consequence relatively expensive. The rate of owner-occupation in cities is accordingly low (empirica 2009, pp. 17–18).[26]

The behaviour of different population groups is influenced, for example, by actor groups, which Stengel calls an "interpretation and dissemination elite" and in the con-

[25] In this context, it has to be considered that in Germany "single-family house" and "property ownership" have virtually become synonyms. "In countries with high rates of property ownership it is shown that also younger and economically less potent households become property owners. This leads automatically to a greater range of properties for sale (e.g. small and modest flats). In contrast to this, the equation of single-family house and property ownership is typical for Germany, whereby the preference for property ownership can hardly be distinguished from that for the single-family house. On the basis of this ambiguity, there is room for the hypothesis that families turn to property ownership because there are no rented flats suitable for families. The underdeveloped single-family-house rental market, in particular, would then be a 'home ownership driver'" (empirica 2009, p. 14, original in German).

[26] Since Germany is the EU country with the highest share of tenants (44%) – by contrast, in the 27EU member States as a whole an average of 26% rent their homes (both figures for 2008) (Eurostat 2010a, b, p. 332) – the so-called investor-user dilemma and the housing market situation are here particularly significant. This means that in Germany the motivation of landlords to invest in refurbishment and modernisation of residential property is presumably highly dependent on the housing market, while in countries with high rates of property ownership large numbers of owner-occupiers should have a personal and also financial interest in regular maintenance and modernisation of their properties.

Where there is a strong demand for flats, even "hovels" are rented, and if supply is greater than demand one might have a competitive advantage with a modernised flat. It is questionable, however, whether capital investment can be recovered by means of comparatively higher rent. An investigation on behalf of the Federal Ministry of Traffic, Building and Urban Development (BMVBS) and the Federal Office for Building and Regional Planning (BBR) showed "that according to private landlords 40% of flats today in eastern German cities in cannot be offered at a cost-covering rent" (Schätzl 2007, p. 102, original in German).

In 2006, more rented flats than owner-occupied flats were categorised as in need of refurbishment (assessment in each case by the head of household). It can be presumed from this that owner-occupiers invested more regularly in modernisation and refurbishment than landlords: "Housing is often more highly valued by owners, which on the whole leads to greater investment in property maintenance and improvement" (Destatis et al. 2008 p. 228, original in German).

text of Sinus Institute milieus one speaks of the "leaders and multipliers milieu" (cf. UBA 2009a, pp. 18–21, *original in German*). These play a relevant role in the "shift in interpretation of products, behaviour or ideas" (Stengel 2011, p. 29, *original in German*). While the interpretation elite, comprising representatives of science, culture, media and politics, receives a leap of faith from society and can thus successfully introduce new legitimation, styles and practices into society; the disseminator elite spreads these opinions and trends. The disseminator elite accordingly includes journalists and creative people from the advertising and Internet sectors (Stengel 2011, p. 29).

This means, therefore, that both these groups are helpful in achieving a substantial transformation in the construction and housing area.

4.2.4 Parameters: Barriers to Investment in Housing Stock

The needs of different groups are part of relevant parameters that have to be considered in policy concepts for sustainable construction and housing. It is likewise relevant to identify the specific barriers that prevent *more* being invested in existing buildings. Though investment in housing *stock* in Germany since the year 2000 has exceeded that in *new housing construction*,[27] there is still a great need for investment.

At the same time, adaptation of investment in housing stock to the financial possibilities of buyers or tenants corresponds occasionally to a tightrope walk. As already mentioned, modernised flats in revitalised city districts might be simply too expensive for young families. Where the development and "upgrading" of a district leads to social restructuring processes, since differences between needs, financial possibilities and price development on the market clash with changes in use in the district, one speaks of "gentrification". On the one side there are wealthy customers, and on the other long-time residents who cannot keep up with rising rents.

Revitalisation of older buildings in regions and municipalities with a balanced housing market often founders on the fact it is not perceived as developable potential by flat hunters. This is often the result of a lack of imagination concerning how the old structure could be redesigned and modernised at a reasonable cost. As a result, flat hunters switch to newly-constructed properties on the edge of town or in surrounding areas, while at the same time, the number of vacancies in the centre of town increases. Here, architect competitions or other municipal activities that have an impact of the public can direct attention to exploitable potentials in town centres.

In other regions, on the other hand, the low rent level is the main barrier to investment. On such markets, higher rents cannot be enforced due to low demand. Higher

[27] "From DIW housing construction volume in 2004 of around 129 million euros, 57% was for investment in existing buildings and 43% for investment in new construction. This great importance of investment in existing buildings in Germany will probably continue in the coming years, since in new housing construction no fundamental recovery is to be expected due to the demand situation. For this reason, investment in housing stock plays an important role, also with regard to employment, construction activity and housing supply" (Schätzl 2007, p. 99, original in German).

rents are necessary, however, for investments to bring a return in the medium to long-term. A lack of equity capital on the part of landlords is also seen as a problem (cf. Schätzl 2007, p. 100). On account of the forecast demographic development, in some regions vacancy rates will markedly increase and the investment climate consequently also worsen (Schätzl 2007, p. 99).

Complex interactions therefore exist between housing markets and the needs and values of population groups, their financial possibilities and access to information as well as economic barriers on the part of landlords, which have to be investigated in depth in order to identify specific "policy levers".

4.2.5 Identify Policy Levers

Following intensive analysis of parameters and reasons for the present trends in construction and housing, it is import to identify the right "levers" for policymakers. The following questions arise: In which areas should particularly high potentials be utilised? Which developments support the objectives of sustainability policy and should therefore be intensified? Which trends lead in the "wrong" direction from an ecological and economic point of view, and how can they be counteracted? Where is political control particularly promising, since there are "allies" – that is, stakeholders – who are pursuing the same objectives? Criteria for relevant policy levers should at this point therefore be "ecological relevance", "political and social realisability" (depending on target group, barriers and allies) as well as "technical and administrative cost" (in implementation).

One example for a relevant policy level is action in the case of public construction projects. Here, no further actors (apart from within public administration itself) have to be convinced, and the chances (ecological relevance and social realisability) are therefore high at a comparatively low administrative cost. The German government already sets a good example, particularly in the area of non-residential buildings: The "Guide to Sustainable Construction" ("*Leitfaden Nachhaltiges Bauen*") for federal government construction projects (office and administrative buildings) is binding and lays down among other things: "The demand for space and land requested by users should be critically examined in terms of need and appropriateness, and with particular regard to oversupply, as well as with the objective of avoidance of new construction through optimized use of building stock" (BMVBS 2011, p. 51, *original in German*). This includes an analysis of variants in which the following options should be investigated:

- Renting of properties, including possibly necessary conversion or extension work
- Purchase of existing buildings, including possibly necessary conversion or extension work
- Leasing or instalment purchase
- New construction, conversion or extension work through self-construction
- Public-private partnership (with PPP suitability test)

Table 12.3 Assessment of relevant "policy levers", own representation

	Ecological relevance	Realisability	Effort
Increase investment by owner-occupiers and landlords in existing buildings through incentives and/or regulative law	High	Medium (some barriers)	Medium (depending on measure)[a]
Increase transparency for tenants and purchasers concerning the condition of existing buildings	Medium	Medium (some barriers)	Low
Entrench sustainable land use in planning law (Regional Planning Act, Building Code, Land Use Ordinance), create incentives for regions and municipalities to sustainably design regional planning and urban land use planning (less designation of building zones)	High	Low (strong barriers)	Medium
Increase transparency for municipalities: Long-term housing need development Infrastructure follow-up costs through designation of building zones[b]	High	Medium (some barriers)	Medium

[a]Should financial incentives be set: high, if in this respect returns through taxes are considered; low, with tightening up of regulative law considerable resistance has to be expected from the property sector
[b]cf. on this also Penn-Bressel (2013)

At the same time, "the principles of lifecycle-orientated optimization of costs, in particular later operating and other occupancy costs as well as risk-costs, have to be considered. Besides the purely cost-related comparison of variants, a cost-benefit analysis is recommended, in order, among other things, to appropriately consider quantitatively non-subsumable aspects of sustainable construction" (BMVBS 2011, p. 52, *original in German*).

Beside exemplary public construction projects, Table 12.3 shows further relevant "levers".

4.2.6 Precise Measures

With the following description of precise measures, the identified "policy lever" of "increasing investment in building stock" should be gone into. Based on the research findings of the scenario project, the German Federal Environment Agency has

Table 12.4 Potential target groups and measures to increase investment in existing buildings, own representation

Target group	Incentives
Landlords who do not renovate a building because:	
They want to avoid costs	Financial support through favourable loans both for energy-efficient refurbishment and for modernisation in accordance with current housing needs[a]
They do not recognise potentials	Improvement of legal bases for ecological rent indices, and support of municipalities in determining such indices (customary local comparable rent exclusive of heating may be higher in energy-efficient buildings than in non-refurbished buildings)
The cost is judged to be too high and	Under certain conditions, regulation of obligatory upgrading of energy performance[b]
They do not trust craftspeople to carry out high-quality work	Promotion of regional networks of craftspeople and architects who offer "qualified service from one source"
Landlords who do not renovate a building:	Financial support by way of grants.
Because demand for living space is low and they fear more vacancies, or that they will not be able to impose higher rents after modernisation	Specific urban and neighbourhood development: uphold local infrastructure (trade, services, health care, local public transport etc.), so that no self-perpetuating effect occurs
Persons who, instead of purchasing property from building stock, create their housing on a greenfield site. Here, the focus is on clearly defined population groups, their needs and barriers	Specific urban and neighbourhood development for a "good neighbourhood" (attractiveness of town centres: green spaces, infrastructure suitable for children)
	Professional support in the assessment, purchase and renovation of existing buildings
	Land recycling
	Promotion of networks of craftspeople and regional energy agencies for competent accompaniment of modernisations
	Financial support of the services of surveyors, consultants and planners (like architects, energy consultants etc.)
	Image campaigns for "affordable, centrally located, pre-owned properties", and know how their value and necessary renovation can be competently estimated (e.g. together with building societies, craftspeople, and consumer advice centres)
	Specific information on the "true costs" of a single-family house in the country (e.g. commuting: petrol, time)
	Possibly, extension of the duty to preserve records to cover construction documents

(continued)

Table 12.4 (continued)

Target group	Incentives
	Financial control: newly constructed properties outside town centres made comparatively more expensive than the renovation of existing buildings or redensification (through trading in land certificates, tax on building materials, preferential financial – e.g. fiscal – treatment of investment in existing buildings)

[a]In Germany, the share of small households (one or two persons) is increasing (German Federal Statistical Office 2010b); moreover, age-appropriate conversions are of relevance.
[b]The federal government has already provided for obligatory retrofitting of roof insulation and replacement of boilers in the Energy Saving Ordinance (EnEV). In addition, according to its 2010 Energy Concept the federal government targets at least a doubling of the rate of renovation (BMWi and BMU 2010, p. 22). This lies, depending on definition, calculation method and source between 1 and 2.2% (cf., e.g. BMVBS 2007, p. 42).

drawn up numerous proposals for measures, in order that the sustainability scenario for Germany becomes reality (UBA 2010a). Measures have also been developed in discussions with experts and in dialogue projects, and other measures assessed that have already been the subject of debate on sustainable construction and housing (Wuppertal Institut 2008). In Table 12.4, the focus lies on measures that do not specifically relate to the situation in Germany but are applicable, too, in other countries.

5 Conclusion

How we construct buildings and provide housing now and in the future have an enormous influence on the future viability of our use of raw materials, our energy needs and our use of land. At the same time, there exist great opportunities and potentials for pursuing a sustainable path. Sustainable construction and housing is a complex area, in which the needs of different population groups, markets and demographic change play an important role. Specific analysis of general conditions and trends is indispensable for the design of effective policy measures. Orientation towards the proposed strategic "construction and housing hierarchy" can be useful for decision-makers.

A technical aspect of an increase in efficiency – and its possible contribution to increased resource productivity in the construction sector – is discussed in detail in the following contribution to this book in Chap. 13.

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Chapter 13
Anthropogenic Stock as a Source of Raw Materials: Optimized Utilization of Recycled Building Materials to Conserve Resources

Hermann Keßler and Florian Knappe

1 From Demographic Change to Resource Conservation

Existing buildings and infrastructure installations and the valuable materials contained in these represent an enormous source of raw materials for future generations. Meanwhile, the amount of these materials which are referred to as anthropogenic stock has reached an order of magnitude of 10.1 billion tons in the residential buildings alone of German cities and communities. Mineral building materials such as bricks and concretes (altogether 9.7 billion tons) form the largest share, but this figure also includes constructional steels and other metals (106 million tons), timber (247 million tons) or plastic materials (7.6 million tons) (UBA 2010a, b).

However, the useful life also of these building materials is limited, and it does not always depend on the structural-physical quality of the buildings involved. In Germany and in many other countries of Europe alike, the population will continue to dwindle from a current figure of 82.4 million to less than 70 million by the middle of the present century. This would correspond to the level of the year 1963. According to a prognosis of the Federal Office for Building and Regional Planning, this will be accompanied by a continuing migration from the new to the old federal Länder (BBR 2006). Thus, more than half a million people will contribute to dwindling population figures by 2020, that is, a thinning of the population density and general shrinking of the importance of the regions affected. In many East German but also in a number of West German communities, vacancy rates in residential

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buildings will again increase. Urban planning challenges will result in more dismantling and refurbishment and, thus, lead to the generation of more construction and demolition wastes.

Such trend is intensified by a foreseeable change in housing requirements: Demographic change is accompanied by an ageing of the society. The number of young people is on the decrease, while that of old people is on the increase. Thus, the number of persons aged 80 years and above will triple to as many as 10 million, while in contrast, that of children and adolescents will decrease by 30–40%. This means a trend towards smaller and smaller households. Already today, no more than one third of the almost 40 million existing households are uniting two or more generations under one roof. Such development will accelerate: On the one hand, more single households, more childless households and more households of the elderly will require appropriate refurbishment of existing buildings. On the other, such development will cause a jump in vacancy rates in situations unsuitable for appropriate refurbishment.

An essential objective of the national sustainability strategy of the German federal government published in 2002 under the title “Perspectives for Germany” consists in a doubling (as referred to 1994) of the raw materials productivity by the year 2020 (Die Bundesregierung 2002). In this context, the term of raw materials productivity denotes the relation between economic well-being in the form of the gross domestic product and the consumption of raw materials required to achieve it. According to the 2010 integrated environmental and economic accounting (“Umweltökonomische Gesamtrechnung 2010”) of the German Federal Statistical Office, this raw materials productivity increased by 46.8% in the 1994–2009 period. However, a major part of such increase was to be attributed to economic growth (plus 18.4%), while the material input proper had decreased by no more than 19.4% since 1994, which was insufficient to reach the ambitious target in time. Nevertheless, there is an industrial sector that was able to increase its share in raw materials productivity, in contrast to this development, between 1994 and 2008, the input of building materials dropped by 27%, or 215 million tons. How much more could, for example, the raw materials productivity be increased in this sector if in addition to the absolute decrease in the consumption of primary raw materials such as gravel, sand, cement and stone, a substitution by secondary raw materials took place: Materials originating from building construction are subjected to high-quality recycling and reused in building construction.

This is why innovative solutions are required which take into account the entire life cycle of buildings. With regard to both the materials and the procedures used, the different life stages from construction to demolition or refurbishment of a building should be examined for their resource conservation potential. Subsequently, it is required that the potentials identified be taken to advantage in all fields, and secondary raw materials are returned to the best substance cycles that are available.

2 Potentials for Resource Conservation By Using Recycled Materials in Building Construction

Construction and demolition of buildings involve enormous material flows. In 2000 alone, almost 150 million tons of mineral building materials were used in the construction of residential buildings, according to projections published (UBA 2010a, BGR 2009). Monitoring reports for 2004 reveal that mineral demolition materials from construction and demolition debris amounted to about 50.5 million tons (ARGE 2007, UBA 2007). Of these, 62% were recycled. This material was reused in building operations, however, the major part of it in road construction and landscaping, which in general are classified as inferior types of reuse as compared to that in building construction.

The production of mineral building materials, all of which are near-surface primary raw materials, uses natural land. Estimates by the Federal Institute for Geosciences and Natural Resources (Bundesanstalt für Geowissenschaften und Rohstoffe) assumed the annual land use to have amounted to about 16 km^2 in 2001 (BGR 2003). According to the decreasing material input observed since the late 1990s, this also means a decrease in land use by almost 3.7 km^2. However, today and in contrast to land used for housing development and road construction, these areas are not subject to permanent use. Nevertheless, it has been a controversial issue whether these areas, which are subject to renaturation and recultivation upon termination of raw material mining, may eventually regain their original quality. At least some methods such as wet gravel extraction below groundwater level do result in ecological impairment. On principle, any extraction of natural stone in mines and quarries will considerably interfere with the natural balance and landscape ecology.

In addition, results of research by the German Federal Environment Agency (Umweltbundesamt – UBA) have shown large quantities of copper and constructional steels to be contained in the anthropogenic stock which, however, will disappear again by way of demolition (UBA 2010a). Thus, almost 2.6 million tons of copper are contained in the anthropogenic stock formed by existing buildings (status as per 2005). It is assumed that by 2020, this quantity will increase by about 33,000 tons, including about 17,000 tons in residential buildings. Every year, 6,100 tons of copper will become lost from existing residential buildings (13,000 tons, as referred to the total number of existing buildings).

What concerns constructional steels, the dimensions involved are even larger: Of these, about 103 million tons are bound in the anthropogenic stock. In 2020 alone, their quantity contained in existing buildings is assumed to increase by 640,000 tons while at the same time, an amount of 350,000 tons originating from existing buildings will have to be recycled. By 2050, this ratio will become completely inversed to 330,000 tons of input against 870,000 tons of output.

Hence, a qualified demolition or dismantling and refurbishment, respectively, of buildings will be of great importance for the recycling and reuse of materials. The residual fractions generated during these processes are of considerable relevance in terms of resources, given the quantities alone that will have to be coped with. The quality and quantity of the secondary raw materials produced will be determined by the technologies used in dismantling of buildings and in processing of the construction and demolition debris. For the recycling of high-quality building materials, demolition/dismantling and processing of the waste should be carried out in an environmentally compatible way: Interfering substances and pollutants originating, for example, from dyes and paints, flame retardants, adhesives and sealants should be removed from the cycle and disposed of in a way that is compatible with general welfare.

Now, provided the availability of appropriate qualities from selective demolition and subsequent processing, which would be the quantities of demolition material that could in fact be offered on the market as aggregates for concrete production, in compliance with the demand? At any rate, the demand will not amount to almost 31 million tons based on a total of 50.5 million tons of demolition material, 62% of which are said to be recycled. Such calculation should not be limited to the amounts of mineral materials generated on the German national level.

To begin with, there are two special aspects to be taken into account: Firstly, the market for mineral raw materials is different from, for example, the globalized metal market: The former is a preferentially regional market that may be described as working economically only within a radius of about 30 km hauling distance. This requires consideration of the demand for raw materials in regional terms, as compared to the market for secondary raw materials. Only a few Euros per ton will decide on the choice between the existing alternatives. Secondly, the demographic development will result in spatial disparities between regions characterized by scarcity and those characterized by a surplus of recycled materials that may be reused in building construction as aggregates for concrete production (the latter being the case preferentially in the new federal Länder). The Federal Environment Agency has commissioned an analysis of both aspects.

In the medium term, that is, until 2020, the resource conservation potential from the substitution of primary gravel and sand by recycled material (processed crushed concrete) is estimated to amount to about 11 million tons per year, on a regional basis. This corresponds to as much as 12.5% of the present annual gravel and sand input as an aggregate for in situ concrete, precast concrete and concrete products used in building construction. However, there is no regional demand in building construction for a potentially usable amount of 3.8 million tons (surplus region) on the one hand, while on the other, there is a demand of about 3.4 million tons in scarcity regions that cannot be satisfied on a regional basis. This situation is prevailing in spite of the already existing technical potential for processing and recycling of construction wastes that can produce high-quality aggregates from demolition material (mainly from concrete) of building construction. The uses and rates of recycled aggregates in concrete production are regulated by standards and guidelines.

What concerns the potentials outlined above, it has always been assumed that the framework conditions prevailing today will remain unchanged over the years.

In the long run, there will be a shift with regard to the relationship between the material output from existing buildings and material input into new buildings. It may be derived from the emerging demographic dynamics that in 2050, almost everywhere demolition activities will clearly exceed construction activities, particularly with regard to residential construction. As a result, the maximal resource conservation potential to be achieved in the building construction sector by high-quality recycling will decrease to 3.3 million m^3 per year, in a long-term view. Simultaneously, the surplus of recycling material will increase to 6.2 million m^3 per year on a nationwide level.

It follows that in the long term, the maximal technical resource conservation potential as a result of high-quality recycling may be fully achieved by using the recycling material obtainable from building construction wastes of mineral nature. Other sectors which could be of interest because of the quantities involved might include concrete uses in civil engineering and in the construction of roads, pavements, canals and pipelines.

This means that in a summarizing view, large productivity potentials from such resources, that is, the substitution of gravels, sands, stones etc. with recycled aggregates are still lying idle. But why have they remained unused in Germany up to the present? To answer this question, some information is given below on the current situation of this industrial sector in Germany.

3 Disposal of Construction and Demolition Debris: Current Situation and Developmental Trends

According to the Monitoring Report published by the working group of contributors to the recycling-based economy in the construction sector, 200.7 million tons of mineral construction and demolition wastes had to be disposed of in 2004, with its major part consisting of soils and stones (ARGE 2007). 72.4 million tons, corresponding to 36.1%, consisted of construction and demolition debris or roadway rubble. In parallel to the economic situation in the building sector and the current demand for building materials, a decrease in the generation of mineral construction wastes has been observed in recent years. A slightly opposing trend was seen only for roadway rubble, being an indication of increasing expenditure on road maintenance.

If the fraction of soils and stones is left unconsidered, construction and demolition debris constitutes the most relevant type of waste among the mineral construction and demolition wastes. Also the amount of debris generated during this period until 2004 showed a decreasing tendency (Fig. 13.1). The authors assume that the abolition of the first-home buyer allowance from January 2006 will furthermore contribute to this trend, at least in the residential building sector. In contrast to the trend for other types of waste, however, also the recycling rate has markedly decreased in this sector.

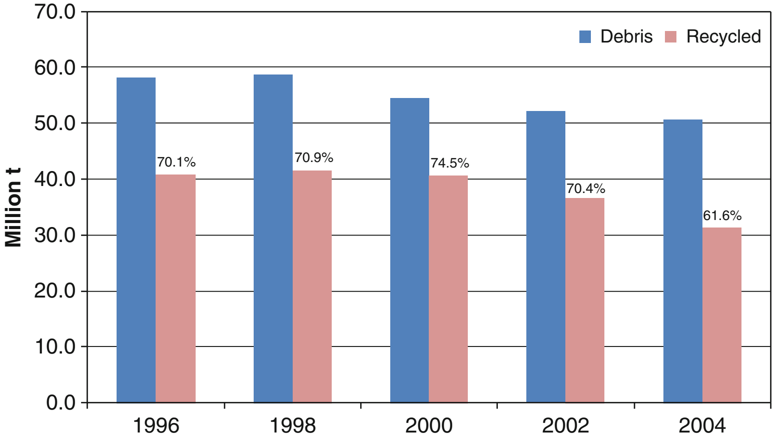

Fig. 13.1 Construction and demolition debris generated and recycling rates in 1996–2004, KWTB Monitoring Reports/IFEU

The figure shows that in 2004, no more than about 62% of construction and demolition debris was processed and used as recycled building material. A considerable share of construction and demolition debris was directly used without being further processed. Thus, 16.6% was used for the refilling and recultivation of quarries and gravel pits and the rehabilitation of cavities left by open-cast lignite mining and of slide-prone slag heaps from hard coal mining. 5.2% of construction and demolition debris was directly used for landfill construction. About 9% was disposed of on landfill sites without any utilization target.

