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Towards Sustainable Resource Management in the European Union

Wuppertal Papers

No. 121 · January 2002
ISSN 0949-5266

NRW.

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Content

Abstract

A policy framework for sustainable resource management (SRM) is required both to guarantee the materials and energy supply of the EU economy and safeguard the natural resource basis in the future. Goals and strategies for sustaining the metabolism of the economy are described. Data are presented on the material throughput and physical growth of the EU's economy, on total material requirements (TMR), its composition, the decoupling from economic growth, and the increased shift to other regions. A first future target Material Flow Balance (t-MFB) of the EU is outlined. Detailed data reveal the "top ten" resource flows. Policy design for SRM should aim at an integrated and balanced approach along the material flow, comprising resource extraction, the product cycle and final waste disposal. Strategies and potential instruments to manage fossil fuels, metals and industrial minerals, construction minerals and excavation are discussed. Possible priorities and examples are given for target setting, focusing on limited expansion of built-up area, reduced use of non-renewables, increased resource productivity, and shift to sustainable cultivation of biomass.

Key words: metabolism of the economy, resource management, material flows, physical growth, strategies for sustainability, total resource requirements, policy design, target setting

Zusammenfassung

Eine politische Rahmensetzung für ein Nachhaltiges Ressourcenmanagement (NRM) wird benötigt, um langfristig die Versorgung der EU-Wirtschaft mit Materialien und Energie ebenso zu sichern wie die natürliche Ressourcenbasis. Ziele und Strategien für einen nachhaltigen gesellschaftlichen Stoffwechsel werden beschrieben. Daten werden vorgestellt zu Stoffdurchsatz und physischem Wachstum der EU-Wirtschaft, ihrem Globalen Materialaufwand (GMA), seiner Zusammensetzung, Abkopplung vom Wirtschaftswachstum und seiner zunehmenden Verlagerung in andere Regionen. Eine erste Zielstoffstrombilanz der EU wird skizziert. Detaillierte Zahlen belegen die "Top Ten" der Ressourcenflüsse. Die Politik eines NRM sollte auf einen integrierten und balancierten Ansatz entlang des gesamten Stoffstromes von der Ressourcenextraktion, über den Produktzyklus bis zur Entsorgung abzielen. Strategien und potentielle Instrumente für das Management von fossilen Energieträgern, metallischen Rohstoffen, Industriemineralien, Baumineralien und Aushub werden diskutiert. Mögliche Prioritäten und Beispiele für Zielsetzungen werden vorgestellt. Der Fokus liegt auf der Begrenzung des Wachstums von Siedlungs- und Verkehrsfläche, der Reduktion des Einsatzes nicht-erneuerbarer Ressourcen, der Erhöhung der Ressourcenproduktivität und dem Umstieg auf nachhaltige Produktionsweisen für Biomasse.

Stichworte: Gesellschaftlicher Stoffwechsel, Ressourcenmanagement, Stoffströme, physisches Wachstum, Nachhaltigkeitsstrategien, Globaler Materialaufwand, Politikgestaltung, Zielsetzung

Introduction

The 6[th] Environment Action Programme (6EAP) of the European Commission defines objectives and major priorities for environmental policy over the next 5 to 10 years. One of four 'priority areas' within the 6EAP is "*Sustainable Use of Natural Resources and Management of Waste*" (CEC 2001). Main objectives within this priority area are:

- to ensure the consumption of renewable and non-renewable resources does not exceed the carrying capacity of the environment;
- to achieve a de-coupling of resource use from economic growth through significantly improved resource efficiency, dematerialisation of the economy, and waste prevention;
- to decouple the generation of waste from economic growth and achieve a significant overall reduction in the volumes of waste generated through improved waste prevention initiatives, better resource efficiency, and a shift to more sustainable consumption patterns, and

As regards resource efficiency and management, the 6EAP states that although many of the existing policy measures are directly or indirectly affecting the use of renewable and non-renewable natural resources, the Community still "lacks a coherent policy focused on achieving an overall decoupling of resource use from economic growth" (CEC 2001). Therefore, as a first step, the Community will develop a "*Thematic Strategy on the Sustainable Use of Natural Resources*". A Green Paper on this Thematic Strategy is due in autumn 2002.

This paper intends to provide background information for the design of an effective strategy of sustainable resource management (SRM). It shall also facilitate to widen our perspective for that purpose. The historical approach was to safeguard human health by protecting the environment against certain chemo-toxic hazards. It was about things which we do not want. The future approach of SRM, and a much more challenging task lying in front of us now, is to secure the supply of society with materials and energy. It is about things which we need and the pre-conditions to provide them.

1 Goals and strategies for sustainable resource management

Sustainable resource management aims at securing the physical basis of society and economy in the long run and in a way that neither resource extraction or use nor subsequent final disposal of waste and emissions exceed the capacities or tolerable limits of nature or society, respectively.