Feedback from the recycling sector has shown that still today, a major share is disposed of on landfill sites instead of being recycled as building material. This applied particularly to construction and demolition debris with high shares of brick material. Many landfill sites are in a stage of decommissioning or profiling. In order to be able to utilize residual capacities and model the final dimensions of such sites, landfill operators fight for large quantities of wastes to be received by them. Eventually, not more than 150–160 out of almost 380 (status as of 1999) municipal solid waste landfills will be operated on a long-term basis. At present, this situation becomes evident by an intensified acquisition of large quantities of construction and demolition wastes.

Therefore, fresh efforts should be made with regard to dismantling, processing of construction and demolition debris and reuse of the recycled materials. It should be the aim of such activities to develop an attractive secondary building material of high quality that may be returned to the economic cycle. In Germany, however, the material processed in mobile or stationary facilities does not find its way back to building construction so far. Instead, it is almost completely used in road and pavement construction as an anti-frost layer or base course, or in earthwork operations.

4 Challenges to the Construction and Demolition Industry

The trend forecast has already demonstrated another shift of activities to be expected in the future: Construction in the open countryside will be abandoned in favour of land recycling and, thus, construction within existing settlements (Keßler et al. 2008). Due to the demographic change observed in our society, the demand for a major extension of floor spaces will continue to decrease also in the future. For a number of years, the demand has focussed on urban agglomerations, and within the latter, on the cores of settlements. Hence, construction activities will increasingly move to these core areas. This will result in a conservation of land as a resource. The latter has been one of the seven primary fields of action in the German National Sustainability Strategy. In this context, the aim consists in reducing the land use for residential purposes, industry and transport from 120 ha per day to 30 ha in 2020. In 2007, this figure still amounted to about 100 ha per day.

In addition, construction activities in the years ahead will increasingly be characterized by preservation and restoration of existing buildings. A considerable share of the transport infrastructure, but also of building constructions was built in recent decades. These buildings will increasingly require basic refurbishment. In many cases, demolition and replacement by new buildings will be preferred for economic reasons.

It has to be expected that also in road and pavement construction, the demand will be more than satisfied in the medium term – at the latest when this sector will cease to focus primarily on an expansion of roads and pavements. Already now, a decrease of traffic intensity has been predicted for the first time for some East German regions. This will in turn have effects on the need for new developments and expansion of the transport infrastructure and, thus, on the demand for building materials. Urban road reconstruction is based on a complete upgrade, that is, both the bound and unbound layers are completely removed and reconstructed in equivalent masses. By using such approach, a considerable share of wastes may be recycled and reused in road construction. In contrast, extra-urban roads are often repaired by overlay construction. This means that a completely new road structure is built on top of the old one in order to save the costs of demolition and disposal of excess waste material. On principle, it would be possible to completely upgrade the road structure and reuse a relevant share of the existing waste material also in these cases. The resulting elevation of the level of extra-urban roads has been considered as not being critical, in most cases.

As a consequence, any demand for building material arising in the redevelopment of existing buildings will increasingly be associated with a direct generation of mineral construction wastes because it requires reconstruction or removal of existing building structures. It is expected that, with clear regional differences, the specific relationship between the demand for building materials and the supply of recycled building materials will become much closer as compared to the situation prevailing today.

All materials used in erecting the buildings of our technical sphere, be it residential buildings, non-residential buildings or measures to improve infrastructure, constitute the anthropogenic stock and, thus, mankind's most important raw material source of tomorrow. Knowledge about the quantities and composition of the materials used is an important basis for forecasts as to the type, the quantity and quality of materials the demolition industry may be faced with, and the times when this will be the case. Such knowledge will also be a prerequisite for the development of preventive concepts for reuse of valuable materials as secondary raw materials and, thus, of resource conservation potentials that have remained unused so far.

In this context, an important approach consists in linking the input of building materials with the recycling of the processed material flows. Taking into account the entire life cycles of buildings, the necessity becomes evident to identify optimization potentials from the drawing board to dismantling and their implementation in practice. A convenient production of high-quality secondary raw materials after the utilization phase of buildings and a high-quality use of recycled materials in building construction will ask for recyclable construction solutions and ecofriendly building materials.

In view of the predicted obvious increase in the specific amount of construction and demolition debris generated, there will be an urgent need for developing new applications and marketing channels for recycled building materials (UBA 2008). Already today, the marketing of recycled products via the classical channels is facing problems again and again. It will be necessary to enhance the handling of mineral construction and demolition wastes not only in the context of optimizing resources management but also in order to ensure an adequate security and safety of disposal.

An important approach to optimization will include the reuse of residual materials in building construction in the form of recycled products. In this regard, an obvious option consists in the processing of residual building materials to result in aggregates that may be used in concrete production, thus competing with gravel or natural stone split (Keßler et al. 2008).

5 The Future Belongs to Resource-Saving Recycled Concrete

In Switzerland, this development may be observed on an almost nationwide level. In the city of Zurich, the public authority of urban development (Hochbaudepartment) has set the objective of economic, social and ecological sustainability for the 2002–2006 legislative period. This has been successful insofar as numerous public buildings were erected using recycled building materials. As a result, the use of resource-saving recycled concrete has become established on the market on a sustainable basis. Meanwhile, also numerous principals of private construction projects have taken to the notion of sustainable building and, therefore, deliberately use secondary raw materials.

There is another reversion of trends emerging that may promote the use of recycled materials: As compared to the 2005–2012 period, the construction of new housing projects comprising detached and semi-detached houses will have decreased by 50%, that is, to about 79,000, at the end of the period that follows (2020), according to the regional planning forecast. In contrast to this, the construction of new housing in multiple dwelling units will decrease by no more than 10%, that is, to about 115,000, within the same period of time (BBR 2006). Unlike today, construction will focus on multiple dwelling units. Particularly these, like commercial buildings (office and sales spaces, workshops etc.) are preferentially built from concrete. While in general, the demand for building materials of all types will decrease, the importance of concrete as a building material will grow correspondingly. This will constitute a basically favourable situation for recycled materials because owing to mixing facilities and the production of ready-mix concrete, respectively, the latter will meet with a better sales situation than bricks as a building material.

Due to increasing dismantling or reconstruction activities of buildings from the post-war period, the share of concrete in construction and demolition debris is constantly on the rise. Already today, a major share of the construction and demolition debris generated in the Canton of Zurich consists of granular concrete material, with an increasing tendency. Unlike broken bricks, granular concrete is suitable for use as an aggregate for concrete production and, therefore, has a higher potential to substitute natural materials.

Already in the 1990s, the options of using recycled materials as aggregates in concrete production instead of gravel or broken natural stone were demonstrated in an impressive way by comprehensive research projects. However, in contrast to neighbouring countries, this is not reflected by the practice of building in Germany.

Actually, the standards, DIN 10945/EN 206-1 and DIN 4226-100 / EN 12610 provide for all basic requirements of an enhanced use of recycled concrete, regulating among other items, the composition and use of concrete from recycled aggregates. In the Canton of Zurich, numerous building projects of the cantonal building authority were supported by comprehensive research conducted by the Swiss Federal Laboratories for Materials Science and Technology (Eidgenössische Materialprüfungsanstalt – EMPA). In a wide variety of buildings, it was possible to illustrate in an impressive way that concrete from recycled materials showed properties analogous to those of concrete from natural materials.

In addition, structural studies have demonstrated that there were no significant differences between primary and recycled concrete with regard to failure load, deformation of beams, concrete compression, tensile bending strength etc. The properties of shrinkage and creep were somewhat more pronounced in recycled concrete, while in contrast, the compressive strength was somewhat higher at similar w/c ratios. Up to 50% shares of secondary material in the aggregate, also the modulus of elasticity was comparable to that of primary concrete.

The wide scope of application is demonstrated in an impressive way by the example of Switzerland and particularly the Canton of Zurich with its numerous buildings that have been erected in recent years. Concrete from secondary material has been successfully applied in practice according to EN 206 up to the strength classes C 35/45 and exposure classes at least up to XC4/XD1/XF1. As a result, 90% of the concrete market may be covered by such types of concrete in that region. As an example, housing for 500 residents was created in an extremely resource-saving way in the Werdwies residential quarter in the city of Zurich.

In a trendsetting way, the Zurich Cantonal Office of Waste, Water, Energy and Air Quality (Amt für Abfall, Wasser, Energie und Luft – AWEL) developed a strategy to

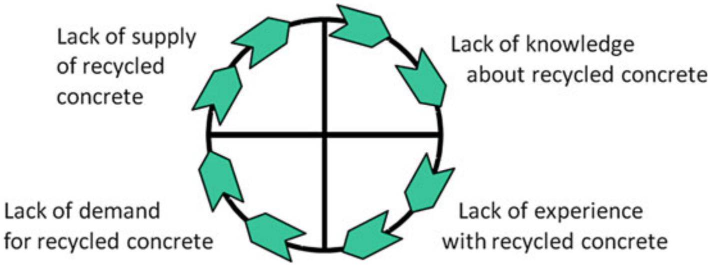

Fig. 13.2 Problem of demand for and supply of recycled concrete, IFEU

promote recycled building materials by initiating an action entitled "Gravel for Generations". It has been the aim of this action to increase the importance of recycled building materials on the gravel market and to completely integrate such materials into the construction market as attractive alternatives to primary building materials (Cahans 2010).

6 Overcoming Obstacles: Improving the Acceptance and the Resource-Saving Use of Recycled Concrete in Germany

In Germany, the resource conservation potential of a high-quality use of recycled materials in building construction has been hardly taken advantage so far. The substitution of primary raw materials is often thwarted just by a lack of information among principals, engineers or architects involved in construction projects that concerns the properties and potential uses of recycled materials (UBA 2008).

On the other hand, there is also lack of offers to potential customers, that is, the principals, entrepreneurs, engineers and architects who are not yet able to associate sustainable building with the positive image of a building constructed from recycled materials. Examples from other European countries demonstrate that this fact is only in part to be attributed to the low potential for added value arising from recycled materials. Rather, problems regarding demand may be observed that are based on a lack of information. The result is a vicious circle as illustrated in Fig. 13.2.

In this respect, it is particularly the public sector which should play a special role by way of pilot projects offering the chance to gain experience. By initiating flagship projects, the public sector is in a position to publicly suggest the use of recycled materials as a contribution to resource conservation. In this way, it could promote an increased use of recycled materials in building construction and the fixing of a minimum share of such materials to be used in the construction of public buildings and in infrastructural measures.

Buildings are long-term investments constituting, on principle, a reservoir of materials that should, in a perspective, be returned to the cycle of materials. This is the reason why already during the planning and building process it is decided to which extent the materials used may be recycled decades later. Accordingly, the requirements of recycling-friendly building should be determined at an early stage. This aspect could be reflected, for example, in registers of materials. These may, on the one hand, list the essential materials used and include potentially critical substances. On the other, such registers could already take into account the possibilities of selective dismantling (e.g. by means of guidelines or sub-legal requirements).

In a direct or indirect way, principals, building contractors, planners and architects of construction projects are in the position to exert a decisive influence on material flows by choosing the materials to be used (recycled materials, renewable raw materials etc.) on the one hand and determining their future recyclability, on the other. Now which could be the options to increasingly oblige the principals of construction projects to take on intergenerational responsibility? This responsibility could find its expression, for example, in an extended "building passport". The information documented in such passport could also include the input of raw materials in the basic construction and their qualities, as well as the shares of recycled materials and renewable raw materials used, and data on the recyclability of the building. Similar to the obligation to apply a certification system to buildings of the federal administration, also the principals of private construction projects should be given incentives to document the characteristics of their projects (BMVBW 2001). For example, an incentive to issue building passports for private residential buildings could be created by means of requirements made by real estate financiers and insurance providers. Last but not the least, a building passport could serve to provide valuable information for prospective buyers in the case of a change of ownership. Since owners may often change during the lifetime of a building, some data may no longer be available at the time of demolition. At present, the collection of data on materials involves a complicated procedure including inspection by experts and estimates. In contrast, an innovative material or building passport could ensure that data and information on a building required for high-quality recycling be available at the time of reconstruction, dismantling or demolition.

In the future, documentation of the raw materials used in constructional measures of any kind will increasingly gain in importance because buildings will be our sources and mines of raw material of tomorrow (keyword: Urban mining).

7 Flagship Projects Providing Initial Incentives to Use Recycled Concrete

7.1 Flagship Project No. 1

Flagship projects are appropriate instruments to communicate information and increase acceptance. In recent years, for example, a pilot urban development project carried out in the city of Ludwigshafen could provide important incentives for wide areas in the south-west of Germany. In all cases, it was possible to convince municipal housing associations to use recycled concrete as a “new” building material in an exemplary way. An important prerequisite to achieve this consisted in an intensive scientific support, aimed at addressing and answering all open queries raised by the building industry regarding the use of the building material from the angles of environmental protection, resource conservation and its constructional suitability. In addition, the first and all the following incentive projects in the federal Land of Baden-Württemberg were accompanied by documentation and comprehensive public relations activities (www.rc-beton.de).

The first flagship project was carried out by a municipal housing association in Ludwigshafen who built a guest house on the banks of the Rhine river in the context of the redevelopment of an old harbour and industrial site. The construction involved was a four-story residential building whose rising walls and ceilings were built from recycled concrete. Based on the highly positive experience made, it was decided already at the time of the erection of the shell construction to exclusively use recycled concrete also for the exposed concrete walls of this building and of two other buildings erected at the same time. The total mass of recycled concrete used for this project amounted to about 600 m^3. The shell construction was finished in late 2009.

Suitability testing showed excellent concrete qualities for all parameters regarding the properties of both wet and hardened concrete. Therefore, other principals and building contractors became aware of this building material as a result of public relations activities. Only on this basis, recycled concrete could be included in the price list of a Ludwigshafen company producing ready-mix concrete, and it became marketable. As a result, numerous other building projects could be supplied with recycled concrete. Of the following building projects, only the first ones were included in the documentation. These were two single-family houses and an administrative building in the town of Malsch in the federal Land of Baden-Württemberg.

7.2 *Flagship Project No. 2*

Flagship projects will fulfil their function only if they are able to bring forth other self-supporting incentive projects. An example is provided by a building and housing society in the city of Stuttgart which at present is gradually reconstructing its housing stock in the Stuttgart-Ostheim district and thus, the entire quarter. The existing buildings are refurbished or in part replaced by new buildings. In the current construction stage of two buildings, 1,500 m^3 of recycled concrete were used, corresponding to 65% of the total quantity of concrete required (IFEU Heidelberg). For this purpose, the Waiblingen concrete manufacturer had to use the maximum admissible shares of recycled aggregates stipulated by the guideline of the German Committee of Reinforced Concrete (Deutscher Ausschuss für Stahlbeton).

Already during this project, the manufacturer added recycled concrete to his product range and supplied other building projects, which included later construction stages in the Stuttgart-Ostheim project. Thus, a market was created for this product, and by using recycled aggregates, the manufacturer gained a relevant

Fig. 13.3 Recycled concrete is making waves – incentive projects, status as of October 2010, IFEU

competitive advantage in the fiercely competitive concrete market. By using old buildings as an "anthropogenic quarry" in close proximity to the site of concrete manufacturing, the short hauling distance proved to be decisive for the costs compared with those of primary gravel.

On completion of the first building in October 2010, a wide range of public relations activities was started also for the Stuttgart region to draw attention to this building material also among other builders (Fig. 13.3).

And thus, incentive projects are spreading a positive influence in the south-west of Germany. In the industrial park "Wohlgelegen" in the city of Heilbronn, for example, a science and technology centre (Wissenschafts- und Technologiezentrum – WTZ) is built for completion in 2012. The project is supported by EUR 4.9 million from EU funds and EUR 1.6 million from funds of the federal Land of Baden-Württemberg. Together, the two five-story buildings, referred to as WTZ I and WTZ II, will have a gross volume of 18,100 m^3 and a floor area of 4,300 m^2. Probably, the demand for recycled concrete will clearly exceed that of the Stuttgart flagship project.

8 Recycled Concrete from an Ecological Viewpoint: The Stuttgart-Ostheim Flagship Project as an Example

The structural-physical properties of recycled aggregate as a secondary raw material are almost similar to those of natural stone split. Therefore, the concrete mixture formulations used were identical with those of conventional concretes, with minor differences only regarding the quantities of aggregates (sand and stone). The shares

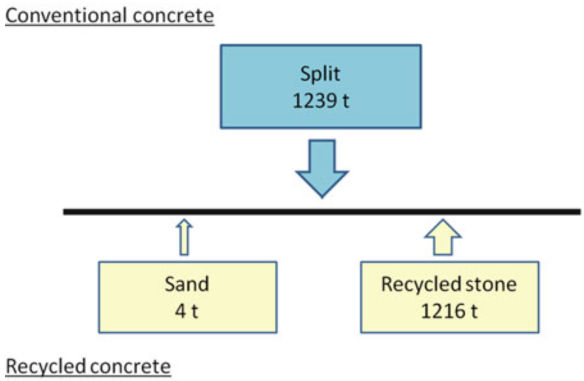

Fig. 13.4 Mass balance for the building project of the Bau- and Wohnungsverein Stuttgart, IFEU

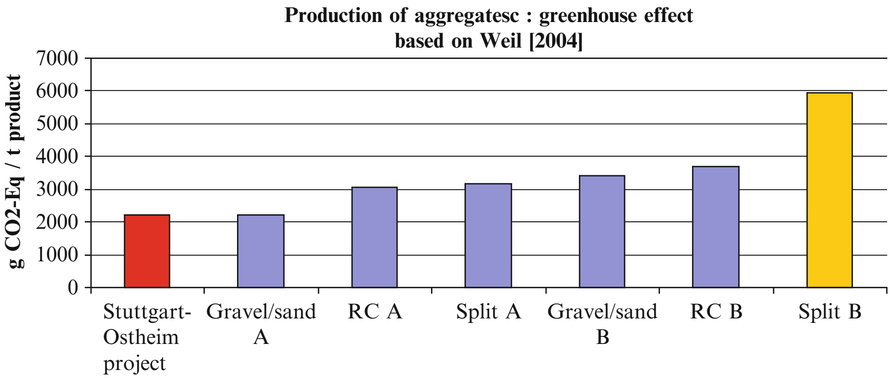

Fig. 13.5 Comparison of the environmental impact of the production of aggregates – greenhouse effect (*RC* recycled aggregate)

of all other components of the mixture (cement, auxiliary chemicals) remained the same without any losses in quality. This is important in terms of the ecobalance (life cycle assessment): A 95% of the ecological burden due to concrete production with regard to the greenhouse effect is to be attributed to the production of cement. Therefore, changes to the mixture formulation would have significant effects on the life cycle assessment.

Based on the quantities of the different types of concrete used in the building projects described above, it is possible to calculate the mass balances for the alternatives, that is, recycled concrete versus conventional concrete (Fig. 13.4).

When comparing the total quantities of aggregates used over the entire duration of the building project, the difference between the two options of concrete production amounts to no more than 19 tons. The production of an amount of recycled concrete of comparable utility is associated with a plus of about 4 tons of sand and a minus of 23 tons of stones. The differences demonstrated are assumed to be within the variation range of the specific weights of the individual materials.

Analysis of the process of treatment of the waste concrete to produce a recycled aggregate has shown that the use of energy may compete with that required for the production of gravel or of split from natural stone, as documented by Weil (2004). This will even apply if the total use of energy is only attributed to the recycled aggregate and not to the other products as well. Figure 13.5 illustrates the results for the greenhouse effect as an environmental impact category. There are only minor differences. The results are obviously determined to a major degree by the specific framework conditions of the individual establishments, cf. also the results obtained by Weil for the production of recycled aggregates (RC A and RC B). It is not possible to derive from these facts disadvantages inherent to the system of the production of recycled aggregates.

Given the tendency of an identical use of raw material for the production of recycled concrete and the tendency of an identical environmental impact for the production of recycled aggregates and aggregates from primary stone, the essential differences inherent to the system consist in the environmental impact associated with transport and the interference with the natural balance and the landscape associated with the mining of raw materials.

This is the reason why from the angle of life cycle assessment, ideal framework conditions for the use of recycled materials would mean that in contrast to the use of primary gravel, there is a small distance between the sites of demolition, processing and use. For the above building project in the urban agglomeration of Mannheim-Ludwigshafen, the recycled aggregate was produced at a distance of about 7 km from the ready-mix concrete plant. It was used to substitute gravel which otherwise would have had to be obtained from outside the immediate urban agglomeration limits (>20 km).

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Chapter 14
The Importance of Rare Metals for Emerging Technologies

Armin Reller, Volker Zepf, and Benjamin Achzet

1 Introduction

When watching the newspapers, reports and headlines during the last months and years, you could have gotten the impression that raw materials and commodities are running out of stock and insurmountable problems would prevail. Climate-relevant or green technologies are in peril as not enough raw materials would be available. Pointing fingers on China due to export restrictions on rare earth elements or power cuts in South African mines succeeded predictions that electromobility would boost demand for several materials far in excess of supply. All of these announcements seemed to get proof by ever rising commodity prices at the stock exchanges. However, a closer and more scientific look shows a different picture. Extremely volatile prices occurred with no sound economic reasoning, while some demand predictions did and do not withstand even simple extrapolations. Often a single-sided picture is drawn, which does not address all options, especially when considering emerging technologies (EmTech) and the required materials for them. Consequently a more distinct look is necessary that addresses both the terms 'importance', 'rare metals' and 'emerging technologies'.

It is the intent of this chapter to give common definitions and understandings of these topics and of course a description of the actual metals required and their impact on these technologies. It should be obvious that in a short text neither all technologies nor all respective elements can be addressed in depth. There will be emphasis on some technologies, whereas other technologies and elements are basically just listed without having the intent to be comprehensive.

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1.1 Importance

The theory of the long waves invented by Nikolai Dimitrijewitsch Kondratieff (1892–1938) – named ‘Kondratieff-Cycles’ by Joseph Schumpeter in 1939 – details wavelike economic growth phases driven by basic innovations and following an expansion, stagnation and recession scheme. Starting at around 1780 until about the year 2000, five phases or cycles with 40–60 years duration each are identified: (1) steam engine, (2) railway and steel, (3) chemistry and electrical engineering, (4) petrochemicals and automobiles and (5) information technology. Today a sixth cycle seems to be at the pole position, whose labelling could be biotechnology and genetics but also nanotechnology or just human enhancement. For each of these cycles, some materials and technologies were a prerequisite and of utmost importance to achieve a breakthrough in innovation. In the historic evolution of these basic innovations, a fundamental change in material usage from single to polyfunctional materials can be observed. From the Stone Age, Bronze Age and Iron Age to the Industrial Revolution, materials had primarily been used due to their mechanical functionality. In the late nineteenth century, materials had to fulfil more than just the original mechanical function. Additional requirements for higher performances like temperature and corrosion resistance were requested. This trend, from mechanical materials to functional materials, with specific multiple characteristics, increased during the course of the Kondratieff Cycles. Several thousand types of functional materials have been developed until today and especially for future (green energy) technologies. Polyfunctional materials, intelligently combined and arrayed, will result in even more functionalities and thus will play an essential role in future applications. For example, the use of solar energy can be achieved by using photovoltaic cells based on cadmium-telluride cells fitted with several layers of other materials and sealed within two plates of glass. Another option is to use other semiconducting materials like CIGS (copper-indium-gallium-selenide) or silicon. A different approach would be the gain from thermal solar systems where high-reflective materials like aluminium or silver alloys are needed. Looking at the energy sector again, wind energy can be used to convert mechanical energy into electricity. One possibility is to use mainly copper-based generator and gearbox technology or use strong and huge permanent magnets. They require the rare earth elements neodymium and praseodymium which provide the strong magnetic characteristic and dysprosium or maybe terbium to enhance the temperature resistance. A further example, (bio)fuel production, is highly dependent on metallic catalytic materials like platinum-based alloys to enhance the yield. And not to forget, all energy technologies are to some extent based on specialized steels with recipes containing chromium, nickel, molybdenum and other spice metals.

As a consequence almost all elements in the periodic table today can be functionalized in different technologies and be used in a polyfunctional manner. Due to partly unique properties, some elements can be indispensible for a technology. As there are literally innumerable important applications today, starting from fulfilment of the most basic needs like food production (fertilizers for agriculture and biofuel production) up to satellite technology requiring strong gallium-based solar panels, competitive applications are not the exception but the norm. With regard to the expected global population growth from presently around 7 billion people to about 10.6 billion in 2050 (medium variant) (United Nations 2011) combined with an increasing wealth of at least a certain percentage of the population, a general increase of demand has to be expected. As climate-relevant objectives have to be met on top of all this as well, a sound understanding of the optioned technologies; the required materials, both in quality and quantity; and possible alternatives is indispensable. So *importance* can be summed up with the ethical imperative to satisfy not only economics and ecology but also global sustainable development.

1.2 Determination of Rare Metals

First of all, it has to make clear that rare metals are not the same as rare earth metals. The similar name is often misused and therefore leads to confusion. *Rare metals* is a term that has no official list of elements associated with it, so it is advisable to think about the terms *rare* and *metals* initially on a more theoretical level. *Metal* seems to be unambiguous, but within the periodic table of elements, there is the distinction between several types of metals (alkali, alkali earth, transition), semi-metals and non-metals. The arrangement and position within the table have been determined due to the chemical and physical properties like conductivity. The boundaries however are fluent as several elements can have different modifications and thus would count both as a metal and, in another modification, as non-metal. So the question has to be allowed whether non-metals should be included in the quest. To illustrate the issue, phosphorus and selenium are good examples as they are generally non-metals but of great importance to practically activate functional metal compounds, for example, in the biofuel production or CIGS photovoltaics. So with the specific array of metals or elements, a property-function synthesis is achieved, which is the new underlying materialistic principle.

The term *rare* again leads to a variety of characteristics and there is no conjoined definition. A look into the geological side leads to the abundance tables of the elements, which are derived either from sampling of the earth's crust or from samples of chondrites (Allègre et al. 2001). The resulting abundance tables are still not representative as an indicator of the actual physical attainability. For that, an element has to be enriched sufficiently within a mineral to become mineable. The determination of the status mineable underlies a dynamic process depending mainly on commodity prices and mining techniques. Then, even if the element would be available in a deposit, it still is not guaranteed that the material will be available on the (free) market for sale. Politics, geopolitics, bilateral contracts, trade restrictions as well as ecological and sociocultural factors may interfere with the actual availability of a material. This complex situation led to the development of new considerations about criticality. The word *criticality* originated from the 'Strategic and Critical Materials Stock Piling Act' in 1939. At this time indispensible raw materials for military

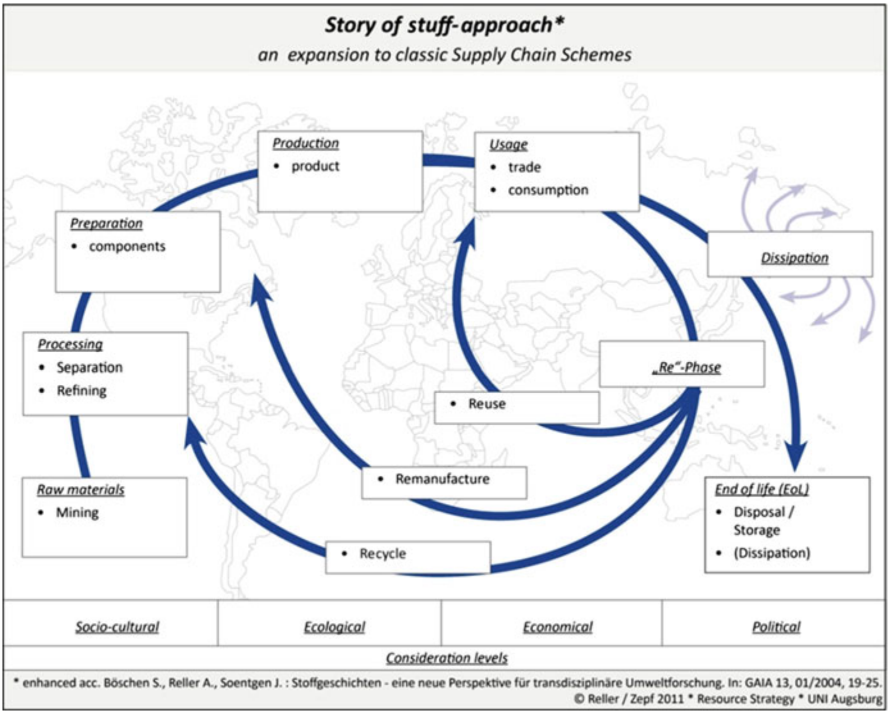

Fig. 14.1 Generic supply chain scheme for mineral raw materials

applications had been stored because of the assumption of an uncertain supply situation during war times. They had been called 'critical raw materials'. In 2008, the National Research Council (NSC) published a book about critical minerals where a methodology was introduced to determine critical minerals (NSC 2008). The resulting matrix follows two tracks: one being *supply risk*, the availability and reliability of the supply, and two the *impact of supply restriction*, which basically evaluates the importance of the mineral for use. This approach focuses more on economical issues, but ecological, sociocultural and sustainable issues may not be forgotten. So an expanded approach according to the 'story-of-stuff' theory, introduced 1996 by Huppenbauer and Reller, seems appropriate (Huppenbauer and Reller 1996). Figure 14.1 shows a sketch of the approach ranging from considerations starting with the geology, mining, processing, preparation, manufacturing and usage, via the re-phases to finally dissipation or deposition.

This methodology is principally based on a scientifically sound and elaborate narrative about one material. The intent is embracing information together with emphasis on obvious and hidden problems as well as offering links to solutions in general terms. The audience is then asked to act and develop detailed solutions according to their special expertise.

In summary, rather the term *rare materials* would be preferred. *Rare metals* or *rare materials* can be attributed and sorted in different ways, and a fixed list is not advisable in favour of a dynamic list which is based along the characteristics of the story-of-stuff scheme and with regard of the functionality of a material.

2 Emerging Technologies (EmTech)

First, the term 'emerging technology' (EmTech) needs a short explanation as the term is not unambiguous. EmTech are difficult to define mainly due to the fact that the development of technologies is per se a dynamic process. So the question always will be, what is state of the art already, and which technology is still emerging? Wind energy technology, for example, raises the question whether it is still emerging – because the technology is getting improved with new, stronger turbines being planned – or whether wind energy has to be considered as available 'off the shelf' already. Another question would be whether essential improvements like direct drive wind turbines are still emerging or are they already beyond that state. This dilemma cannot be solved in short but should be kept in mind.

There exist several different approaches about the determination and sorting of EmTech. A search on the World Wide Web with the words 'emerging technology' usually lists the acronym NBIC (nanotechnology, biotechnology, information technology and cognitive science) at the first positions. NBIC was initially used in a concept hosted by the US National Science Foundation (NSF) called 'Converging Technologies for Improving Human Performance' in 2003 (Rocco and Brainbridge 2003). These fields give an idea of where and what can be expected from future technologies. Other but similar categorizations have been created, for example, by Garreau (2005) using GRIN (genetics, robotics, information technologies, nano) or GRAIN (genetics, robotics, artificial intelligence, nano) adopted by Mulhall (2002). These are without doubt emerging technologies as such. It is in this context also important to note that inventions made in these areas may as well render technologies of today or other EmTech nearly instantaneously obsolete. Nanotechnology for example could lead to the ideal situation of fewer (material) quantities needed for the manufacturing of a product.

Now all of these sortings lack the incorporation of technologies which are intended to improve the basic needs and requirements, that is, environment, construction, (daily) life and lifestyle, mobility, energy supply and storage. With a look at the global population prospects, it seems very likely that the basic needs along the hierarchy of needs, first described by Maslow (1943), will require emerging technologies to satisfy the sheer quantity of these basic needs (Maslow 1943). So, as these are deemed more evident for the near future, a different categorization will be used herein (see Table 14.1). The emphasis in this chapter will be on energy and storage areas, whereas the other fields will be only briefly discussed.

Table 14.1 Overview of emerging technologies and end-use sectors

Emerging technologies – sortings

Sorting based on hierarchy of needs and daily life requirements

Environment	*Construction*	*(Daily) Life*	*Mobility*	*Information & communication technology*	*Energy*	*Energy storage*
Catalysis	Buildings	Medicine & pharmacy	Electrovehicles	Displays	Renewable energies	Traction batteries
Lighting	Steel	Desalination	Hybrid vehicles	Communication network (urban & rural)	Wind	Grid stabilization
	Glass	Water purification	Increased efficiency (optimization of existing technology)	Mobile communication	Solar	Grid quality
	Infrastructure (road, rail …)	Refrigeration	Weight reduction	RFID	Hydro	Island application
	Superalloys	Heating/Cooling	Traffic control		Biomass	4-C-market
					Geothermal	
					Fission (?)	
					Grid	
					Smart Grid	
					Hardware	
					Software (Control)	

'Classic' nominations

NBIC (NSF 2003)	***GRIN*** (*Garreau 2005*)	***GRAIN*** (*Mulhall 2002*)
Nanotechnology	Genetics	Genetics
Biotechnology	Robotics	Robotics
Information technology	Information technologies	Artificial intelligence
Cognitives science	Nano	Nanotechnology

Table 14.2 Potential critical elements for catalysis

EmTech	Potential critical raw materials
Refining, FCC	Pt, Re, Ce, La
Automotive catalysts	Pt, Rh, Ce

Table 14.3 Potential critical elements for lighting

EmTech	Potential critical raw materials
LED	Y, Eu, Tb, La, Ce

2.1 Environment

Catalysis has to be seen twofold: first, as a catalyst required in the fluid catalytic cracking (FCC) process during petroleum refining to produce fuels and gasoline and, second, as a prerequisite for automotive catalysts. For both applications platinum, cerium and lanthanum are used; rhenium in the FCC and rhodium for autocatalysts in addition (Hagelüken et al. 2005). In the oil refining process, the FCC technique is a widespread one as it allows to convert heavy fractions of the crude oil into lighter ones which allow the production of gasoline and diesel. This supports the common imbalance between supply (of oil) and demand (of gasoline and diesel). In the automotive catalyst sector, the metals contribute to the cleaning of the harmful exhaust particles. NO_x, CO and HC are converted to CO_2, H_2O and N_2. So the lack of catalyst materials would on the one hand reduce the quantity and quality of light fuels like gasoline and diesel, whereas in mobile catalysts a lack of catalytic material would release the harmful and toxic exhaust particles into the environment. That definitely collides with accepted environmental standards and global agreements (Table 14.2).

Lighting – Modern lighting presently changes from classic incandescent lamps using a tungsten filament to more energy-efficient lamps. As incandescent lamps successively are banned in several countries (Eco-Design Directive 2005/32/EG and (EG) Nr. 244/2009), more energy-saving lamps like fluorescent lamps and light-emitting diode (LED) technology are gaining momentum (EU 2005, 2009). For these diodes, next to the obvious parts like caps, glass covers and electrical inlays, especially the phosphors, that is, luminophores or luminescent substances, are crucial for the achievement of the desired light and colour. These phosphors, mainly three-band phosphors, are on the inside of the glass covers and consist of the rare earth elements yttrium, europium, terbium, lanthanum and cerium in specific combinations and concentrations. When they get attracted, they provoke a coloured or white illumination of the lamp. Except maybe lanthanum and cerium, the supply of rare earth elements is presently and at least in the near future critical, if not endangered, as China has set export restrictions and tariffs on rare earths due to own demand and environmental problems during the mining and processing phase (Chinese Ministry of Commerce 2010). Without these LEDs, the global energy-saving goals cannot be met. Substitutions are not available today and may become available as OLED (Table 14.3).

Table 14.4 Potential critical elements for construction

EmTech	Potential critical raw materials
Steel/Infrastructure	Cr, Ni, Mo, Mn

2.2 Construction

Steel – even though it is a long known and used material – still is the backbone for a huge array of applications ranging from conventional construction to high-tech uses in aviation, shipbuilding and modern building construction. The UN World Urbanization Prospects (2009) confirms that the level of world urbanization crossed the 50% mark in 2009 and estimates a gain of urban population by 2.9 billion until 2050 (United Nations 2010). This in turn results in a continuous effort to enlarge urban settlements as well as renew older areas, for both modern and sustainable buildings have to be designed and built. As most of the biggest cities in the world are located in tropical and subtropical zones, the buildings have to withstand extreme conditions and require special strengths, corrosion and temperature resistances. At the same time, the materials need to be very lightweight to save material and/or energy during the life cycle of the product, vehicle or vessel. To achieve these characteristics, several metals have to be alloyed to get specialized and multifunctional steels. First, chromium has to be added to achieve an initial corrosion resistance (stainless steel). Additions of nickel, molybdenum and manganese enhance corrosion and temperature resistance, ductility and strength durability even more. Other metals are also alloyed to achieve the desired specific efficiency. Substitution is only partially possible, usually with the loss of some efficiency.

Infrastructure is considered as the need for new roads, railways and navigable rivers or the maintenance of the existing ones, not only in the industrialized world but above all in developing countries like China, India or the countries of Africa. There these elements are required in huge quantities. So the need for special steels, next to concrete and other construction materials, is expected to increase (Table 14.4).

Glass today is maybe an underestimated material. Glass demand is supposed to increase as mainly urban construction, and automobile production are expected to increase in future. Special UV protection glass will be required for aviation and façade glass. Whereas the basic materials for the production of glass, silicon, sodium and calcium dioxide, are available in sufficient quantities, the metal oxides needed for polishing, colouring, discolouring and UV protection get into focus. Cerium oxide accounts as the most efficient polishing agent which also can be used to fulfil all the other stated purposes (Metall Rare Earth Limited 2011). As in 2011 the prices for the rare earth elements, including cerium, showed a dramatic increase of more than 100% (see Fig. 14.2), not so much the availability (cerium is one of the most abundant rare earth elements), but the economic use of the cerium and thus the glass beneficiation is at stake (Metal pages 2011).

Superalloys are known since WW II and still are the backbone of high-tech applications, mainly in aviation jet engines and gas turbines. Higher operating temperatures in jet engines contribute to a better exhaust regime and to higher

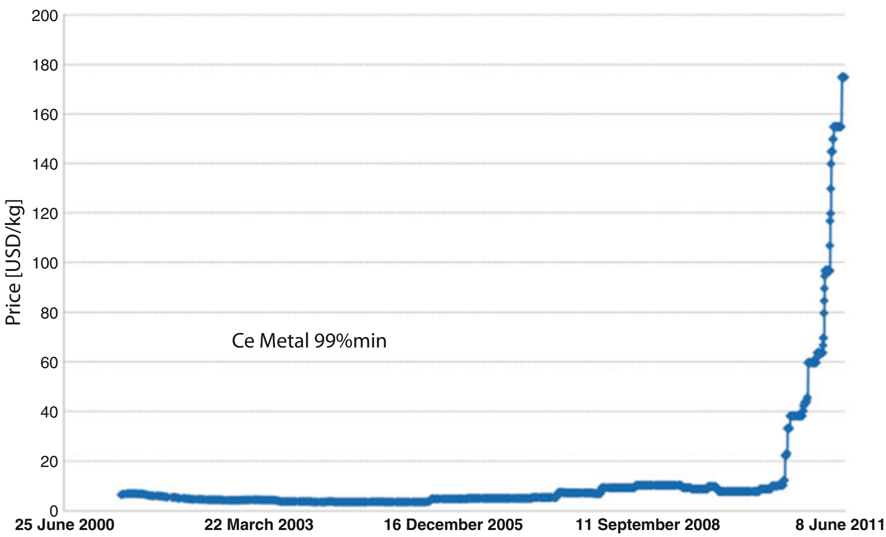

Fig. 14.2 Price development for Ce metal 99%

Table 14.5 Potential critical elements for superalloys

EmTech	Potential critical raw materials
Superalloys	Ni, Co, Cr, W, Mo, Ta, Nb, Ti, Al

performance. Bowman (2000) states that Fe, Ni, Co and Cr and to a lesser degree W, Mo, Ta, Nb, Ti and Al are used for superalloys (Bowman 2000) (Table 14.5).

2.3 Life

Under this paragraph we understand some basic needs like medical care, drinking water availability or temperature control in buildings. This list is not all inclusive, but it shall show some often neglected relationships. Health today is of great importance to principally the entire global population. It shall not be discussed that only a fraction of them savour the privilege to have a solid medical care. Nevertheless pharmaceuticals and drugs increasingly use rare metals as ingredients, like, for example, platinum for the treatment of several kinds of cancer. Today about 7 t equalling approx. 3% of the annual platinum production is used for drugs. Thorenz and Reller state that the medical standards improve worldwide, and thus, a further increase in demand has to be expected (Thorenz and Reller 2011). There is also the need for very corrosion-resistant metals in desalination installations, in water purification and also for heating and cooling systems or air conditioners. One example shall be explained a little bit further: magnetic refrigeration. New technologies see an option for permanent magnet-based refrigerators in order to substitute environmental critical CFCs (chlorofluorocarbon). This seems to be a wise substitution, but it gets in competition with other permanent-based applications like electromotors or some types of wind turbines as described later in this text.

2.4 Energy

Renewable energies are of predominant importance at present due to mainly two reasons: first, the global need for the reduction of CO_2 emissions and, second, the expected increase of demand, especially from developing countries like China and India with an unprecedented economic and population growth that eventually will lead to an increased energy consumption.

In 2008, the global share of renewable energies was 7% and is predicted to increase to 14% in 2035 (International Energy Agency 2010). One reason is the global effort to reduce greenhouse gas emissions; the other is to abstain from an energy sector. After the tsunami catastrophe in Japan early 2011 with the subsequent nuclear accident at Fukushima, Germany decided to drop the entire nuclear energy production by approximately 2021. That in turn means that renewable energies will have to bring a considerable bigger share on the energy production. As neither solar energy nor wind power are capable to supply the base load and biomass, geothermal and hydro cannot provide enough energy alone on a global meso- to macro-level, a multitude of energy systems are necessary within a network to level off any deficiencies and provide in the end a stable energy supply, both for base load and also for peak loads. For hydro and geothermal energy production, special steels are required. The installation of biomass energy production facilities is of minor criticality, whereas the fertilizers needed for a quantitative sufficient harvest get in a competitive use to the global food production. This issue is of humanitarian and ethical importance. In the solar energy arena, there are several technologies available; however, their efficiencies vary considerable. Thin-film panels based on amorphous silicon achieve between 5% energy conversion efficiency, copper-indium-selenide (CIS) and copper-indium-gallium-diselenide (CIGS) panels vary from 10 to 12%, cadmium-telluride (CdTe) panels achieve about 10–16%, and gallium arsenide (GaAs) panels up to 40% for end-user products (Fölsch 2009; BStMWIVT 2010). For all of these technologies, research is underway to increase efficiency. Compared to efficiency levels of about 90% for hydro energy, this research indeed seems necessary. This also gets momentum when considering the fossil primary energy consumption of the different technologies. Whereas PV requires about 3,400 GJ/GWh, geothermal only requires about 350 GJ/GWh (BMU 2007). A bit more emphasis shall be laid upon wind energy. Technically two types of wind turbines both with horizontally mounted axis dominate the market: gearbox and generator systems and direct drive systems that do not require a gearbox. By this technology, fewer mechanical parts are required and thus failure rate decreases. So in practical terms, these turbines require less maintenance (cost) and are suited for offshore

Table 14.6 Potential critical elements for energy technologies

EmTech	Potential critical raw materials
Solar	Cd, Te, Ga, As, Si, Cu, In, Au, Ga, Se
Wind	Steels, Nd, Pr, Dy, Tb
Hydro, geothermal	Stainless steels
Biomass	Stainless steels, fertilizers (P, K)

installations. The classic gearbox-type turbines require obviously the metals as for steel for the gearboxes and generators and not to forget the steel needed for the mast. Now the direct drive systems are based on strong magnets that transfer the mechanical energy further onto electrical energy. These magnets can be built either with copper-based magnets or with strong rare earth-based permanent magnets. Especially neodymium and praseodymium but also to some extent dysprosium and terbium are used. Basically the entire production of rare earth elements is provided by China. With severe environmental problems and an increasing domestic demand, China has set up export tariffs and export restrictions on the rare earths (Chinese Ministry of Commerce 2010). Therefore, a potential shortage could prevent these PM-based direct drive systems to be built. However, in 2010 the global share of these direct drive systems was 17.6%, equalling about 35 GW of installed capacity (2008: 14%) according to BTM (BTM Consult 2011). And not all of these direct drive systems are rare earth magnet based. So it has to be considered a myth that with the supply risk for rare earth elements no more wind turbines can be established. This does of course not say that PM-based direct drive systems are even more efficient than the 'classic' types (Table 14.6).

2.5 Information and Communication Technology (ICT)

ICT consists of all technical developments that handle information and aid in communications. It is an industry which is mainly based on semiconducting materials with a high diversity of used materials. For example, more than 60 elements are fabricated in modern mobile phones (Donner 2011). The fast ongoing technical development in this industry sector leads to a dynamic usage of different materials in quantity and quality. New generations of smartphones could contain GaAs or GaN based transmitter amplifier and the U.S. Geological Survey is estimating that the gallium demand could raise by a factor of four (U.S. Geological Survey 2011a). Gallium is a rare semiconducting metal with an in-transparent supply situation but also an essential metal for thin-film solar cells, light-emitting diodes (LED) or integrated circuits. A possible substitute for gallium is germanium. But the critical situation remains the same, as both metals have an uncertain supply situation and germanium is also a high-performance raw material for integrated circuits, glass fibre cable and many more ICT applications.

In liquid crystal displays, indium-tin-oxide (ITO) is used for polarization as it acts as a conductive and transparent layer. The concerns about the availability of indium and the high price level of the raw material pushed the substitution possibilities ahead. Today it is foreseeable that indium can and will partially be substituted by technologies like flour tin oxide (FTO) (Ziemann and Schebek 2010).

Radio-frequency identification (RFID) is a cross-sectional technology which is used in almost any section of an economy where logistics, transport and identification processes are involved. They do have an identification and information function for supply chain management processes with an enormous market potential if the price of the tags can be reduced (Angerer et al. 2009). For the antenna material, silver is the material of choice because of its good electric conductivity. With a dynamic demand growth for RFID tags, this could lead to a future important end-use sector for silver. Together with a further potential growth rate in some types of photovoltaic modules, this could lead to a high competitive market situation.

In general the ICT industry is highly dynamic, and the selected technology and raw materials do only represent a snapshot of the current situation. The introduction of long-term decisions like recycling or substitution to reduce potential material risks is therefore very difficult to implement. It is obvious that the industry is dependent on many polyfunctional materials with an unsecure supply situation, and potential risks have to be evaluated and handled in an economic way.

2.6 Energy Storage

In general there are four big drivers for the current and future demand of energy storage technologies. These drivers are electrical grid stabilization, energy island application, 4C market and traction batteries for electric vehicles.

A stable electrical grid is paramount and can only be achieved by a balance of supply and demand of electric energy. With unpredictable fluctuating energy sources like solar or wind energy, this balance cannot be ensured. The solutions for this problem are primarily based on different types of energy storage technologies and a smart integration of the consumer, the producer and the energy storage itself, also called ‘smart grid’. The different types of energy storage technologies can be basically differentiated between short- and long-term storage solutions.

Generally *short-term energy storages* compensate short energy variability, and therefore, they are essential for the power quality of the grid. Typical technologies are flywheels, double-layer capacitor and superconducting magnetic energy storage (SMES). Moreover, some battery technologies based on lithium, nickel or lead are partly suitable dependent on their specific technical characteristics (VDE 2009). Regarding the raw material demand of these technologies, quite a few critical raw materials can be involved to ensure the desired and required power stability or quality (Table 14.7).

Long-term energy storage has the function of a load shift and therefore acts as an integral part of the energy management of supply and demand. Today the most

Table 14.7 Potential critical elements for short-term energy storage technologies

EmTech	Potential critical raw materials
Double-layer capacitors (DSKr)	Ba, Bi, Ta, Ru, Co
Flywheel	Steels
Superconducting magnetic energy storage	Y, Ba, Sr, Bi, Nb, Ga
Accumulators (Li/Ni/Pb systems)	Li, Co, Mn, Cd, La, Ce, Pb

Table 14.8 Potential critical elements for long-term energy storage technologies

EmTech	Potential critical raw materials
Hydro pump storage	Steels
Air energy storage	Steels
Hydrogen	Steels, Zr, Pt
Redox flow batteries	Va, Br, Zn, Pb, Ce
High-temperature batteries	None

efficient way for long-term energy storage is hydro pump storage systems providing 75–80% efficiency (VDE 2009). But the penetration of these systems as well as compressed air energy storage (CAES/A-CAES) and to some extend hydrogen storage is dependent on specific geographical and geological conditions. Further possibilities of large-scale energy storage with no obvious natural limitations are redox flow batteries and high-temperature batteries. Redox flow batteries, for example, can be most efficiently realized with vanadium, which is mainly driven by its chemical property having four oxidation states. The Boston Consulting Group is expecting a cumulative market potential in 2030 for vanadium redox batteries (VRB) of about 124 GWh (Pieper and Rubel 2011). This would end up in a demand for vanadium of about 1.2 Mio tons for the next 20 years (Hykawy 2009). The worldwide production of vanadium is currently around 56,000 tons (US Geological Survey 2010). Considering that vanadium will remain an essential tuning metal in the steel industry, these numbers are indicating a potential new competitive functionality in the future. A possible resource strategy for vanadium is of course recycling but also a substitution with high-temperature batteries like sodium-sulphur.

Not to forget, all types of energy storage are not serving grid stabilization unless they are connected and controlled by an energy grid system. This system is often called *smart grid*. The transmission of electric energy is basically dependent on electric conductive raw materials like copper and aluminium, which in general are abundant metals with a high recycling potential. But critical raw materials can be found in the communication system for a smart grid where high-performance semiconducting materials like gallium or germanium are needed.

Energy island applications are storage solutions used in locations with no connections to a bigger electrical grid. This is often the case in developing regions of Africa or Asia, where a grid extension is simply uneconomic. Today mainly diesel aggregates are providing the energy supply for these areas. But electric energy storage technologies are required if the area is using renewable energy sources like PV or wind turbines. Basically all types of accumulators, redox flow batteries and

Table 14.9 Potential critical elements for energy storage technologies (4C market)

EmTech	Potential critical raw materials
Li-ion batteries	Li, Co, Mn
NiMH batteries	La, Ce, Sn
Capacitors	Nd, Sn, Ru, Bi, Ta

high-temperature batteries, are applicable, and the raw material dependency is similar to the long-term energy storage shown in Table 14.8.

The 4C market (*c*amera, *c*omputer, *c*ellular phone, *c*ordless tools) is today the biggest end-use sector for accumulators like Li-Ion batteries, nickel-metal hydride (NiMH) and NiCd batteries. The dominating technology today with 90% market share in portable applications is Li-Ion mainly because of the better energy density (Hannig 2009). Today these batteries are principally dependent on lithium, cobalt as a cathode material (LiCoO) and on a carbon-based anode material. To push the energy capacity even higher, the cathode material is expected to be substituted by other compositions where cobalt is partly replaced by manganese (Mn) and Ni (Whittingham 2004). Moreover, recent developments in cathode material research lead to lithium-phosphor materials like LiFePO, which just recently have entered the market.

Therefore, the criticality of cobalt in this end-use sector could be reduced in the near future. The criticality of cobalt is coming from the fact that over half of the world production is dependent from the Democratic Republic of the Congo. There, the production is estimated to occur under unpredictable environmental and social conditions (U.S. Geological Survey 2011b). Therefore, the availability as well as the compliance of social responsibility requirements has to be critically questioned.

Besides the electric power supply for many electronics like mobile phones, also the performance depends on short-term energy storage. Different capacitor technologies have been developed to satisfy the market specifications. Especially tantalum-based capacitors still remain a preferred option for high-performance application which needs high-stability characteristics (Jayalakshmi 2008). More than 10% of the tantalum production is presently coming from Rwanda, and similar concerns are given as it was the case for the Democratic Republic of the Congo (Table 14.9).

Further potentially growing end uses of energy storage technologies are traction batteries for electric vehicles. Next to the capacitors for short-term energy storage, there are mainly electrochemical storage systems in place for the automotive sector. High-temperature batteries (NaNiCl), Li-Ion, NiMH, NiCd, lead acid batteries or hydrogen storage systems are possible storage solutions. As Li-Ion technology is again the best available option at present, due to the specific energy density and cycle stability, a growing trend for Li-Ion batteries is expected to make the dream of the electric car come true. Lithium therefore will experience enormous growth rates. With an estimate of 100 million light vehicles to be produced annually, by 2020, 3% are expected to be full electric cars, 2% plug-in hybrids and 15% full hybrids. This sums up to a lithium demand expected to be 60,000 tons per year (Achzet 2010). This would be more than twice the production volume of the year 2010.

2.7 Mobility

Mobility can be considered as a basic human need, and it shows as one of the biggest energy end-use sectors. To meet the demand of the society in a sustainable way, efficient transportation systems have to be in place. The main material demand for this development, either for individual or public transport, is lightweight structural materials like aluminium, magnesium or titanium alloys and carbon fibre (CFK) materials (Apelian 2009). Generally the same kind of criticality is given as it has been the case for construction materials. Moreover, these strategic materials can be economically handled in a closed-loop supply chain. For example, the recycling of aluminium to produce quality secondary metal requires only about 5% of the energy required to produce primary metal, and huge tonnages will become progressively available (Harmer 2009). To be able to access these secondary material potentials, alloy specification and processes have to be adapted to the use of secondary materials.

3 Summary

Rare metals, as fuzzy as this term may be, fulfil very specific physical and chemical tasks, which are usually not or only partially substitutable. And if so, the substitutes are also very often rare metals themselves. Now the problem arises not so much when considering one technology like a wind turbine alone but when looking along the production diversity of a metal. It is obvious that a lot of competitive applications exist today, and for most of them an increasing demand is expected. Good examples are the rare earth metals neodymium and dysprosium. They are needed for electromotors (about 200–500 g/car) and for direct drive wind turbines (about 200 kg/MW of installed power) and for magnetic refrigerators, as well as for several small electromotors in the computer and military industries. Now the question will be, will there be enough supply, and if not, how shall the problem be dealt with? Instead of a wind turbine with 5 MW of power (about 1,000 kg of neodymium needed) roundabout, 2,000 electrocars could be built. So the topic has been solved considering not only material requirements but also politics, economics, environmental issues and also ethical perspectives.

A solution might come into sight when talking about functionalities rather than single technologies. That means that to remain with the example given, the requirement given is renewable energy. This could be provided by the use of conventional, copper-based or rare earth-based wind turbines. Of course, if a copper-based turbine shall be chosen, it has to be evaluated how much efficiency loss is expected in comparison to rare earth-based ones. So it requires an iterative cycle that has to be answered on several different technical, economical, ecological and socioeconomic levels. And a solution may become obsolete very fast, as soon as one prerequisite is changed. For example when a strong non-rare earth permanent magnet should be developed, or if the supply of a raw material should rise suddenly due to new mining techniques or when new processing technologies allow the handling of lower mineral grades than ever before, then this will hav a dramatic impact on any remedy action underway.

Rare metals provide the functionality of basically all emerging technologies within a variety of constraints: economical, ecological, technical, socioeconomical, geopolitical and maybe humanitarian. The problem does not arise within one single technology but rather in the competitive application of a single element of material. Thus, shortage and supply risks are given. Solutions show up of course in the classic re-phases (reuse, remanufacture and recycle) and in substitutions. Another approach however is the consideration of functionalities rather than single technologies. Thinking in functionalities could prove better solutions and the early avoidance of shortfalls by using diversities and alternative technologies that provide the same/required functionality.

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Chapter 15
Recycling of Precious and Special Metals

Christian Hagelüken

1 Recycling Motivation for 'Technology Metals'

Special and precious metals are of specific importance for clean technologies and other high-tech equipment. Important applications are information and communication technology (ICT), consumer electronics, as well as materials used in sustainable energy production such as solar cells, wind turbines, fuel cells, and batteries for hybrid cars. They are crucial for more efficient energy production (in steam turbines), for lower environmental impact of transport (jet engines, car catalysts, particulate filters, sensors, control electronics), for improved process efficiency (catalysts, heat exchangers), and in medical and pharmaceutical applications. For example, electronic products can contain up to 60 different elements and in their entity are major demand drivers for precious and special metals: Just the annual sales of mobile phones and computers account, for example, for about 3% of the world mine production of gold and silver, 15% of palladium, and over 20% of cobalt (Hagelüken and Meskers 2008). Driving forces for the booming use of these 'technology metals'[1] are their extraordinary and sometimes exclusive properties, which make many of these metals essential components in a broad range of applications. Building a more sustainable society with the help of technology hence depends to a large extent on sufficient access to these metals, as pointed out in a recent EU report on 'critical metals' (EU Commission 2010).

The use of technology metals has accelerated significantly over the past 30 years, and in many cases the booming demand especially from consumer mass applications

[1] The term technology metals is used in this chapter as a synonym for the precious metals (Au, Ag, and the PGMs Pt, Pd, Rh, Ru, Ir) plus the special/specialty metals (among others In, Ga, Ge, rare earth elements, Sb, Se, Si, Te).

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drove up metal prices significantly (e.g. spread of autocatalysts boosted demand and prices for platinum and palladium; LCD applications drove indium). New technological developments are expected to push their demand further. Hence, efficient recycling of technology metals will gain an increasing importance and will be a future necessity to secure metal supply. Even if for most metals an absolute depletion of geological resources is not likely to be expected in the foreseeable future, a significant secondary metal supply contribution is crucial to overcome temporary and structural resource scarcities, as explained hereafter.

Temporary scarcity, that is, the supply of a metal is for a certain period not able to meet the demand, is a phenomenon which has been already widely experienced. Mine supply can lag behind due to strong demand growth (new technological developments, growth in existing applications, speculative buying) or by disruptions in the supply chain (trade distortions, political developments, armed conflicts, natural disasters, etc.). Temporary scarcities are a main reason for the sometimes extreme price volatility in (precious) metal markets. This risk increases with high regional or company concentrations of mine supply. Often, different factors come together and then accelerate the development. Emerging future technologies can trigger further temporary supply constraints: Thin film photovoltaics would boost the demand for tellurium, indium, selenium, and gallium; mass applications of electric vehicles will require large amounts of lithium, cobalt, and some rare earth elements; and fuel cell cars would need significantly more platinum than is used today in a catalytic converter. Developing and expanding mining and smelting capacities is highly capital intensive and risky and it takes many years to materialise. Hence, temporary scarcities are likely to happen more often in the future, and comprehensive recycling is needed to mitigate such effects and counteract primary supply shortages.

The *structural scarcity* is most severe for many technology metals, which are often not mined on their own but occur only as by-products from major or host metals. Indium and germanium, for example, are mainly by-products from zinc mining, gallium from aluminium, and selenium and tellurium from copper (and lead). The platinum group metals (PGMs) occur as by-products from nickel and copper mines and as coupled products in own mines. Since the by-product ('minor metal') is only a very small fraction of the host ('major') metal, their supply could be at risk if the volume mined does not meet a surge in market demand. For example, it would not be economic to raise zinc production just to meet an increased germanium demand. Therefore, metals normally produced as by-products or coupled products have highly complex demand/supply and price patterns; their supply is to a large extent price inelastic. End-of-life (EoL) products contain again various metal combinations, but these often differ significantly from natural deposits. A by-product in mining can turn into a 'host metal' in recycling. Hence, efficient recycling can provide additional supply of crucial by-product elements independent from the described complexities of their mine supply.

Moreover, many technology metals are an important ingredient for multiple emerging technologies, so a competition between applications becomes likely, and increasing demand from various segments will intensify the pressure on supply. Substitution is not likely to become the solution for many of these metals either since the required functional properties can often be met only by metals from the same metal family. These consequences of the by-product character of many technology metals are often not considered sufficiently in the discussion about resource availability.

Independent of whether or not supply constraints are likely, the impact of mining of lower grade ores and from more challenging locations must not be overlooked. It will inevitably lead to increasing costs, energy demand, and raising emissions, it will impact the biosphere (if mining in rain forests, arctic regions, oceans), and it can increase the dependence on certain regions. This can imply significant constraints on emerging technologies, unless effective life cycle management enables the increasing use of recycled (secondary) metals in the forthcoming years (Hagelüken and Meskers 2010).

2 Recycling Basics

Metals are not consumed; they are only transferred from one manifestation into another, moving in and between the lithosphere and the technosphere. Thus, the latter becomes our future 'renewable' resource in society. Thoroughly extracting 'urban mines' is the only sustainable solution to overcome long-term supply disruptions. For example, a typical primary gold mine will yield around 5 g/tonne of gold. In electronic scrap, this rises to 200–250 g/t of computer circuit boards and even to 300–350 g/t for mobile phone handsets, making it a much more attractive source. A catalytic converter contains some 2,000 g/t of PGMs in the ceramic brick, compared with average PGM concentrations in the mines of below 10 g/t. If we factor in the high CO_2 impact of primary production due to the low ore concentration, difficult mining conditions, and other factors, the recycling of scrap becomes even more attractive from a sustainability standpoint. Recycling of scrap metals usually has a much lower CO_2 impact if state-of-the-art technologies are used. Clearly, scrap cannot replace all primary production when total demand is considered; mining and recycling are complementary systems in the drive for a more sustainable use of metals.

Metal combinations in products often differ from those in primary deposits, which results in new technological challenges for their efficient recovery. Very low concentration of technology metals in certain products or dissipation during product use sets economic and technical limits in many cases, and technical challenges exist especially for complex products such as vehicles and computers.

Recycling technologies for precious metals and base metals like copper or lead have been developed over centuries and in most cases today are capable in achieving high recovery yields when it comes to the final metallurgical recovery step. Recycling of special metals is usually connected to base and precious metal metallurgy but still offers potential for optimisation in many cases. However, recycling of consumer products and some industrial products is much more than metallurgy and requires a complete chain, starting with collection, sorting, and dismantling/preprocessing to separate components containing valuable metals or to upgrade relevant fractions for subsequent metallurgical end-processing (Fig. 15.1). In this

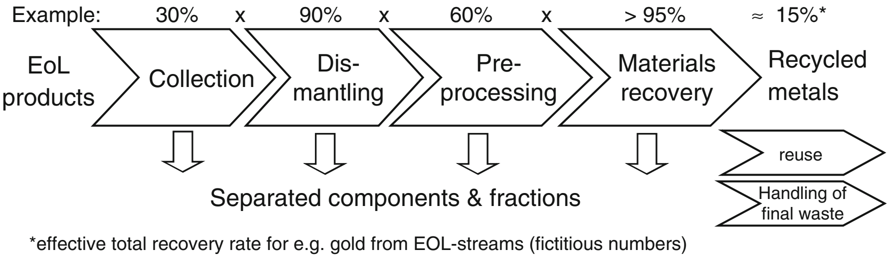

Fig. 15.1 The recycling process chain for consumer products – the actual recovery rate is determined by the weakest link (EoL = End-of-Life)

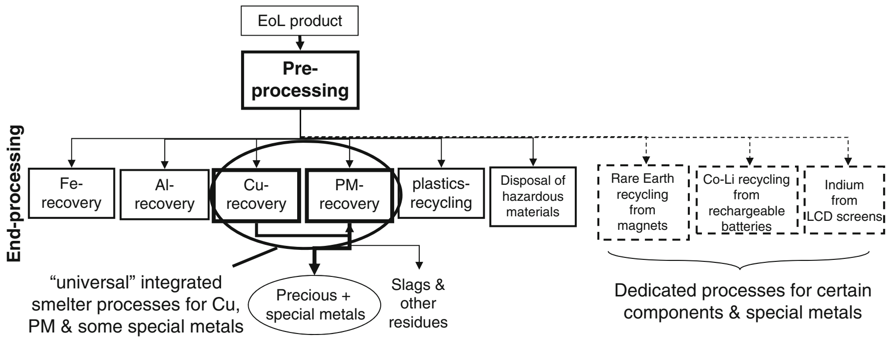

Fig. 15.2 Pre-processing is used to channel relevant material fractions into the most appropriate final recovery processes

final step, technology metals are extracted by pyro- and/or hydrometallurgical processes and purified to pure metals which are delivered back to the market for a new product life. Thus, the real physical metal recycling takes place at the very end of the chain, but the preceding steps are decisive to direct effectively and as comprehensively as possible the various metal-containing fractions into the most appropriate final recovery process (Fig. 15.2).

Metals that during their path through the recycling chain are dissipated – for example, into dust fractions – or that are diverted by unintended co-separation into the wrong end-processes, such as precious metals directed into steel plants or aluminium smelters, are lost (Meskers et al. 2009b). The total efficiency of a recycling chain is the product of the individual efficiencies of each subprocess; hence, the weakest step in the recycling chain has the biggest impact on the overall recovery rate. In practice, today the biggest precious and special metal losses do indeed happen due to insufficient collection or other downstream problems prior to end-processing, and although state-of-the-art metallurgical processes usually achieve over 95% precious metal recovery rates for many consumer products, the total chain efficiency is mostly below 50% only. For special metals, the situation usually is even worse.

The probability that a product/material is efficiently recycled largely depends on:

- The intrinsic metal value of the material, in dependence of its absolute metal content and the relevant metal prices: This determines the economical attractiveness of recycling and sets a benchmark for recycling technology and overall recycling costs. Materials containing precious metals often make recycling rather attractive.
- The material composition: This goes beyond the chemical composition but also includes the physical characteristics such as shape, size, and type of connection between materials or components. It impacts the technical recovery processes, that is, which processes should be used in sorting, pretreatment, and refining. The product/material composition usually has a significant impact on recovery costs as well as on the technical recovery yields that can be achieved.
- The application segment of a product and the way how it is used: The former refers to the type of use sectors in consumer or business to business markets, and the latter refers to new or reuse products, user behaviour, risk of dissipation, product mobility, country of usage, etc. This impacts the probability for products and metals to enter into an appropriate recycling channel at their end of life (EoL).

The interactions of these aspects with economic feasibility and social desirability of recycling and the supporting role legislation can play will be discussed later on.

Effective recycling could, in theory, lead to an infinite metal cycle without a decrease in quality, since for most metals in principle no ‘downcycling’ occurs (other than for paper or plastics). In practice, however, metals are lost from the life cycle because, for various reasons, they cease to be accessible for recovery. The role of recycling is to minimise these metal losses, which can take place on all levels of a metal/product life cycle (Fig. 15.3).

Primary metal production is usually not included when recycling is discussed. Nevertheless, the improved treatment of tailings, slag, or other side streams from mining, smelting, and refining can contribute significantly to resource efficiency and supply of technology metals. Improved efficiency in the primary production combined with the reprocessing of historic primary stocks will provide a large and rather easy accessible additional metal source for most by-product metals like indium, germanium, molybdenum, rhenium, or gallium. For precious metals like the PGMs, these inefficiencies in the primary chain have been largely overcome already due to their higher economic value.

In manufacturing, the challenges to recycle production scrap usually increase when moving further downstream in the production process.[2] For some ‘high-tech’ manufacturing technologies – like sputtering – scrap arisings are significant (>50%!) and offer a huge recycling potential for many special metals. In the case of indium, germanium, and ruthenium, this has been increasingly applied over the last years.

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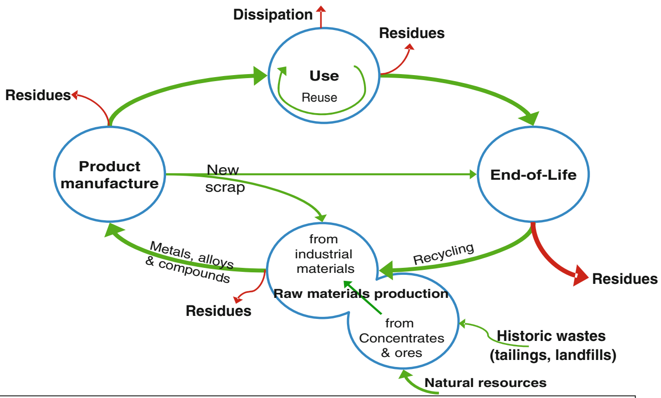
[2] For example, indium recycling gets increasingly more difficult for target manufacturing → spent ITO target → scrapings from the sputtering chamber → broken or out-of-spec LCD glass → entire out-of-spec or obsolete LCD monitor.



Principle improvement measures within the lifecycle:

1 Raw materials production
- Frame conditions & mining technologies to maximise extraction yields.
- Metals yields in ore processing, smelting and refining.
- Recycling of (historic) tailings, slags, flue dusts, sludges and other residues.

2 Manufacturing & product sales
- Product design & built in recyclability
- Recycling of production residues throughout the manufacturing chain.
- business models / recycling incentives for EoL products.

3 Product use phase
- Minimise dissipation
- extent product lifetime
- product/component reuse.

4 End-of-life
- Comprehensive product collection & feed into efficient recycling channels.
- Optimization & innovation in logistics and pre-processing technologies.
- Yields & range of recovered metals in smelting & refining.
- Metals recovery from residues (slags, effluents, bottom ashes, dusts etc.)
- Extraction of metals from landfills/stockpiles

Fig. 15.3 Lifecycle of products/metals with principal points of intervention to improve resource efficiency

Metal losses occurring during the product use phase are hardly recyclable due to their mostly dissipative nature.[3]

The recycling of EoL products will be the key in achieving a sustainable use of metals. Expressions like 'urban mining' or 'mine above ground' refer to the resource potential in our 'wastes'. This has also been recognised by governmental bodies such as the European Commission, which strives to make Europe a 'recycling society' and seeks to prevent the creation of waste and to use waste as resources. Supportive legislative measures, like the Directive on End-of-Life Vehicles (ELVs) from September 2000 and the Directive on Waste Electrical and Electronic Equipment (WEEE) from January 2003, underline this approach. End 2008, the EU Commission launched the Raw Materials Initiative, focusing on an enhanced access to important metals for the European industry (EU COM 2008).

Does this mean that everything now is on the right track? Could the closed loop for most metals be expected to become a reality soon? How well does this all fit to the recycling of technology metals?

[3] One example is PGM loss from car catalysts: In contrast to earlier conditions, today's autocatalysts under European or American driving conditions emit hardly any PGMs during the use phase. However, under typical 'developing country' driving conditions (e.g. bad roads, low car maintenance, misfires, bad petrol quality), a catalyst is likely to be mechanically destroyed, and with broken ceramic catalyst, PGMs are blown out from the exhaust and dissipated along the roadside.

3 Impacts on Recycling Efficiency

The success by which metals will finally be recovered from EoL products depends on a set of main impact parameters as well as on the set-up of the recycling chain as a whole. Depending on the products and materials involved, various logistical and technology combinations are required, and many different stakeholders are involved. Success factors are interface optimisation between the single recycling steps, specialisation on specific materials, and utilisation of economies of scale. The key impact parameters comprise technology and economics, societal/legislative factors, and the life cycle structure of a product (Hagelüken 2007b).

3.1 Technical Impacts on Metal Recycling Rates

Technical capability to recover metals effectively from products needs to be evaluated under a systems perspective that considers the entire recycling chain. Technical conflicts of interest cannot be fully avoided, and for complex streams trade-offs exist, that is, some metals cannot be recovered. Setting the right priorities is important. Considerations in this context are:

- Complexity, that is, the variety of substances in a product: Cars and electronic devices are examples of highly complex products, each consisting of a large number of complex sub-assemblies and components. Many substances are used in numerous combinations, often closely interlinked, and comprise both valuable and hazardous substances. Precious and special metals are frequently key elements in such products or in one of their key components.
- Concentration and distribution of metals: The recovery of technology metals that occur on a parts-per-million (ppm) level (e.g. in circuit boards, catalysts, or LCD screens) is technically more challenging than the recovery of copper from a cable, aluminium from a wheel rim, or lead from a car battery, since the latter are highly concentrated in these components.
- Coupled recovery: Similar to coupled production in primary production, a limited number of valuable 'paying' metals provide the economic incentive for recycling, enabling the additional recovery of 'by-product' metals with subeconomic value or concentration. For printed circuit boards, for example, the drivers for recycling are gold, silver, palladium, and copper; however, various special metals can also be co-recovered if appropriate technologies are used.
- Product design and accessibility of components: A good 'design for recycling' eliminates the use of (hazardous) substances that hamper recycling processes (e.g. mercury in backlights of LCD monitors), avoids inappropriate closely interlinked substance combinations, and ensures the accessibility of critical components. The catalytic converter is an example of an easily accessible component. It can

be cut from the exhaust system prior to shredding and fed into the appropriate recycling chain. The opposite is the case for car electronics widely distributed over the vehicle and thus seldom removed prior to shredding. Consequently, most technology metals contained in car electronics are currently lost during the shredder process.

3.1.1 Metal Recovery: Smelting and Refining

Complex products require a well-organised and dedicated process chain (Fig. 15.1), involving different stakeholders. Especially for the efficient recovery of technology metals in low concentrations from complex components, high-tech metallurgical processes are required. For example, Umicore's integrated smelter-refinery in Antwerp recovers 14 different precious and special metals together with the major metals copper, lead, and nickel, which are used as metallurgical collector (Fig. 15.4). For precious metals from circuit boards or catalysts – in spite of their low concentration – yields of close to 100% are realised, while simultaneously tin, lead, copper, bismuth, antimony, indium, selenium, and others are reclaimed (Hagelüken 2006). In other, dedicated processes, the company recovers cobalt, nickel, and copper from rechargeable batteries (Meskers et al. 2009a), germanium from waver production scrap, and indium from indium tin oxide (ITO) sputtering targets. Research is ongoing to extend further the range of feed materials (e.g. into photovoltaic applications) and additionally recovered special metals (e.g. Ga, Li). For metals that already follow other metal streams or can be separated from the off gas or effluents, recovery might be achieved through affordable adjustments of the flow sheet and/or the development of dedicated after-treatment steps. On the contrary, for metals that oxidise easily and are dispersed as a low-grade slag constituent, economic recovery can become extremely difficult or even thermodynamically impossible.[4]

The combination of metals and toxic and organic substances with halogens in many EoL products requires special installations and considerable investments for off-gas and effluent management to secure environmentally sound operations (prevention of heavy, metal, dioxin and dust emissions, etc.). In practice many recovery plants, in particular in Asian transition countries, are not equipped with such installations. Electronic scrap is 'industrially' treated there in noncompliant smelters or leached with strong acids in hydrometallurgical plants with questionable effluent management; here the focus is primarily on recovery of (only) gold and copper. The largest part of electronic scrap is handled in the informal sector in thousands of 'backyard recycling' operations. This involves open-sky incineration to remove plastics, 'cooking' of circuit boards over a torch for de-soldering, cyanide

[4] Examples are tantalum or rare earth elements used in electronic applications. Present only in very low concentrations (e.g. in circuit boards), they dilute even more into the slag. Due to their dispersion/dilution, the additional energy needed to recover and recycle the metal can exceed the energy requirement for virgin extraction.

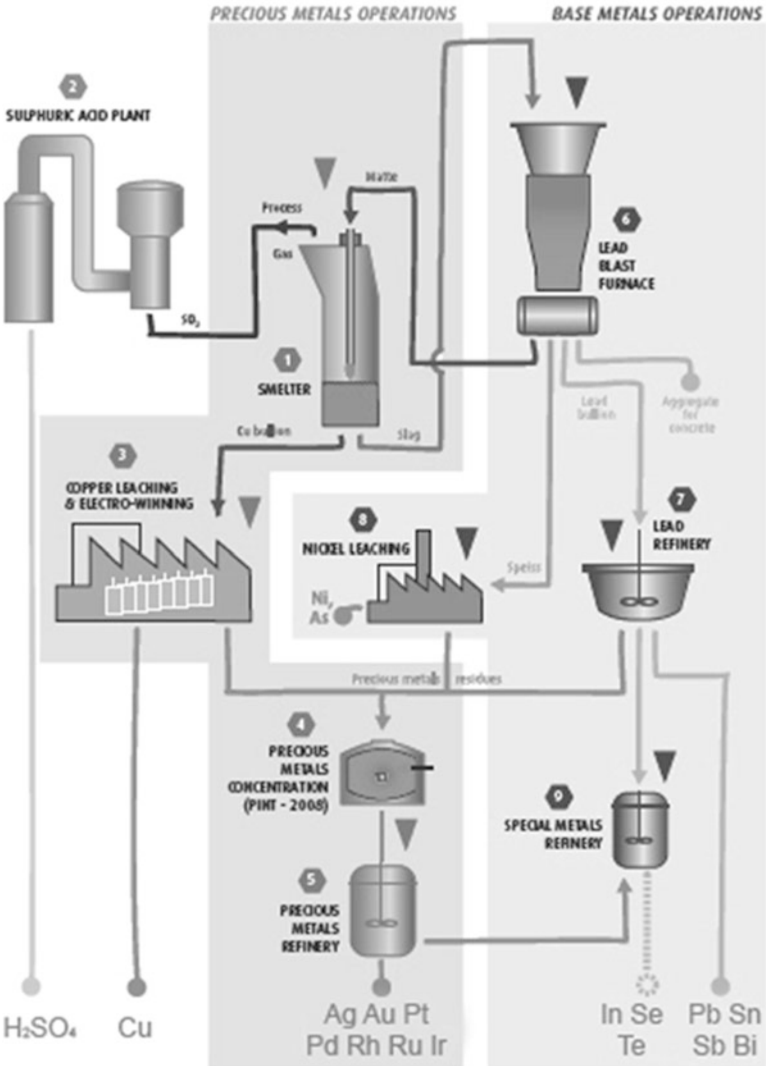


Fig. 15. 4 Simplified flowsheet of Umicore's integrated smelter-refinery process to recover precious and special metals (Hagelüken 2006)

leaching, and mercury amalgamation (Puckett et al. 2002, 2005; Kuper and Hojsik 2008; Sepúlveda et al. 2010). Besides the disastrous effects on health and environment, the efficiency of these processes is very low. An investigation in Bangalore, India, revealed that only 25% of the gold contained in circuit boards is recovered, compared to over 95% at integrated smelters (Rochat et al. 2007). A recent UNEP report gives a comprehensive overview on the situation in developing countries (Schluep et al. 2009).

A challenge is the recovery of metal combinations in products that do not occur in nature. Most metallurgical recovery processes have been developed over centuries around the combinations of metal families and gangue minerals, as shown in the ‘web of metals’ (see Reuter et al. 2005). Some have been adjusted to secondary materials, although the same laws of chemistry and thermodynamics still apply. The main metallurgical routes are copper/lead/nickel metallurgy (including precious and many special metals), aluminium, zinc, and ferrous/steel (see Fig. 15.2). Most primary concentrates are fitting ‘automatically’ into one of these respective recovery routes. This is not the case for EoL products, which consist of (completely) different man-made combinations. Once precious metals enter a steel plant or aluminium smelter, it is almost impossible to recover them. In most cases, however, metallurgical technology itself is not the barrier to achieve good recycling rates. If the economic incentive is there, also for new and difficult materials, the appropriate technological processes can be developed (e.g. mobile phones, lithium-ion batteries, gas to liquid catalysts, diesel particulate filters, or fuel cells).

3.1.2 Preprocessing

The goal of preprocessing is to generate appropriate output streams for the main smelting and refining processes (see above) by disintegration (‘shredding’) and sorting. It must be able to deal with a feed which changes over time and consists of many different models and types of equipment (Reuter et al. 2005). While this largely works for major metals, it is much more difficult to achieve for technology metals. Quantification of the losses during preprocessing for the different routes and the impact of material combinations (product design) is necessary to evaluate the efficiency of processes and improvement possibilities, mainly in the technical interface between metallurgy and (mechanical) preprocessing. The complexity of high-tech EoL devices leads to incomplete liberation of the materials, as these are strongly interlinked. For example, the precious metals in circuit boards occur with other metals in contacts, connectors, solders, hard disk drives, etc.; with ceramics in multilayer capacitors, integrated circuits (ICs), hybrid ceramics, etc.; and with plastics in circuit board tracks, interboard layers, ICs, etc. Small-size material connections, coatings, and alloys cannot be liberated during shredding. Hence, incomplete liberation and subsequent incorrect sorting result in losses of technology metals to side streams (including dust) from which they cannot be recovered during metallurgical treatment (Meskers et al. 2009b; Reuter et al. 2006).

An industrial test with WEEE indicated that the percentage of silver, gold, and palladium reporting to fractions from which they could be recovered (circuit board and copper fractions) was only 12, 26, and 26%, respectively (Chancerel et al. 2009). High-grade circuit boards and cell phones or MP3 players should thus be removed prior to mechanical preprocessing to prevent irrecoverable losses. These components/devices can be directly fed into a smelter-refinery process, recovering most of the metals with high efficiency (over 90%).

For low-grade WEEE, such as small domestic appliances or most audio/video equipment, the direct smelter route is usually not applicable, and some degree of mechanical preprocessing is required. Instead of intensely shredding the material, a coarse size reduction followed by manual or automated removal of circuit board fractions can be a valid alternative. Trained workers in this context are often able to remove more selectively certain complex target components than automated sorting technologies. Wherever affordable and trained manual labour is available, like in many developing and industrialising countries, manual dismantling, sorting, and removal of critical fractions, such as circuit boards or batteries, combined with state-of-the-art industrial metal recovery processes (which then are mostly located abroad) can be a valid alternative. Such 'best of two worlds' approaches for WEEE are currently being investigated in the framework of the StEP initiative[5] by the United Nations University. It needs to be noted, however, that the concept addresses the significantly rising volumes of domestic electronic scraps in developing countries. WEEE generated, for example, in Europe needs to be treated by the available efficient local systems. It must not be shipped to developing countries just to get access to cheap labour, as this would imply large volumes (whole devices) which cannot be properly monitored in the importing countries. Hence, currently the risk of misuse and final substandard treatment would be much too high. Nevertheless, in industrialised countries, the outsourcing of well-defined dismantling steps (e.g. for computer disk drives) to local social initiatives can contribute to improved overall recycling efficiencies. Looking at these examples shows that there is not one optimal recycling approach. Especially for the initial steps of the recycling chain, it needs to consider the specific local frame conditions.

Altogether, a holistic optimisation of product design, sorting method and depth, and destination of the various fractions produced can lead to a substantial increase in overall yields, especially for technology metals. Often, new developments in products lead to new challenges. An example is the middle- and upper-class car of today. This 'computer on wheels' contains numerous electronic components containing in total a lot of technology metals. However, the electronic parts are scattered throughout the vehicle, current shredder technology will not be able to recover these, and also cost-effective manual dismantling seems difficult.

3.1.3 Collection

Effective collection systems are a prerequisite for metal recovery, and the respective infrastructure must be adjusted to the local circumstances. Collected EoL products are sorted into several categories, which are (at least in the EU) determined by legislation at a country level. For logistic purposes, a reduction of the number of categories is often attempted; however, too much reduction results in a very heterogeneous mixture of high-grade and low-grade materials, which reduces the effectiveness of

[5] *S*olving *t*he *E*-Waste *P*roblem (www.step-initiative.org)

the preprocessing and recovery processes following collection. A balance must be struck between too many and too little categories, to maximise the overall recovery of technology metals along the recycling chain.

3.2 *Economic Impacts*

High prices for metals and resources offer, in principle, a solid basis for stimulating recycling efforts. The scrap value is determined by the intrinsic monetary value of its contained substances and the total costs that are needed to realise that value. Thus, value is determined by metal market prices as well as the variety and yields of recoverable substances. The costs comprise logistics, treatment in the subsequent steps of the recycling chain, and costs for environmentally sound disposal of unrecoverable fractions/substances. Complexity of a product and hazardous substances contained therein drive the costs, but 'traces' of expensive precious and special metals or base metals in higher concentrations push up the value.

To illustrate the incentive to recycle complex products/components, consider the following. In mid-2010, the net intrinsic metal value for an average mobile phone handset (without battery) was about 10,000 €/t; for a computer board, 5,000 €/t; and for a catalytic converter, 30–70 € per piece.[6] These values include costs at smelters in compliance with strict emission legislation. At high lead prices, commercial lots of car batteries are attractive to a lead smelter; the same applies at high cobalt prices for lithium-ion batteries treated in dedicated smelters to recover cobalt, nickel, and copper. Taking into account steel and copper prices, EoL vehicles can offer a good scrap value. The more efficient the entire recycling chain is set up, the more of an EoL product value can ultimately be realised.

Although only contained in small amounts per device, precious metals often constitute the biggest share of the intrinsic value. For example, precious metals in a mobile phone, a computer circuit board, or other high-grade devices, which account for less than 0.5% of the weight, contribute to over 80% of the value, followed by copper (10–20% of weight; 5–15% of value). Steel, aluminium, and plastics, which dominate the weight for these devices, make only a small contribution to the overall value. With few exceptions (e.g. Co in rechargeable batteries), the value share of most special metals on a unit level is still negligible, due to their low concentrations and (compared to precious metals) relatively low prices. Many recovery plants focus, therefore, only on copper and precious metals. This means that a large amount of special metals is lost that could technically be recovered. However, in state-of-the-art large-scale recovery plants, special metal recovery can generate additional revenue. This 'by-product recovery' is comparable to investments in by-product recovery for primary materials.

[6] Net value = recovered metals' value minus smelting and refining charges (not considering costs of collection, preprocessing, and shipment in the preceding recycling chain). Value can vary significantly depending on specific quality/type (especially for autocatalysts).

3.3 Societal and Legislative Impacts

It is evident that the awareness to recycle consumer goods is of the utmost importance. Legislation, public campaigns (e.g. from authorities, non-governmental organisations (NGOs), manufacturers), and an appropriate infrastructure for handing in old products are important prerequisites. Europe has progressed quite far in developing a general 'recycling mentality'. Although many people are used to trading or returning old goods to collection points for reuse, some items (e.g. mobile phones or 'high-price' electronics as computers) require incentives to mobilise them out of 'hibernation' or obsolescence. A consumer survey indicated that only 3% of the people return old mobile phones for reuse or recycling, whereas 44% stored them at home (Nokia 2008). The amount of EoL products continues to increase and is influenced, for example, by both the consumer behaviour related to product lifetime and the general consumption of materials. The product lifetime is determined by durability as well as functional, technical, and aesthetical obsolescence; these are, in turn, determined by the product design and social factors such as fashion of the day and lifestyle. It appears that for some first-time owners, the lifetime of a product becomes increasingly shorter, in particular for fashion- and technology-sensitive items like mobile phones, computers, and MP3 players.

Most people in Europe look for a proper solution when they are ready to discard their products. Nevertheless, a lot of goods handed in for recycling or reuse do not enter the appropriate channels. This is not due to missing awareness or legislation but rather to weaknesses in control and enforcement as well as in structural deficits. In many developing countries, in India and China, collection by the informal sector often works well and sometimes builds on a long tradition, due to the attraction of an even low economic value. The problems arise here when the collected and dismantled items are then locally processed for metal recovery by the informal sector or substandard 'industrial' processes.

3.3.1 Impact of Legislation on Technology

Legislation has limited impact on recycling technologies. Examples are:

- Mandatory removal of certain parts from EoL devices (catalysts, circuit boards, batteries). Legislation should, however, not prescribe how (e.g. manually) certain parts have to be removed, since this restricts possible (future) technological solution. Important is the result, that is, that the desired substances are directed in an identifiable way into the most appropriate treatment process or output stream.
- Classification of WEEE into certain qualities for collection (sorting) is necessary in order to obtain optimised streams for further downstream processing.
- Defining technical and environmental treatment standards is vital for the recycling industry, because they help create a level playing field and promote innovation. The strict control and enforcement, that is, through certification, of these standards is crucial, especially with respect to recycling of European scrap in plants in developing and transition countries.

However, legislation can also negatively impact recycling results by setting wrong priorities which might lead to the use of less appropriate technologies: One example is the obligation to meet certain weight-based recycling rates, as it promotes the recycling of the main product constituents, which are not necessarily the most important ones from an economic and environmental perspective. Technology metals with low concentrations are not taken into account here at all. There are examples of technology developments, for example, for mechanical processing of mobile phones, aiming at increasing separation of plastics (high weight percentage) but hazarding the consequences of high losses in precious metals (see above). Although this might meet the legal recycling goal, it is counterproductive from a resource efficiency point of view.

3.3.2 Impact of Legislation on Recycling Economics: Recycling Drivers

Recycling is currently either driven by value, when the value of recovered substances is significantly higher than the cost of separating them out of a waste stream, or by societal concerns related to EHS (environment, human health, and human safety) and/or volume aspects of waste streams. Societal concerns are best addressed by legislation. Several Directives as for instance WEEE, Packaging, and ELV take this into account.

At mid-2010 prices, products such as mobile phones, computers, and cars have a positive net value if handled in professional recycling chains. Other products (e.g. TVs or monitors, most audio/video equipment, small household appliances) have a negative net value. However, if the true costs of landfill and environmental damage caused by non-recycling would be accounted for, then on a macroeconomic level their proper recycling could be viable as well. Legislation can, and does, provide ways to finance the recycling costs of these ‘negative goods’.

Thus far, legislation has focused on hazardous substances but not on technology metals contained in EoL products. However, significant gaps still remain for their efficient and continuous recovery from a number of waste streams. In spite of the strategic importance of critical metals, in many cases they cannot be economically recovered today based on intrinsic metal valorisation alone. Under a lacking visibility on future revenues, making rational long-term (>10 years) investment decisions for research and development into new more efficient processes and subsequently for installation of new plants and equipment is unlikely to take place either. These market mechanisms lead to fatal consequences regarding the EoL recycling rates and hamper the development of new pretreatment and recycling technologies. Without adequate financing, there is no sufficient motivation for society-driven non-value recycling to take place sustainably.

Waiting for the market to regulate itself by a further raise of special metal prices, which then 1 day would generate enough recycling incentives, is not a realistic approach. Due to a delayed reaction time of metal prices, too many secondary technology metal resources will, in the meantime, inevitably be lost. It follows that there is a need to ensure that recycling revenues are not limited to the intrinsic metal value if one wants to guarantee continued future access to these strategically important resources. From a national economy's point of view, measures (legislative) should be established that ensure that no value-driven recycling of critical technology metals is guaranteed even when volume and environmental drivers are not present.

3.4 Structural Impacts: The Product Life Cycle

In view of the discussion on economic, legislative, and technical factors, one could expect that car catalysts, mobile phones, computers, and cars are products that (at least in Europe) achieve a very high recycling rate because (a) efficient technologies and sufficient capacities to recycle these goods in an environmentally compliant way exist; (b) legislation, consumer awareness, and a collection/recycling infrastructure are widely in place; and (c) economic incentives for recycling are attractive.

However, for all these products, actual recycling rates are below 50%. The most eye-catching example in this context is the valuable car catalyst (Hagelüken 2007a). On a global level, only 50–60% of the PGMs are finally recovered. In Europe, this level is even below 40%, due to its large exports of EoL vehicles. This happens although (a) it is easy to identify and remove the catalyst from a scrap car at the dismantler (required by the ELV directive); (b) a large number of catalyst collectors are aggressively chasing catalytic converters at dismantlers, scrap yards, and workshops, paying high prices per piece; and (c) appropriate smelting and refining technologies are able to recover close to 100% of the PGMs contained in a catalyst. Something must go essentially wrong with additional factors playing a negative role during the life cycle.

4 The Significance of Life Cycle Structures

A comprehensive research project investigated the structural factors that play a role in the life cycle of PGMs in detail[7] (Hagelüken et al. 2005). Structural factors investigated were product lifetime, sequence of product ownership, sequence of locality of use, system boundaries/global flows, and structure of the recycling chain. Two distinctly different life cycle structures were identified: 'closed cycles' and 'open cycles', commonly referred to as direct (closed loop) and indirect (open loop) systems. The structural factors identified for PGMs can be extended to other metals in industrial and consumer products in general.

[7] Areas of investigation include all relevant application segments for PGMs: automotive catalysts, chemical and oil refining catalysts, glass manufacturing, dental applications, electronics, jewellery, electroplating, fuel cells, etc.

4.1 Closed Cycles for Industrial Processes

Closed loops prevail in industrial processes where metals are used to enable the manufacture of other goods or intermediates. Examples are PGM process catalysts (e.g. oil refining catalysts) or PGM equipment used in the glass industry. For PGM, the manufactured goods (e.g. petrol) do not typically contain PGM themselves. Instead, the metals are part of an industrial product owned by and located at the industrial facility and thus have a high economic value that facilitates recycling. Changes in ownership or location are well documented, and material flows are kept transparent. All stakeholders in the life cycle work closely together in a professional, industrial manner. As a result, closed-loop systems are inherently efficient, and more than 90% of the PGMs used in industrial processes are typically recovered. Key is that the industrial structure of such life cycles 'drives' old products into the best fit recycling processes, which is not the case for most consumer goods in 'open cycles' (see below).

A long product lifetime does not negatively affect the achieved recovery rate. Oil refining PGM catalysts with a lifetime over 10 years are still recycled. Thus, the attractive intrinsic PGM value combined with the frame conditions of an industrial cycle is the driver for success. Recycling of industrial products/production scrap without precious metals can be less economically attractive, but the other fundamental frame conditions remain similar. Old industrial infrastructure and machinery offer a significant future recycling potential for steel, copper, and many other metals. Whereas massive infrastructure is difficult to relocate, and thus is a good target for 'urban mining', it has been reported that second-hand machinery is also increasingly leaving Europe (Janischewski et al. 2003).

4.2 Open Cycles for Consumer Products

Open-loop systems (Fig. 15.5) are prevalent in the recycling of EoL consumer products, such as cars and electronics. Their complex structure and lack of supportive frame conditions evoke inefficient/failing metal recovery. As recycling rates for valuable PGM-containing catalysts are below 50%, it can be assumed that for most technology metals this situation is even worse. Many participants in the life cycle are not aware of the (economic) metal value in EoL consumer goods. Although the metal content (and value) per product is low, the huge product sales represent a significant metal resource and economic value in total.

Consumer products often change ownership during their life cycle, and with each change the connection between the manufacturer and owner becomes weaker. This is compounded by the fact that change of owner often means a change of location and that highly mobile consumer goods are spread all over the globe. Trading of old equipment and donations to charities have led to steady but non-transparent flows of

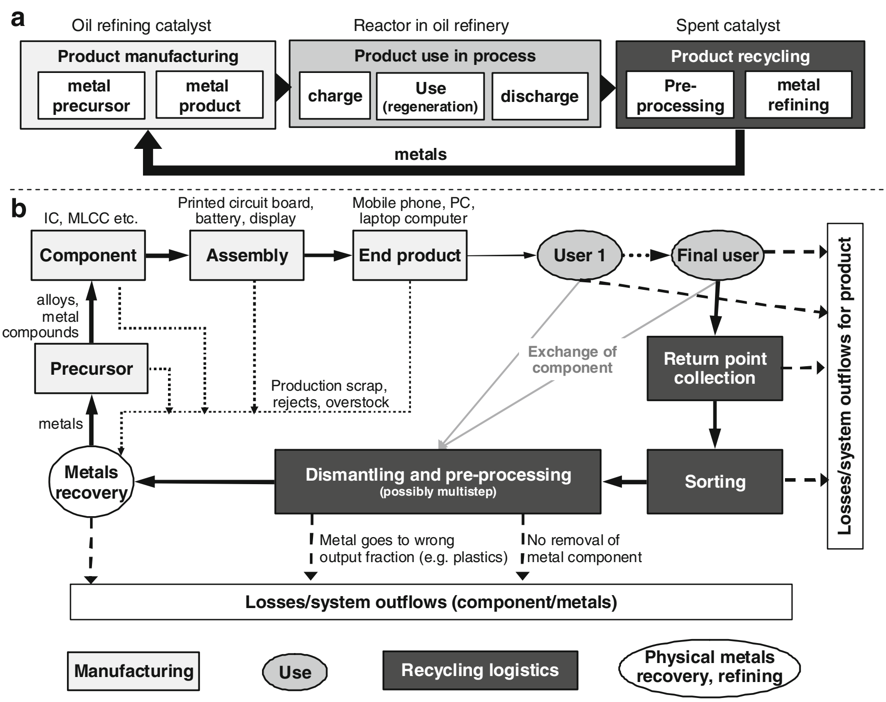


Fig. 15.5 (**a**) Closed loop systems for industrial applications (example process catalyst) versus (**b**) Open loop systems for consumer goods (example consumer electronics)

material to Eastern Europe, Africa, and Asia (Buchert et al. 2007).[8] A clear distinction between an EoL product for recycling and for reuse is dependent on location (i.e. waste in Europe = reuse in Africa). Traders take advantage of this by exporting for reuse, although a fair amount of these exports evade the Basel Convention waste export procedures. Thus, old products collected in good faith for recycling or reuse can escape, in a dubious way, only to resurface in primitive landfills or disastrous backyard 'recycling' operations in developing countries. The insufficient cooperation along the life cycle and recycling chain (although 'extended producer responsibility' has been implemented) combined with insufficient tracking of product and material streams along the entire chain explains why inefficient open cycles continue to exist.

[8] It is estimated that about 50% of used IT electronics leave Europe one way or another. For mobile phones, less than 5% of the theoretical recycling potential is currently being realised globally in a compliant way. For 2006, monitoring results for ELV in Germany showed that out of 3.2 million deregistered passenger cars, only 504,000 were recycled in Germany, while 2.06 million were exported as 'used cars'. A gap of 640,000 cars addresses mainly unregistered exports. A recycling rate of 86.2% was reported (Umweltbundesamt 2008), but this refers only to the 504,000 cars

5 Conclusions: Requirements to Improve Recycling

Recycling technology has made significant progress and further improvements extending the range and yield of metals are underway. Design for sustainability based on a close dialogue between manufacturers and recyclers can further support effective recycling as it starts already in the design and manufacturing phase and proceeds all along its lifecycle.

However, the biggest challenge to overcome is the insufficient collection of consumer goods and inefficient handling within the recycling chain. As long as goods are discarded with household waste, stored in basements, or ending up in environmentally unsound recycling operations, the total recovery rates will remain disappointingly low, as it is the case today for most consumer goods. Legislation can be supportive but monitoring of the recycling chain, advanced certification schemes for treatment operations, as well as tight enforcement of the regulations are crucial for success. The high amount of doubtful exports of old electronics and cars leads to a situation where state-of-the-art, high-financial-investment recycling facilities in industrialised countries are underutilised because 'recycling' and the associated environmental burden of environmentally unsound treatment are 'outsourced' to the developing world. The usually primitive 'backyard recycling processes' applied in these countries focus on (highly inefficient) gold and copper recovery, while most other technology metals are completely lost. The 'urban mine' is thus wasted irreversibly.

To effectively close the loop for consumer products, new business models need to be introduced that provide strong incentives to hand in products at their end of life. This can include deposit fees on new products, or product service systems like leasing or other approaches. Especially for emerging technologies (electric vehicles, photovoltaics, etc.), setting up 'closed-loop structures' will be essential and manufacturers who put successful models in place can thus secure their own supply of technology metals in the future.

In an ideal system, the sustainable use of metals could indeed be achieved by avoiding spillage during each phase of the product life cycle. Such losses occur at various stages and it is necessary to analyse the specific impact factors to identify the most appropriate means for each stage. It is important to understand that universal means to improve recycling do not exist. If material properties or technology constraints have the main impact, then completely different measures will be required than if societal or life cycle issues are the main loss driver (McLean et al. 2010). Setting up the most appropriate recycling solutions needs to deal with this complexity and interdependencies in a global context (Fig. 15.6). It cannot be achieved without a holistic and interdisciplinary system approach.

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scrapped in Germany. Calculated on the 3.2 million deregistrations, Germany's recycling rate would fall to 13.5%. Although 1.8 million of the exported cars go primarily into other (mainly Eastern) EU states, it can be assumed that a big portion will ultimately leave Europe. The export of about 2.5 million cars represents a secondary materials potential of 1.3 million tonnes of steel, 180,000 t aluminium, about 110,000 t of other nonferrous metals, and about 6 t of PGM. Significant quantities of ELVs are also exported from other European countries (Buchert et al. 2007).

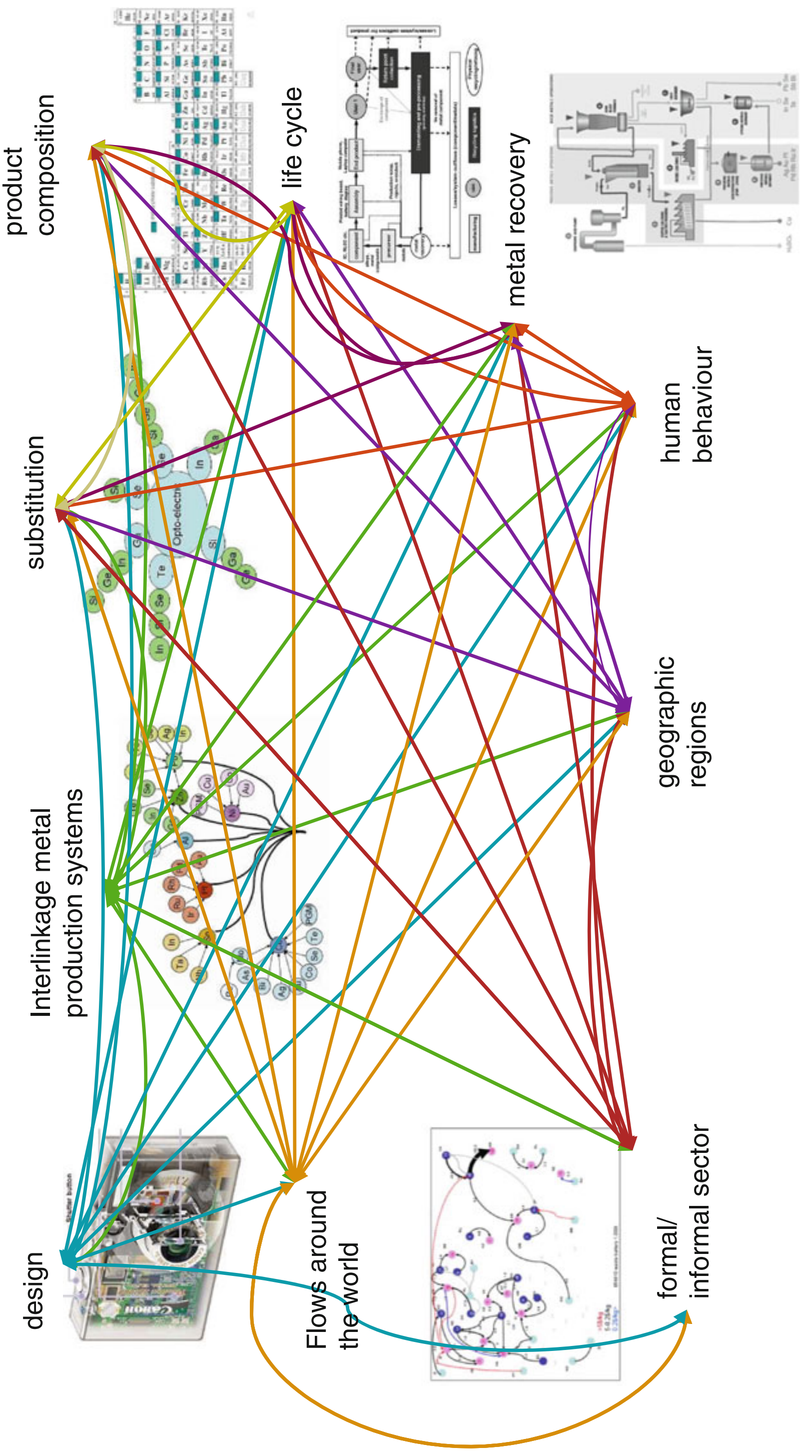

Fig. 15.6 An interdisciplinary approach is needed to improve resource efficiency and recycling

Effective recycling systems would thus make a significant contribution to conserve natural resources of scarce metals and secure sufficient supply of technology metals for future generations. It would further mitigate metal price volatility and decrease the climatic impacts of metal production, which is energy intensive, especially in the case of (precious) metals mined from low concentrated ores.

To summarise, efficiently recycling our EoL products today is insurance for the future. To fully utilise this potential, it needs a paradigm shift on different levels:

- Attitude needs to change *from a* waste management to a resource management perspective, reflecting the significance which our scraps have for society. This will foster collection, appropriate treatment, and enforcement of legislation. Specifically for critical technology metals, measures need to be installed to promote their recycling even in the absence of (current) value, volume, and environmental drivers.
- Targets need to be adapted accordingly. The current focus on mass is insufficient; instead much more emphasis must be placed *on* quality/efficiency of recycling and the recovery of critical metals. This goes in hand with a certain prioritisation, and it is indeed reasonable to recover less mass (e.g. of plastics or steel) if this leads to a significant improvement in the recovery of technology metals.
- Recycling practice needs to reflect the new requirements. Since this industry has a key role for our future needs, the traditional structures of a (somehow dirty) scrap business do not fit any more. High-tech recycling plays in the same league as clean-tech manufacturing and renewable energy generation. Company structures, appearance, and stakeholder cooperation in recycling must fit to this, with much more emphasis on transparency and business ethics as it is the case today.
- Finally, the vision from a manufacturer's perspective needs to change. Until today, producer responsibility and recycling are often more seen as a burden, implied by law. In fact it is an opportunity for manufacturers to sustainably get access to the raw materials needed for their future production. To fulfil this vision, creative business models to close the loop are essential.

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Chapter 16
Transboundary Shipment of Electronic Scrap

Knut Sander and Joachim Wuttke

1 Introduction

Electrical and electronic goods are one of the fastest growing and most dynamically developing product groups all over the world. In parallel, significant quantities of used electrical and electronic goods are being exported from European markets to developing countries. Notified waste exports of such equipment from Germany into countries outside the European Union (EU) have not been recorded to an appreciable extent. Condition and quality of the exported used electronics, however, suggest that a significant proportion of the exported equipment can be expected to be non- or not completely functioning (Sander and Schilling 2010).

This chapter will highlight the backgrounds behind the export of electronic scrap and its relevance under environmental and resource aspects.

2 Legal Frameworks for Transboundary Waste Shipments

In Germany and all other EU member states, transboundary shipments of waste are regulated by the Waste Shipment Regulation (WSR) (EU 2006), which is based on the "Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal" and the Decision of the OECD Council on the Control of

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Transboundary Movements of Wastes Destined for Recovery Operations (OECD 2001). The WSR fully transposes the procedural rules of the Basel Convention and the OECD Decision into directly applicable law of the EU (Wuttke and Baehr 2008).

It comprises a ban on exports of waste for disposal outside the European Union (with the exception of the export to countries which belong to EFTA and are Party to the Basel Convention). The WSR in addition prohibits all exports of hazardous waste for recovery to countries to which the OECD Decision does not apply.

The provisions of the WSR aim to ensure proper transfrontier shipment of waste as well as a disposal of waste not posing a risk to health and environment and, inter alia, to protect developing countries against certain imports of waste.

The WSR applies to wastes as defined in the Waste Framework Directive. The differentiation between waste and products is therefore very important. Some guidance for this differentiation is provided by a paper produced within the framework of the OECD (1998) and a Communication from the Commission to the Council and the European Parliament (EU 2007a). For waste electrical and electronic equipment, the Correspondents' Guideline No. 1 gives assistance (EU 2007b).

2.1 Waste Classification

The waste classification system of Basel Convention contains two waste lists: List A (hazardous wastes – Annex VIII) and List B (nonhazardous waste – Annex IX). Based on the Basel listings with minor editions and changes, the OECD implemented the Green and Amber Waste List system which is part of the OECD Decision. The waste classification of the WSR is based on the OECD Decision and in addition uses the European List of Waste (EU 2000) for the purpose of export restrictions. Consequently, the WSR includes the following waste lists:

- Green listed wastes (Annex III)
- Mixtures of green listed wastes (Annex III A)
- Additional green wastes[1] (Annex III B)
- Amber listed wastes (Annex IV)
- Wastes subject to the export prohibition (Annex V)

Whereas the entry A1180 of Annex IV is of relevance to hazardous electronic scrap, the entry of relevance to electronic scrap in the Basel Convention List B (B1110) is not applicable in EU law. OECD entries GC010[2] and GC020[3] apply instead.

[1] Annex IIIB is worked out in a committee procedure. This regards green wastes not listed at the Basel/OECD level but which can be shipped between EU member states without notification.

[2] Electrical assemblies consisting only of metals or alloys.

[3] Electronic scrap (e.g. printed circuit boards, electronic components and wire) and reclaimed electronic components suitable for base and precious metal recovery.

Table 16.1 Waste classification according to decision 2000/532/EC

Waste code	Waste description
16 02 10*	Discarded equipment containing or contaminated by PCBs or PCTs other than those mentioned in 16 02 09
16 02 11*	Discarded equipment containing chlorofluorocarbons
16 02 12*	Discarded equipment containing free asbestos
16 02 13*	Discarded equipment containing hazardous components[a] other than those mentioned in 16 02 09 to 16 02 12
16 02 15*	Hazardous components removed from discarded equipment
20 01 21*	Fluorescent tubes and other mercury-containing waste
20 01 35*	Discarded equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components[a]

[a]Hazardous components of electrical and electronic equipment include, for example, accumulators and batteries listed under 16 06 and classified as hazardous, mercury switches, glass from cathode ray tubes and other coated glass

The waste classifications in the European Waste List relating to electronic scrap are listed in Table 16.1 above.

2.2 Provisions of Waste Shipment Regulation

Transfrontier waste shipment is subject either to the procedure of prior written notification and consent by the authority or to general information requirements. Furthermore, export and import restrictions are based on the classification of the waste (see above). Table 16.2 gives a simplified overview of the provisions of the WSR, which depends on the intended management method and the classification of the waste.

2.2.1 General Information Requirements

Shipments of “green wastes” for recovery when shipped in amounts of more than 20 kg and all waste destined for laboratory analysis up to a maximum of 25 kg are subject to the general information requirements. Such shipments have to be accompanied by a form (consignment information).

However, shipments of “green wastes” into certain new EU member states are subject to time-limited exceptions pursuant to Article 63 WSR which require consent for the shipment of “green wastes”.

When exporting “green wastes”, that is, nonhazardous wastes for recovery, to a country to which the OECD Decision does not apply, various control procedures according to Art. 37 of 1013/2006 apply. Which procedure is required for specific countries of destination and for specific types of waste is defined in a binding regulation (Regulation (EC) 1418/2007). This Commission Regulation will be adapted

Table 16.2 Simplified overview of permissible transfrontier waste shipments under the WSR

	Between EU member states	Import into the EU	Transit through the EU	Export out of the EU
Waste for disposal	Consent required	Consent required	Consent required	Prohibited[a]
"Green wastes" for recovery (Annex III, IIIA and IIIB of WSR) that do not contain any hazardous constituent	Information requirements[b]	Information requirements	Information requirements	Information requirements or special provisions[c]
All other waste	Consent required	Consent required	Consent required	Prohibited[d]

[a]Export to Iceland, Lichtenstein, Norway and Switzerland is permitted with prior written notification and consent

[b]Transitional arrangements still apply to some new EU member states. Export to Bulgaria requires written consent until the end of 2014, to Latvia until the end of 2010, to Poland until the end of 2012, to Romania until the end of 2015 and to Slovakia until the end of 2011

[c]Further restrictions by the national law of the non-EU country in question may exist. See also special provisions for exports in countries to which the OECD Decision does not apply

[d]The export of hazardous wastes for recovery to countries to which the OECD Decision does not apply is prohibited

on an ongoing basis. This information is also available in a paper called "country list" (UBA 2010) compiled by the Focal Point to the Basel Convention at the Federal Environment Agency of Germany.

2.2.2 Procedure of Prior Written Notification and Consent

All transfrontier waste shipments which are not subject to the general information requirements or otherwise exempted by the provisions of the WSR are subject to the procedure of prior written notification and consent.

The procedure of prior written notification and consent comprises obligations concerning prior checks (before the beginning of the waste shipment) and verification of the waste's fate (for each waste shipment). The notifier has to notify the planned shipment of waste to the competent authority in his home country by means of a notification form and further necessary documents.

2.2.3 Export and Import of Waste Destined for Disposal

EU member states are allowed to export waste for disposal only into other EU member states and in EFTA countries which are Parties to the Basel Convention.

Likewise, the import of waste for disposal into the EU is only permitted from states which are Parties to the Basel Convention and members of EFTA or with which the EU or individual member states have concluded bilateral or multilateral agreements or arrangements.

2.2.4 Export and Import of Waste Destined for Recovery

The export and import of hazardous waste for recovery from or into the EU are likewise prohibited depending on the third country involved. The export for recovery of hazardous waste listed in Annex V of the WSR from the EU into countries to which the OECD Decision does not apply is prohibited.

Concerning electronic scrap, the export of wastes listed in Annex V Part 1 (List A – inter alia A1180) and to Annex V Part 2 (hazardous wastes according to EU law – inter alia the wastes in Table 16.1 above) is prohibited. Further details are given in Correspondents' Guidelines No. 4, which states "*that hazardous electronic scrap according to the European list of wastes* [...] *should, for the purposes of Regulation* (*EC*) *No 1013/2006, be classified as hazardous* electronic scrap *by using the Basel entry A1180, unless another entry contained in Annex IV applies, and that hazardous electronic scrap cannot be classified appropriately as either GC010 or GC020*" (EU 2007c).

The import of waste for recovery into the EU from countries to which the OECD Decision applies which are a Party to the Basel Convention and countries with bilateral agreement is permitted. Such shipments are subject to the procedure of prior written notification and consent.

2.3 Control Authorities According to the German Waste Shipment Law

The German Waste Shipment Law (*Abfallverbringungsgesetz – AbfVerbrG*) supplements the WSR in numerous points. One supplement of particular importance to the export of waste is the allocation of authority responsibilities. Generally, the federal state authorities of the state in which the waste shipment begins or should begin are responsible for measures and duties relating to shipments of wastes out of Germany. They also have responsibilities concerning inspections, as well as certain federal authorities.

According to AbfVerbrG, the Federal Office for the Transport of Goods and the customs offices shall cooperate with the responsible authorities "to the best of their ability" in the inspection of waste shipments. According to state laws, the duty to inspect can also reside with parties other than the authorities responsible for the waste shipment, such as the water police or police.

2.4 Export Monitoring

Both the sources of used electronics and the collection points where sea containers are loaded for shipping are found in various federal states in Germany. The federal states therefore have in practice a monitoring and control function, which in the cases of the export ports of Hamburg and Bremen is extended by a (central) control function in the ports.

Responsibilities for environmental management are shared between the federation, the federal states and municipalities. According to the constitution, the federal states have the power to regulate aspects of waste management which is not regulated by federal law. All federal states have assigned competent authorities responsible for the supervision of waste management on a regional level. These authorities are responsible for authorising and monitoring waste management facilities, for controlling waste shipments and coordinating suspected cases of illegal waste shipments which are reported by the inspection authorities like customs, police or the Federal Office for the Transport of Goods (BAG).

2.4.1 Federal State Level

For example, in the federal state Hamburg, the water police is responsible for inspecting transfrontier waste shipments and carries out appropriate inspections with regard to the export of suspected waste electrical and electronic equipment. In order to bundle information more efficiently, the responsible waste management authority of Hamburg (BSU) and the police are in agreement that the BSU initiates and controls the communication with the appropriate state authorities. Under the direction of the BSU, information and experience have been exchanged since the start of 2007 between the inspection authorities (customs and police) and the BSU on a regular (half-yearly) basis in order to continually optimise and adapt enforcement to the actual circumstances.

2.4.2 Federation Level

The *Federal Office for the Transport of Goods* (*BAG*) is an independent federal authority in the Federal Ministry of Transport, Building and Urban Affairs. It supervises among others the transportation of waste by vehicles for road freight (GüKG 1998). The BAG's inspections are carried out on motorways, federal and state roads in part undertaken in cooperation with the police and other supervisory authorities (Kropp 2008).

According to the *Federal Criminal Police Office* (*BKA*), in the period between 2004 and 2008, a total of 27 suspected cases relating to the export of used electronics or WEEE were registered in which the state police investigated preliminary proceedings in accordance with § 326 para 2 of the Penal Code (StGB) on illegal handling of hazardous waste. The majority of the preliminary proceedings were caused by the water police in Hamburg and Bremen. Police waste transport inspections to gather evidence were identified as crucial for enabling proceedings.

The sampling and carrying out of targeted inspections is in the opinion of the BKA helped by cooperation between police and customs authorities. The current legal uncertainty in administrative enforcement relating to the difference between used electronics and electronic scrap has proven to be a hindrance to instigating criminal proceedings.[4]

3 Quantitative Aspects of the Transboundary Shipment of Electronic Scrap

Reliable data about exported volumes of electronic scrap are not directly available. The major reason is that the exports happen in the grey zone between the export of second-hand goods and waste. Thus, the export of such equipment is hidden in the official statistics in huge mass flows of other exported goods.

By evaluating internal statistics of German ports and combining information about volumes and values of the exports, a detailed and secured estimation about the export situation from Germany has been elaborated in 2010 for the Federal Environment Agency in Germany (Sander and Schilling 2010). It revealed that in 2008 around 155,000 t of used equipment has been exported from Germany to African and Asian countries.

The detailed analysis of the port-statistics of Hamburg regarding the values of the exports allowed the presumption that the quantity-relevant exports were made

[4] Apart from cooling appliances containing CFCs.

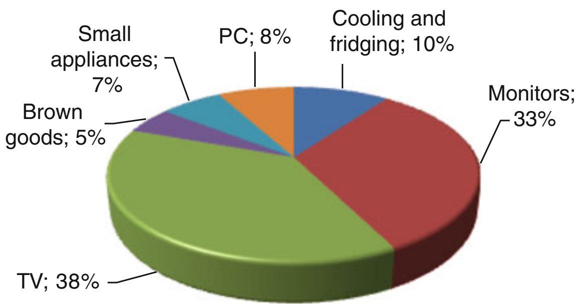

Fig. 16.1 Export fractions according to the equipment type

up primarily of used equipment with very small value. Even in case of a “best-case estimate”, low prices appeared such as 3 € per video monitor, 4 € per TV set or 20–30 € per refrigerator/freezer. The actual value, however, certainly does not correspond to these best-case considerations and is assumed to be at 1 € per video monitor or TV set. The very low average values as well as the outcome of several export controls made clear that a relevant portion of the equipment has been in a very bad state. An indeterminable amount has been exported illegally as used equipment in spite of its status as electronic scrap.

In order to estimate the export volumes for Europe, an extrapolation of the figures from Germany has been done as a quick check based on the following questions:

- Do other countries with appropriate port facilities and shipping lines to Africa and Asia have a significant better situation regarding the control of exports?
- Do those countries have a legal situation which solves the major issues related to the export (e.g. legally binding differentiation between second-hand product and waste)?

Based on the quick check, one can estimate that the total export volume of the European Union is at around one million t per year.

The question what type of equipment has been exported bears considerable data uncertainties because neither public nor internal statistics are seen as reliable descriptions of what is actually stowed in the overseas containers. This has been confirmed by several container inspections. Primarily, there is a tendency to underestimate small appliances (e.g. entertainment electronics) and equipment which is exported in relatively small quantities (e.g. PCs). Smaller items of equipment are also underestimated in quantity since they are essentially more often (unregistered) vehicle payloads in used vehicles than large items of equipment (Fig. 16.1).

The quantity of exported PC monitors in 2008 was in the order of 50,000 t. This corresponds to about two million appliances. Also for this type of equipment, the investigations revealed that they can hardly be new equipment, but a relevant portion is assumed to be in a very bad state.

For Comparison: In 2008 320,000 t of new IT and telecommunication equipment has been put on the market in Germany and 155,000 t has been collected separately in the system according to the ElektroG (Electrical and Electronic Equipment Act).

It is to be noted that the exported quantities as well as the equipment mix were probably essentially influenced by the innovation cycles in the countries of dispatch, like the replacement of CRT screens by flat screens. In this respect, the view of 2008 can be understood to be only a spotlight.

The quantity of refrigerators and freezers exported into countries of destination, taking into account the quantities not represented in the export statistics, was probably in the order of 15,000 t per year. Various sources estimated the fraction of old refrigerators yielded in 2008, which are free of chlorofluorocarbon (CFCs), to be 10–30% of the total quantity occurring. It was suspected that the quantity of CFC-free refrigerators yielded in Germany in 2008 to be below 10,000 t/a. On the basis of these assumptions, it can be presumed that significant numbers of refrigerators containing CFCs have been exported.

At least 65,000 t of lead-containing class from cathode ray tubes has been exported. With these components, barium oxide and strontium oxide and a coating of a mixture of phosphorous which may also contain cadmium and other heavy metals especially in older equipment had been shipped to countries in Africa and Asia (ICER 2003).

Additionally an unknown amount of persistent organic pollutants has been exported, for example, as components in the more than 22,000 t of plastic parts and printed circuit boards.

4 Who Is Involved in the Export?

A broad range of different types of exporters can be identified. It is characterised at one end by professional remarketing enterprises which trade a high number of equipment (some reported a total trading volume by companies in Germany of more than one million appliances per year, and the export volume described by some companies was far above 100,000 appliances per company and year). They acquire their material preferably from big companies and public authorities and prefer to get large batches of similar equipment. At the other end of the range, one can find so-called waste tourists. These are people from the countries of destination like Nigeria and Ghana who come to Germany, acquire/collect equipment for one or two overseas containers, send the containers and go back to the countries of destination to take the delivery of the containers. "Waste tourists" often get low numbers of equipment per source and often material with a very low quality. They often buy equipment for the low-budget market in the countries of destination. In between these ends, a broad variety of intermediate types can be found.

In the case of waste tourists, the export chain involves a number of stages which are visualised in Fig. 16.2.

Waste tourists and small-volume exporters act often in a context of a network of personal contacts. Often a closed community of people from the same country can be found in such networks. Which community establishes at which place is often accidentally. They acquire material for export from a broad variety of sources. The study conducted for the German Federal Environment Agency (Sander and Schilling 2010) identified up to 4,000 sources in Germany. The material is aggregated at

Fig. 16.2 Export chain – example of waste tourists

Fig. 16.3 Collection places (type "A": retailer)

Fig. 16.4 Collection places (type “B”: intermediate storage)

collection places. Those places can be locations where material is traded (location of type “A”) (Fig. 16.3) or locations which are exclusively designed for intermediate storage of the material until the container is full (location of type “B”) (Fig. 16.4).

Collection places of type “A” are always combined with additional places where the overseas containers are filled. In contrast to the situation at collection places of type “B”, the material is stored in the overseas container in a short time frame (often the container is available for filling up for a maximum of three days). Filling of containers is done in those cases at different places. Sometimes the location of the shipping agent is used, sometimes halls in commercial areas and sometimes parking lots. Containers on collection places of type B might be filled slowly over several weeks or even some months.

A specific case is the export of WEEE via second-hand cars. Acquisition routes are the same as described above for waste tourists (Figs. 16.5 and 16.6).

5 Treatment Situations in the Countries of Destination

Major countries of destination for electronic scrap from Germany are Ghana, Nigeria, South Africa, Vietnam, India and the Philippines. An analysis of the treatment situation in the countries of destination (Sander and Schilling 2010) has shown that, in most cases, no treatment infrastructure is available which is even only roughly comparable to that which the European member states consider for themselves as minimum level of protection for the environment and health.

Fig. 16.5 Payload of second-hand cars for export

Fig. 16.6 Second-hand cars to be exported from the port of Hamburg

In few countries of destination (e.g. South Africa, India), there are available treatment and recycling facilities for some types of equipment as well as for fractions from the treatment of equipment. However, control and monitoring mechanisms do not appear to have been established with an effectiveness which ensures that equipment, which has been exported from Germany, actually reaches these facilities.

Via the very heavily manually characterised dismantling of the equipment, often a good separation of material is achieved in the first stage of the recycling chain.

This, however, concerns only fractions for which sufficient revenues can be achieved on the respective regional market. The dismantling takes place essentially through the informal sector. Above all, in African countries, the degree of organisation of the informal sector is marginal. Through this, the market access for the sale of fractions is very heavily dependent on parochial conditions. Therefore, prices, which are achieved on the world market for fractions from the dismantling of electronic scrap, are often not simply transferable.

The reclamation efficiency for precious metals or noble earths with the treatment processes applied in the important countries of destination is as a rule lower than with state-of-the-art processes according to European standards. Some elements are not reclaimed at all in several countries of destination (e.g. palladium). The recycling of ferrous metals is classified as less problematic.

6 Loss of Resources, Risks for Human Health and Environment and the Economic Drivers Behind the Export

With the electrical and electronic equipment, valuable resources have been exported. Examples for 2008 are 37,000 t of steel, 8,000 t of copper and 3,000 t of aluminium, 1,500–3,000 kg of silver, 300–600 kg of gold and 120–240 kg of palladium.

The resources in the exported electronic scrap had an intrinsic value of nearly 40 million €.

These resource values are an important economic driver for the export of equipment which is in such a bad state that it cannot be reused in the countries of destination any more.

Some components like CRT glass, batteries and capacitors have negative values in Europe. The (saved) costs for disposal of hazardous components of the exported electrical and electronic equipment were in 2008 in the order of 10 million €. Treatment costs in Europe are significantly influenced by labour costs and costs for investments in technologies and operating costs. Low labour costs for separation of valuable resources, environmentally unsound disposal of hazardous components and relatively good prices for dismantled spare parts in the countries of destination result in revenues which are more than sufficient to cover the (low) costs for transports of the containers to the countries of destination. For CRT monitors, the economics are, for example:

- Transport costs for one CRT monitor from Hamburg to Nigeria: 1.50 €
- Intrinsic material value of one CRT monitor: 3.20 €
- Disposal costs in Germany for one CRT monitor: 4 €

For Comparison: The social situation in countries of destination like Nigeria is characterised by a high portion of population below poverty line. In the case of

Table 16.3 Reclaimable volumes of precious metals from exported electrical and electronic equipment

	Best techno logy (kg)	Technology optimised under short-term economic aspects (kg)
Ag	1,464	1,090
Au	191	140
Pd	98	36

Table 16.4 GWP and CED reduction potential from the use of secondary resources contained in exported electrical and electronic equipment

	GWP reduction potential of component (in case of 100% reclamation) (kg CO_{2eq})	CED reduction potential of component (in case of 100% reclamation) (MJ)
Steel	−60,265	−782,710
Al	−72,324	−1,339,536
Cu	−8,072	−159,804
Ag	−152	−2,372
Au	−5,447	−93,044
Pd	−1,089	−20,060
Total	−147,349	−2,397,527

Nigeria, 70% of the population has an income of less than 1 $/day (CIA 2010). This means that one nonfunctioning monitor represents the intrinsic material value of more than 2-day incomes for 70% of the inhabitants of Nigeria and one PC represents the intrinsic material value of more than 3-day incomes.

Treatment technologies in state-of-the-art installations achieve high reclamation rates for precious metals and rare earths contained in exported equipment. Table 16.3 summarises the amounts of three substances reclaimable when best technologies are applied (column 2) or when technologies are applied which are optimised by economic aspects (column 3).

Because those technologies are not available in the major countries of destination, export of electronic scrap leads to extensive loss of resources like the loss of 70% of gold and silver and 100% of palladium in the equipment.

By reclaiming those valuable elements, environmental burdens from the production of primary resources can be prevented. The reclamation of secondary raw materials shows significant environmental benefits compared to the primary production. Table 16.4 describes potential environmental benefits from the reclamation of resources contained in the exported electrical and electronic equipment for the parameters global warming potentials (GWP) and cumulative energy demand (CED) for selected substances.

When the equipment is treated in the countries of destination with technologies which are not state of the art, the described environmental potential from the reclamation of secondary resources cannot be realised.

The negative effect on climate protection and the regional environment is to be seen in addition to the direct risks to human health and the environment from some treatment technologies applied in the countries of destination and the environmental damage from the disposal of non-valuable components and treatment outputs.

7 Measures/Options

In the study run for the Federal Environment Agency (Sander and Schilling 2010), a bundle of measures has been developed to reduce unwanted export of electronic scrap. Improvement of the situation cannot be achieved via a singular measure. The developed measures combine mid- and long-term activities and target numerous protagonists/players. An intensive monitoring of potential sources of equipment destined for export everywhere will not be possible due to restricted human resources and a desired high controlling efficiency. Control measures should therefore be focused on those spots which concentrate equipment destined for export (collection and loading points, ports). Due to the transnational character of this problem with exports, pure legislative approaches cannot solve the accompanying difficulties completely. Therefore, voluntary measures on the level of manufacturers (but also of the remarketing and waste treatment companies) have been developed (Table 16.5).

It can be expected that the combination of these measures will mitigate the problem for Germany. In order to improve the situation in the countries of destination structurally, further activities on an international level are necessary.

Overall, it can be expected that the combination of these measures can ease the problem for Germany. For a fundamental improvement of the situation in the countries of destination, however, further measures at an international level are necessary.

The inclusion of provisions for the waste export problem in the amendment of the WEEE Directive is considered sensible and very helpful by the inspection authorities. With regard to the current wave of exported CRT monitors, the effects of the directive would not unfold until after the directive has been implemented in the member states, that is, too late. In view of the large scale of old CRT monitors and televisions being exported, a solution which would have a short-term impact should be found.

Table 16.5 Measures proposed in a study of the German Federal Environmental Agency

Measure		Addressee	Implementation level
Statistics			
1a	Evaluation routines for the export databases should be developed and implemented in order to simplify or enable monitoring	German Federal Ministry of Finance (BMF) supporting work by enforcement authorities	Short term
1b	A simple access to the export data should be provided for the waste surveillance authorities (if necessary also of those German federal states other than Hamburg), in order to enable a monitoring of the development of quantities	BMF	Short term
1c	It should be permanently ensured that the police forces have access to the exports databases	BMF	Short term
1d	European statistics for important exported types of equipment such as monitors, television sets, refrigerators should be differentiated between new/used equipment in that appropriate codes are introduced into the combined nomen clature (a worldwide harmonisation is recommended as long-term perspective)	BMF	Medium term
Sources of exported equipment			
2a	The collection of bulky waste should take place in such a form that protection against pilferage of waste electrical and electronic equipment is provided	Federal states/municipalities	Short term
2b	The public should be more intensely informed about its own role in relationship to the export of waste electrical and electronic equipment and its negative effects	German Federal Environment Agency (UBA)/German Association of Municipal Waste Management and City Cleaning in VKU, all protagonists	Short term
2c	Manufacturers should elaborate and implement explicit corporate policies for the export of used electrical/electronic equipment and waste electrical/electronic equipment	Manufacturers/German Ministry for the Environment (BMU)	Short term
2d	Quality label and voluntary self-binding agreement for resellers should be elaborated and implemented (objective: non-export of nonfunctional equipment in non-EU states). The integration of the label development in the UBA-promoted project "Second Life" is recommended	BMU/UBA	Short term

2e	A voluntary self-binding agreement of manufacturers and exporters for the non-export of nonfunctional used equipment should be presented at the CeBIT Trade Fair in 2011	BMU	Short term
2f	Corporate policies for the export of nonfunctional equipment should be taken up by company ranking	Ranking organisations	Medium term
Legal regulations and controls			
3a	The distinction between waste and non-waste for EEE/WEEE should take place via the amendment of the WEEE Directive. The existing draft should be refined in detail on this point	BMU, UBA	Short to medium term
3b	A systematic survey of the collection points for equipment for export in the German federal states should take place, and criteria for the identification and checking of such points should be elaborated	Federal states, municipalities	Short term
3c	Risk profiles for the export of WEEE and UEEE should be developed further, and exchange between the responsible authorities should be intensified	BMF, UBA, environment authorities in NL and BE; Focal Point to the Basel Convention	Short term
3d	Investigations using police means in certain potential areas of origin for exported WEEE/UEEE should be initiated (equipment which has already been in the waste regime and is to be exported as used equipment)	Environment authorities, department of public prosecution	Short term
Cooperation with countries of destination			
4a	Investigations should take place into how a re-export of fractions from the manual and mechanical disassembly of WEEE from the countries of destination into industrial states can take place	EU, German Ministry for Economic Cooperation and Development	Short term
4b	European countries and manufacturers should provide support with the build-up of suitable waste treatment facilities and infrastructure in countries of destination	Manufacturers, EU, German Ministry for Economic Cooperation and Development	Medium term

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Chapter 17
The Limited Resources of Phosphorus and How to Close the Phosphorus Cycle

Christian Kabbe

1 Phosphorus: An Underappreciated Resource

It is to be feared the common saying "*The true value of things has always been recognized only after their disappearance*," proving true once more in the case of phosphorus.

Phosphorus is one of the crucial ingredients of life and cannot be replaced by any other element or substance. It is the key element in our genome, cellular membranes, skeleton and the molecule adenosine triphosphate (ATP), the organism's main energy storage. An average adult person needs about one gram of phosphorus per day. Annually, 22.5 kg of phosphate rock are required to sustain one person's balanced diet by modern agriculture. Phosphorus is used and reused 46 times on the average by land ecosystems before making its way into the ocean. There, marine organisms may recycle it some 800 times, before its passage into sediments. It takes tens of millions of years to return it to dry land by tectonic uplift (Vaccari 2009). Our modern society breaks up the natural cycle by separation of food production from consumption. This limits our ability to return the nutrients back to the land we have harvested before. In consequence, we need to add phosphorus to the land to keep it fertile. The estimated global mine production of phosphate rock in 2011 added to 191 million metric tons (USGS 2012). The mining, processing and shipping of phosphate rock is very energy intensive and causes immense environmental impacts, primarily caused by open-pit mines and large stacks for stockpiling the radioactive phosphogypsum waste, the gypsum formed as a by-product of processing phosphate rock to phosphoric acid with sulphuric acid. The production of every metric ton of phosphorus generates about 10 metric tons of phosphogypsum. About 80% of the phosphate rock mined is finally used

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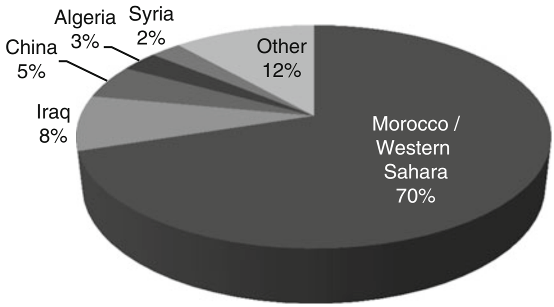
Fig. 17.1 Estimated world reserves of phosphate rock 2011 (The total adds to 71 billion metric tons) (USGS 2012)



for the production of fertilisers. The balance is for the manufacture of elemental phosphorus, which is used for the production of a variety of phosphorus compounds for food additives and industrial application. This proportion emphasises the significance of phosphorus for agriculture and the resulting importance for the food security of a growing population, even if there new exploitable deposits explored and added to the known reserves frequently. Assuming a world being home for nine billion people by the middle of this century, the demand for nutritious food is about to increase definitively and so will the consumption of phosphorus. The FAO (Food and Agriculture Organisation of the United Nations) is assuming an increasing demand of 2% a year (FAO 2008). A theoretical study is even expecting the phosphorus to peak by the 2030s (Cordell et al. 2009). It is then that the demand for phosphorus cannot be met any longer by supplies. As we have observed in 2008, the shortage or just even the agreed certainty of this resource to be limited in availability can make markets nervous and prices rising by several hundred percent. But more substantial the declining quality of the remaining deposits will affect the prices. A lower phosphorus content in the ore and higher concentrations of contaminants like the toxic heavy metals cadmium (up to 147 mg/kg P) (Scheidig 2009) and uranium (up to 687 mg/kg P) (Roemer et al. 2010) will lead to higher costs for mining and processing and hence for food. The era of cheap phosphorus is said to be over (Gilbert 2009).

Another concerning fact is the global distribution of mines and reserves. As shown in Fig. 17.1, only five countries control almost 90% of the easy exploitable phosphate rock. About two thirds of the global phosphate rock mine production are covered by only three countries. China imposed a 135% export tariff in 2008, and the reserves of the United States are expected to deplete within the next 25 years (Vaccari 2009). Both countries are two of the largest consumers of phosphorus. Morocco annexed Western Sahara in the 1970s and is hence controlling the world's largest reserves contrary to United Nations resolutions. But the status of the territory remains unresolved.

Assuming the facts, the food security of a growing population is strongly dependent on the availability of phosphorus. Countries without own natural phosphorus reserves completely depend on imports from just a few exporting countries. Phosphorus becomes therefore a strategic resource for many countries.

In the financial year 2007/2008, Germany had to import 138,000 metric tons of mineral phosphorus (Destatis 2008). The increasing demand, tightening markets and political instabilities might lead to skyrocketing prices and shortage of supplies. The exploration and operation of new lower-grade phosphate mines will expand the pollution of the environment and even cause regional ecocide.

Waiting for a phosphorus scarcity to come is against all reason. It is the order of the day to take any chance to reduce the dependence on phosphate rock and to minimise ecological impacts before the worst case scenario – the phosphorus scarcity – becomes a bitter truth.

2 From Scarcity to Security: Perspectives for a Sustainable Use of Phosphorus in Germany

The basic approach to prevent a possible scarcity from becoming true is to reduce the total demand for phosphorus by reducing the consumption and increasing the number of lifecycles. Unlike oil, phosphorus can be recovered once used.

2.1 Reducing the Phosphorus Consumption

Our modern, intensive agriculture depends on continual inputs of fertiliser. In Germany, an average import of 120,000 metric tons of phosphorus in form of mineral fertiliser is necessary to sustain high yields. There is substantial potential for reducing the demand of phosphorus by reducing the losses, increasing the food chain efficiency and even changing diets. A lot of food is lost on the way from field to fork. Up to 50% of phosphorus in harvests is estimated to be lost in food production and households. Longer distances and more processing steps in the globalised food commodity chain lead to increased wastage. Producing the food closer to the point of demand could reduce food waste in addition to other resources (Lundqvist et al. 2008). Losses also occur at the final destination, the consumer. In the European Union, a high percentage of food waste is estimated to be edible and hence avoidable (WRAP 2008). It does not seem ecologically nor economically reasonable to mine and process phosphate rock for food production with much effort and environmental impacts and then wasting it by throwing or flushing the food away. Compared to vegetarian diets, meat-based diets require up to three times as much phosphorus (Fraiture 2007). So besides food producers, the consumers themselves have the potential and the choice to reduce the phosphorus demand by simply improving their food and meal planning as well as by changing their dietary habits.

Table 17.1 Estimated P reserves in selected kinds of waste

Waste	Quantity of fraction	P reserve of fraction (t P/a)	Percentage of average imports (%)[a]
Waste water (~8 mg P/l, untreated)	~9.4 billion m^3/a	75,000	~63
Sewage sludge (dry matter)	~2.1 million t/a	68,000	~57
Meat and bone meal (6% P)	~180,000 t/a	10,800	~9
Excess manure	No data available!		

[a]Approximately 120,000 metric tons of phosphorus per year

2.2 Phosphorus Recycling

Our western society is characterised by consumption generating plenty of waste. Waste contains the whole spectrum of matter we find and consume on this planet. Several kinds of waste contain selected substances to more extent than others.

In Germany, representing the developed countries, three kinds of waste have been identified to contain enough phosphorus to justify the implementation of new techniques for phosphorus recovery. As shown in Table 17.1, waste water including sewage sludge, meat and bone meal and livestock manure contains the most considerable quantity of phosphorus.

New technologies for the recovery of phosphorus have been in focus of research and development, not only since the spiking prices for phosphorus in 2007/2008. It was in 2004 when the federal government launched an initiative to fund the research and development, as well as the industrial scale implementation of new technologies in the field of nutrient recovery, especially phosphorus. The major goals of this initiative are to conserve natural resources, to make Germany less dependent from the world commodity market and to secure the long-term supply with this essential nutrient.

2.3 Phosphorus Recovery from Waste Water and Sewage Sludge (Ash)

The waste water stream is probably the largest reserve of phosphorus in developed countries. For Germany, the waste water is estimated to carry up to 75,000 metric tons of phosphorus per year, which equals to more than the half of annual imports. Numerous technical concepts have been developed all around the world (Adam 2009a; Scheidig et al. 2010). Besides new sanitation concepts like urine diversion toilets, new technologies have been developed ranging from bioleaching, nanofiltration to wet chemical processes like precipitation and crystallisation in the aqueous phase to thermal treatment of sludge and subsequent acid leaching

Table 17.2 Potentials for phosphorus recovery at waste water treatment plants (WWTP) including sewage sludge in Germany (Montag 2010)

Location at WWTP	Concentration of P	Phase	Percentage of recovered P related to influent (%)
Effluent	< 5 mg/l	Aqueous	Max. 55
Sludge water	20–100 mg/l	Aqueous	Max. 50
Dewatered sludge	10 g/kg sludge	Solid	~90
Sludge ash	64 g/kg	Solid	~90

or thermochemical treatment of the ashes. But the most of them are still waiting for their industrial testing.

In Germany, more than 95% of households are connected to the public sewer system (Destatis 2007). Hence, the implementation of new sanitation concepts like urine diversion toilets across the board would not be an option here but for regions with decentralised waste water treatment and low population density.

Table 17.2 shows the difference in recovery potentials at different points within the waste water stream including sewage sludge in Germany.

2.4 Aqueous Phase

Comparing concentrations of phosphorus and volumes to be treated, the recovery of phosphorus from side streams (sludge water) is much more efficient than the processing of the main stream (effluent). Precipitation and crystallisation techniques like those listed below have already been tested in pilot or even industrial scale:

- AirPrex® by Berliner Wasserbetriebe and P.C.S (Germany)
- CRYSTALACTOR® by DHV (the Netherlands)
- PEARL™ by Ostara (Canada)
- Phosnix by Unitika (Japan)
- REPHOS® by Remondis Aqua (Germany)

All these technologies yield magnesium ammonium phosphate (MAP, $MgNH_4PO_4 \times 6\ H_2O$) by crystallisation/precipitation. MAP is commonly known as the mineral struvite. The major advantage of struvite is its consistence, providing the two nutrients phosphorus and nitrogen at once. It is also characterised by a good bioavailability at slow release rates and far lower contamination with heavy metals than sewage sludge and commercial fertilisers originating from phosphate rock. Advantageously for the propagation of struvite recovery is that the most facilities can easily be integrated into existing waste water treatment plants at moderate costs, also providing additional benefits when installed prior to the sludge dewatering step.

One story of success was written by Ostara, one of the leading companies in the field of nutrient recovery from waste water (Britton 2009) and presents a promising example for other companies in this business. Ostara successfully operates several waste water treatment plants equipped with their PEARL® nutrient recovery

Table 17.3 Variety of uranium contamination of phosphorus according to origin (Roemer et al. 2010)

Source	Concentration of U in mg/kg P
P rock Burkina Faso	67
P rock Gafsa	229
P rock North Carolina	393
P rock Israel	687
P rock Kola (volcanic)	35
SSP (single superphosphate)	748
TSP (triple superphosphate)	407
Struvite (Seaborne, Gifhorn)	9
Struvite (Berlin)	Below detection limit

system. The produced struvite is distributed as a by-product fertiliser under the brand CRYSTAL GREEN® and has already entered several market niches. The approval for application of recovered struvite in organic agriculture is under discussion. Currently, phosphate rock is the only P fertiliser to be used in organic agriculture. Regarding lifecycle, bioavailability and contamination with heavy metals, recovered struvite recommends itself as the cleaner and greener choice. The following Table 17.3 gives an impression of the variety of uranium contamination of phosphorus according to its origin.

2.5 Sewage Sludge

At least 90% of the phosphorus dissolved in the waste water entering a waste water treatment plant is transferred into the sewage sludge during P elimination. The elimination is usually realised by chemical precipitation in form of hardly soluble metal phosphates after addition of iron or aluminium salts, what makes the phosphorus hardly available to plants. If the waste water contained enough organic material, biological elimination with P-accumulating microorganisms is possible (Bio-P), what keeps the phosphorus bioavailable.

The traditional way of using sewage sludge as a fertiliser is its distribution on arable farm land and for landscaping. But as industrialisation continues to rise, the quality of municipal sludge becomes more and more critical. Besides heavy metals and pathogens, the concentration of organic pollutants becomes more and more concerning. Sure, there are legal regulations with limit values to secure that only a certain quality of the sludge considered to be harmless is used in agriculture. But this concept also includes a gap of uncertainty. We need to know what is to be limited and have to quantify it by analytical methods. But what about substances we cannot analyse or do not know to be present? The existence of hundreds of thousands organic substances from anthropogenic sources is undisputed. Not only a few of them are harmful or even toxic. Certainly, a part of them will find their way into one of our biggest pollutant sinks, the sewage sludge. Not to mention accumulation and cocktail effects as well as numerous metabolites or conversion products of originally harmless substances. Finally, the concept of limit values is eligible to cover the tip of an iceberg and to prevent various pollutants from spreading into the environment. But it does not provide security of complete exclusion. Therefore, our monitoring routines must be enhanced with bio-tests. Only bio-tests are able to prove whether the analysed sludge samples are harmful or harmless to the environment and hence to us. In consequence, the testing and bureaucratic efforts are immense for confirming sludge to be secure for direct use in agriculture or landscaping.

Fortunately, the distribution of sludge on farm land is not the only way to make use of its nutritious content. The nutrients can be extracted from sludge by wet chemical processes (e.g. AirPrex to explain: seaborne process is not as good as AirPrex and not even as well recognised as AirPrex (Actually, the name Seaborne is linked to desaster)) yielding struvite or by a new concept in the field of nutrient recovery from sewage sludge, basing on metallurgic techniques, the so-called Mephrec® process (Scheidig et al. 2010). This concept shows for the first time that material recycling and energy recovery from sewage sludge are not mutually exclusive. The Mephrec® reactor, actually a modified melting gasifier, transforms briquetted sewage sludge into a phosphorus enriched slag, whilst organic pollutants are completely destroyed and heavy metals are deposited at the bottom of the reactor. That makes the Mephrec® reactor even suitable for the recovery of rare metals from sludge. The generated furnace gas can be utilised for heat and power generation. The slag obtained from the Mephrec® process is suitable for fertiliser production. Another advantage of this technology is the variety of material input. Besides sewage sludge, any other bio-waste can be used, if it is possible to form briquettes.

2.6 Sewage Sludge Ashes

As shown in Fig. 17.2, the use sewage sludge in agriculture and landscaping decreased down to 29 and 13%, whilst the thermal use by incineration increased to 55%. The incineration is furthermore subdivided in mono- and co-incineration, as shown in Fig. 17.3. Whereas the content of phosphorus is diluted and lost for recovery by co-incineration, mono-incineration features a concentration step. Hence, mono-incineration is crucial for the recovery of phosphorus from sewage sludge ashes. In the year 2008, approximately 475,000 metric tons of sewage sludge (dry matter) was burnt in mono-incineration plants (Lehrmann 2010). That equals to 23% of the total sewage sludge quantity in Germany. Hence, the remaining 56% (29% of the total sewage sludge) of thermally used sludge is lost for phosphorus recovery.

Mono-incineration ashes are permitted fertilisers, if the requirements of the fertiliser ordinance are met. But like in the case of sewage sludge, the bioavailability of nutrients is very limited due to hardly soluble phosphorus compounds. Therefore, subsequent treatment is preferred. A recent publication gives a comprehensive picture of new techniques for the recovery of phosphorus from sewage sludge ashes

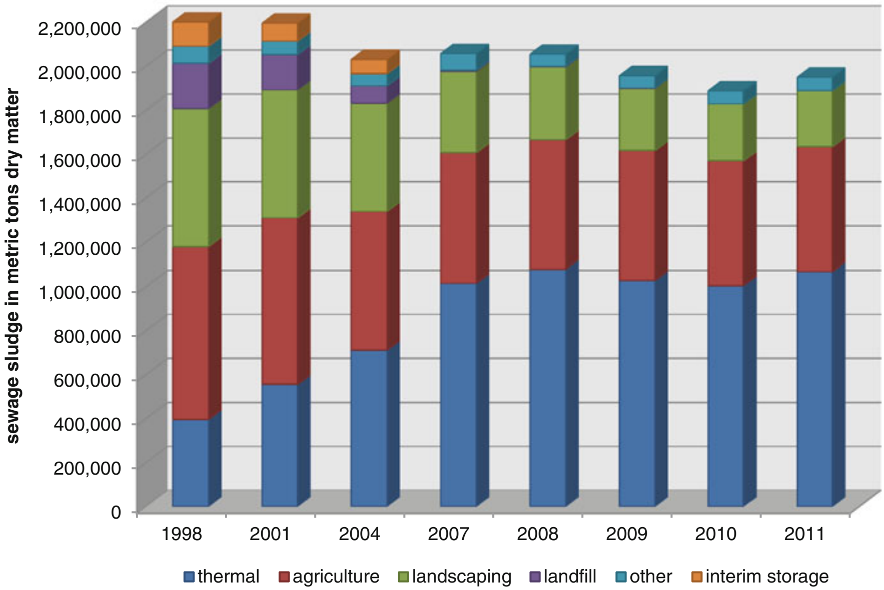
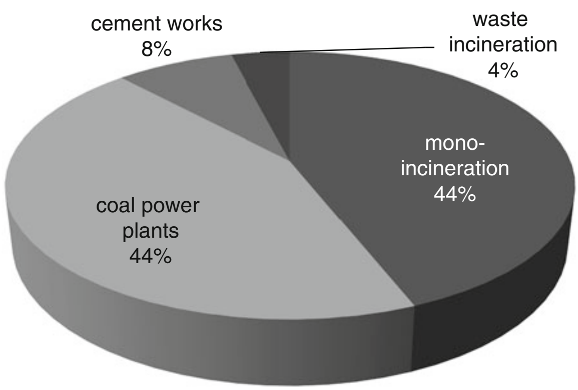


Fig. 17.2 Quantities and use of sewage sludge in Germany from 1998 to 2011 (Destatis 2009, 2010, 2011, 2012)

Fig. 17.3 Proportion of sewage sludge mono-incineration compared to several co-incineration paths (Lehrmann 2010)



(Petzet and Cornel 2010). For example, the phosphorus can be separated from contaminants by wet chemical leaching followed by precipitation, nanofiltration, liquid-liquid extraction or ion exchange. But none of these techniques have been tested in pilot scale. An already tested technique, commonly known as Ash Dec process, is the thermochemical treatment of sewage sludge ashes developed in the European project SUSAN (sustainable and safe reuse of municipal sewage sludge for nutrient recovery) (Adam et al. 2009). With a pilot plant operated in Leoben (Austria), it was shown that heavy metals can be effectively removed by addition of metal chlorides ($MgCl_2$) as chlorine donator (Hermann 2009). At operating temperatures of about 1,000°C in a rotary kiln, volatile heavy metal chlorides are separated from the gaseous phase and thus removed from the ash. Simultaneously the hardly soluble mineral phosphates are transferred into mineral phases with better bioavailability, suitable for fertiliser production.

Another technology for phosphorus recovery from mono-incineration ashes to be mentioned is the electrothermal production of white phosphorus (Schipper and Korving 2009). The company Thermphos (the Netherlands) usually produces white phosphorus from phosphate rock by reduction at temperatures of 1,500°C and addition of coke. As iron forms ferrophosphorus during the process, the stoichiometric ratio Fe/P in the sewage sludge ashes must not exceed 0.2 [mol/mol]. First tests with sewage sludge ashes from the largest European mono-incineration plant Slibverwerking Noord-Brabant (SNB) have been successfully completed. If the Thermphos plant in Vlissingen were completely fed with mono-incineration ashes, 600,000 metric tons of phosphate rock could be substituted.

2.7 Phosphorus Recovery from Meat and Bone Meal (MBM)

MBM has been predominantly used as animal food with high protein and phosphate content. As a result of the BSE crisis, meat and bone meal had been classified in three categories by European legislation. Whilst material of categories 2 and 3 can still be used as fertiliser and livestock feed, category 1 material is prohibited to be returned into the food chain. Therefore and because of its high calorific value (18 MJ/kg), meat and bone meal is mainly used as a substitute fuel for co-incineration in cement works. Hence, the phosphorus in this material is lost for recovery.

A new incineration process is planned to be tested in industrial scale, where meat and bone meal is completely mineralised in a rotary kiln applying temperatures above 1,000°C (Kabbe and Jacob 2009). The addition of alkaline and/or alkaline-earth compounds ensures the phosphate in the combustion product to be as plant available as possible (monophosphate). Due to the high temperature, all organic and pathogenic pollutants are destroyed. The meat and bone meal itself provides the energy necessary for the combustion. Waste heat can be transformed into electric energy (2.7 MW/h) in a steam-power process. The final product with the trade name ULOPHOS® contains 30–40% phosphate and is a feasible fertiliser. If the quantity of 180,000 metric tons of MBM could be processed this way, a yield of 10,800 metric tons of phosphorus could be recovered annually.

2.8 Phosphorus Recovery from (Excess) Manure

240,000 metric tons of phosphorus was annually spread on farm land by manure. Due to high water content, the transportation radius of manure is economically limited. As a result, regions with high livestock density show a surplus of phosphorus in soil, whereas crop farmers in regions with low livestock density need to buy mineral P fertiliser to balance out the deficit. That mineral P fertiliser is usually produced from mined phosphate rock. Hence, more homogeneous distribution of manure over longer distances provides immense potential to decrease the demand of mined phosphorus (Gilbert 2009).

Improved transportability of manure means separation of its nutrients from the aqueous phase and concentration in the solid phase. A very promising and energy efficient separation technology has been developed (Feldmann 2009). It is easy to integrate in circular manure storage tanks and enables the concentration of nutrients in the solid phase.

3 How to Implement and Establish Phosphorus Recycling

There is a wide range of activities for the development of new technologies to recover phosphorus from waste. As the "International Conference on Nutrient Recovery from Waste Water Streams" in 2009 in Vancouver turned out, many newly developed techniques for the recovery of phosphorus from various kinds of waste have been developed. Some of them have already been tested in pilot or even industrial scale. Many presentations of German participants revealed Germany to be amongst the leading countries in the field of research and development on this issue. But countries like Canada, Japan and the United States are a step ahead with industrial application. Switzerland is already preparing legislative measures to implement phosphorus recycling.

There is still need of much effort to implement working phosphorus recycling. For the beginning, pilot plants for testing of the newly developed technologies are necessary to prove their practical feasibility. Besides the large-scale testing, the legal and economic framework must be adapted to the new challenges. As the waste water stream was identified to hold the largest potential for phosphorus recovery in Germany, we suggest to provide financial support not only from funding programmes but also from waste water fees. To give companies a signal of commitment for a secure perspective, the waste water ordinance must be amended by requirements for the recovery of phosphorus.

To avoid losses by co-incineration and to make the most of the phosphorus from sewage sludge, the capacity of mono-incineration plants must be increased significantly. Alternative techniques like the Mephrec® process, combining material and energy utilisation in a single step, must be favoured. The Renewable Energies Act (EEG) must be amended by the remuneration for sewage sludge energy from undiluted incineration (mono-incineration, Mephrec®)

Interim storage facilities must be installed, where phosphorus rich matrices like sewage sludge mono-incineration ashes can be separately stored to keep the phosphorus available for future recovery.

Studies comparing the quality of commercial fertilisers with that of recycling products show that the recycled products have a comparable fertilising effect and contain far less pollutants (Steingrobe 2009). A blending quota for recycled P in commercial fertilisers according to available quantities would help the recycling products to enter the fertiliser market. In case of struvite, the approval for organic agriculture should be considered.

4 Conclusion and Outlook

Unlike for oil, the problem of the limited availability of the essential resource phosphorus is not as present on political agendas as it should be. There is no single international organisation responsible for phosphate resources (Gilbert 2009), and only a limited number of political actors in just a few countries have already accepted the challenge to set the course for future food security.

Facing a growing demand for food of a growing population, the current available resources will be exhausted within decades. The exploration and mining of new, lower-grade deposits will only buy us more time but finally lead into dead end. Fortunately, solutions are within reach. Besides enormous potentials for decreasing consumption by increasing the efficiency of processes during the first lifecycle of mined phosphorus, we have also the option to recycle what we consume. Finally, recycling of phosphorus will provide sustainability and long-term food security.

In Germany, the waste water stream including sewage sludge, meat and bone meal as well as excess manure from livestock holds the highest potential for the recycling of phosphorus. More than the half of imported phosphorus could be substituted by recycled phosphorus. Most promising are techniques yielding bioavailable products like struvite or thermal processes with high recovery rates. Some of them also show that even material recycling and energy recovery are not mutually exclusive. But there is still need for political and financial support to bring these various options to life. Therefore, the author suggests the following measures:

- Legal requirements for the recovery of phosphorus from relevant material flows (e.g. waste water, sewage sludge, meat and bone meal)
- Legal recovery quotes according to best available techniques
- Blending quota for recycled phosphorus in fertilisers according to available quantities, approval of struvite for organic agriculture
- Prohibition of dilution of P-containing matrices, if P concentration is above 2% (separate and returnable storage)
- Financial support for implementation of phosphorus recovery techniques (waste water fee, funding programmes)
- Remuneration for sewage sludge energy from undiluted incineration (Amendment of Renewable Energies Act)
- Withdrawal from co-incineration of P rich sewage sludge until 2020
- Withdrawal from fertilisation with sewage sludge as safer alternatives become applicable
- Promotion of biological P elimination (Bio-P), withdrawal from precipitation with iron salts

If all these measures are promptly implemented, Germany would be able to substitute at least 50% of its annual phosphorus imports by recycled products until 2020. This would be an exemplary signal to the rest of the world and an excellent contribution to conservation of natural resources.

Now we have to take vital steps for the future, if we want to retain food security and a living world.

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Part VI
Concluding Chapter

Chapter 18
About the Need of Resource Efficiency Programmes: The Editors' View

Michael Angrick, Andreas Burger, and Harry Lehmann

In November 2009, one of us summarized the discussions held between Austria, Switzerland and Germany at the first three-country conference dealing with recycling and resource protection issues, which took place in Berlin under the heading "ReSource 2009". The conclusion from the conference was that just as a climate protection programme has helped to compile the various requirements and to instil a broader understanding of climate protection concerns among the public, we now need a resource protection programme which delivers similar results in the field of the conservation of natural resources.

Climate protection has come to be a principal public concern in many countries of the world. Policymakers have realized that taking action is a necessity if a climate catastrophe is to be prevented. It took far more than two decades to gain this insight. There are still significant barriers, and unfortunately, the outcome is uncertain. However, it also has been clear for a long time that environmental protection is a good deal more than just climate protection. The conservation of natural resources is another important module of a comprehensive protection of the environment. In its case, it was not until recent years that public interest in the complex relationships could be won. The aspect of ensuring supplies of raw materials has played a major role for countries poor in resources but having a high demand for them, and it is, of course, of particular importance for a high-tech country such as Germany. It is an irrelevant aspect in terms of an all-encompassing protection of the environment; it can, however, be used as a lever to change minds and attitudes. Protecting natural resources covers much more than establishing security of raw material supplies, which is a country-specific and therefore highly egocentric endeavour. Protecting natural resources means raising the issue of their efficient use and, far

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beyond that, the issue of our production and consumption patterns and therefore, of our lifestyles. The majority of the public has not (yet) realized that probably we and certainly our children and grandchildren will see major changes. In a few years' time, oil – the raw material our dreams are made of – will not be available on the same scale as it is today, not because politically unstable countries in the Near or Middle East will cut off our supplies, but simply because the reserves will become exhausted. We will see a similar development for a number of other raw materials, and yet others will be so scarce that there will be conflicts over access to them. Therefore, it is high time that policymakers take up this issue in all its breadth and depth and make provision to ensure that there will be no conflicts with uncertain outcome or massive interventions in our environment in order to make the last reserves of those scarce resources accessible to us. The German Federal Government has in fact embarked on such a course and commissioned the Federal Environment Ministry to develop a "resource protection programme", which has been adopted by the Cabinet as "Resource Efficiency Programme" (ProgRess) on February 29.

In its raw material strategy of 2010, the German Government already promised to launch the development of a national resource efficiency programme.

ProgRess provides an overview of existing activities, identifies need for action and describes measures to increase resource efficiency in order to achieve the goal, set in the Sustainability Strategy of 2002, of doubling raw material productivity by 2020 compared to 1994. ProgRess builds on the National Sustainability Strategy and its progress reports and focuses initially on abiotic, non-energy resources and the use of biotic resources for production of materials.

In order to successfully implement the measures addressed in ProgRess, many activities need to be carried out by numerous players in society on their own responsibility, and there must be close cooperation between the political, economic and scientific spheres and, ultimately, the participation of all parts of the population. The programme is intended to provide all players with a sound and long-term framework as regards the goals and priorities of sustainable resource use. The implementation of ProgRess will help to preserve the ecological basis of our existence and promote economic capacity, employment, social cohesion and international justice.

Regular evaluation and updating are envisaged to ensure progress and successes under the national Resource Efficiency Programme. This will enable early recognition of any need for adjustment and the initiation of targeted modifications. Figuratively speaking, the programme as it stands represents version 1.0., i.e. it can be assumed that it will be further developed. Mild or loose phrasing initially contained in the programme in the interests of compromise between the ministries can be honed and concretized in later versions.

The German Resource Efficiency Programme will be guided by four ideas:

- Resource policy combines ecological necessities with economic opportunities, innovativeness and social responsibility.
- Global responsibility is a key theme for a national resource policy.
- The dependency of the economy and production in Germany on the consumption of newly extracted raw materials will be lessened gradually, and recycling will be improved and increased.

- Sustainable resource use will be ensured in the longer term through orientation towards qualitative growth and the dematerialization of lifestyles and production methods.

The programme considers the entire value-added chain and formulates approaches for the various elements which, taken together and in interplay with each other, will make an important contribution to the conservation of natural resources.

Internationally, this programme will help to bring back Germany's position as a frontrunner of environmental policy.

As early as 1972, global awareness of the issue of resource protection was raised for the first time by the Club of Rome report "The Limits to Growth". Since then, the protection of natural resources has become a high-profile issue at both international and European level. At the UN conference in Rio de Janeiro in 1992, Agenda 21 was adopted, a global development and environment action programme for the twenty-first century which identifies the conservation and management of resources as one of its priorities.

The follow-up conference, the World Summit for Sustainable Development in Johannesburg, further addressed the protection of natural resources as an essential basis for sustainable development and gave recommendations for measures and implementation. At the UN Conference on Sustainable Development, to be held in 2012 in Rio de Janeiro, the international community will discuss options for moving towards a "green economy"; resource efficiency will play a key role in these deliberations.

The EU also has sustainable development as an overarching goal which applies to all policy sectors and actions of the Union. The EU Sustainable Development Strategy of 2006 identifies the conservation of natural resources as a key challenge, with the main focus on improving the management and avoiding overexploitation of natural resources.

With its programme, Germany will also make an important contribution to the implementation of the European Commission's Thematic Strategy on the sustainable use of natural resources of 2005, which already called on member states to develop national strategies. Since then, the resource efficiency issue has been gaining in importance in the EU. The Europe 2020 Strategy, adopted in 2010 by the European Council, devotes one of its flagship initiatives to a "resource-efficient Europe". The goals of this initiative are to decouple economic growth from resource use, encourage the transition to a low-carbon economy, promote energy efficiency and the use of renewable energy sources and modernize the transport system. The European Commission presented in 2011 the "Roadmap to a Resource Efficient Europe" for implementation of the flagship initiative.

Further activities, for instance, the World Resources Forum, are seen as good opportunities to develop the communication between countries and to improve the understanding for acting.

It is indeed urgently necessary that efforts at European level towards the conservation of natural resources be stepped up and that the European Union shows that it is prepared to play a role in the world and in global environmental protection that is appropriate to its political weight.

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