1.1 Material flows mediating between human activities and environmental impact

Most changes of the environment are brought about by human-induced material flows. The impacts can be quite different. They comprise (eco-)toxic effects, physico-chemical changes (acidification, etc.), nutritional effects (eutrophication or water stress due to groundwater abstraction by mining), mechanical destruction (e.g. by excavation, deposition, clearance), and structural effects (e.g. landscape changes, habitat disruption through infrastructure building). The consequences can be short-term or long-term, direct or indirect, local to global, predictable or unknown.

Each material flow may affect different environmental media at various scales. The flow of construction minerals starts with excavation which gives rise to hydro-geologic and biocoenotic changes. In this process, top-soil is completely removed and restructured. Thereafter, the use of the minerals often leads to additional built-up area, associated with a loss of ecological buffering and/or productive land. Finally, the ultimate demolition of the buildings and infrastructures and their deposition again requires land area and may impact on soil. All these processes require energy whose consumption with current technology burdens the atmosphere with fossil fuel emissions.

The impacts of material flows and stocks can be either *substance specific or system specific*. For instance, the chemical properties of a material or substance determine the eco-toxic effects, and as a consequence we speak of “hazardous materials”. Substances such as heavy metals or persistent organic chemicals may be effective in low doses. If the effect can be measured in quantitative terms, impact based indicators (e.g. on ozone depletion) can be used to indicate substance and effect specific impact potential.

However, there are also impacts which are not specific to materials properties. For instance, the change of landscapes associated with mining and quarrying is rather dependent on the amount of material extracted than on the chemical properties of the material moved[1]. Depending on the natural inventory before the extraction, the same is true for impacts on biodiversity. Even if reclamation activities are performed, abandoned mining sites are usually no longer appropriate for agriculture. Thus the extraction of non-renewables continuously diminishes the capacity of the production of renewables. The same is true for the sealing of land by additional buildings and houses. Thus, the use of "non-renewables" is not only a problem of "depletion" of those resources themselves. It is — and here the hypothesis is taken: even more — a problem of degrading and reducing the capacity of renewable supply. These problems may be regarded as *"creeping hazards"* which endanger a future sustainable supply and management of resources.

Because the property of being a non-renewable resource is largely determined by complex systems conditions and the turnover (quantitative use rate) of the material, the impacts associated with these flows are addressed as "system specific". Indicators designed to capture a generic impact potential for a certain system such as an economy are therefore rather turnover based (e.g. energy consumption, material requirement, water consumption). Specific impact-based and turnover-based indicators are complementary and non-exclusive (Bringezu 2000).

The use of non-renewables is a certain kind of "shifting cultivation" of industrial economies. There are not only irreversible changes to landscapes and detrimental environmental impacts. With regard to the impacts of resource use social effects may also be considered, indicated by legal cases between expropriated communities and state governments (where the community is expected to abandon their homes in order to give access to open-pit mining), NGOs and quarrying companies (in order to diminish disruption of the neighbourhood by noise and dust, or to avoid disruption of natural habitats).

Whereas the single activity and its related up-stream and down-stream flows may be neglected in terms of the ultimate effect, it is the combined impact of all single processes and process lines which determines the overall effect. Most of these activities are market driven and constitute the realm of the economy. It is the volume, structure and composition of the material throughput of the economy and also of its physical growth, which determine the quantity and quality of the resulting environmental (and social) pressure.

[1] This in turn gives rise to various eco-toxic effects, e.g. of leachates from mining

The notion of societal metabolism refers to the physical exchange between society, economy and technosphere (altogether the "anthroposphere"), on the one hand, and the environment, nature and bio-geosphere, on the other hand (Baccini and Brunner 1991, Ayres and Simonis 1994). The metabolism also comprises the material and energy flows and its functions and interlinkages within the anthroposphere. Ayres (1989) was one of the first to coin the term "industrial metabolism". The idea reflects a system perspective where the socioeconomic-technical system is embedded within a surrounding carrier system. A sustainable development requires the coexistence of both subsystems and thus will depend on essential preconditions of the metabolic exchange. The paradigm of a societal metabolism is rooted in different academic disciplines (Fischer-Kowalski 1998, 1999).

1.2 Requirements for a sustainable physical economy

The preconditions for a sustainable societal metabolism[2] may be defined from an ecological systems analysis view as:

- Keeping flows within natural capacities: The extraction of resources from the environment and the release of emissions into the environment can only be continued if the volume and composition of the flows do not exceed the spatial-temporal capacities of the environment. This relates to the local, regional and global capacities of resource supply and the assimilation of emissions and waste by nature. These requirements had long been defined by the so-called *management rules* (Daly 1990). With respect to the different economic regions or countries, the requirements also imply that the material exchange between countries and regions via trade, and inflow and outflow through waterways or the atmosphere should be balanced in quantitative and qualitative terms.
- *Limiting physical growth of the economy:* The physical growth of the technosphere must be superseded by a flow equilibrium of resource extraction and residual release, on a level which guarantees a long-term coexistence of man and nature. Currently the economy of most countries is in a phase of physical growth with the input of primary materials exceeding the output of emissions and waste. This expansion of the technosphere in form of additional buildings and infrastructures cannot be continued infinitely when one regards the limitation of available land. Sufficient land is required for the reproduction of biomass by agriculture and forestry as well as for nature conservation. The

[2] The terms "societal metabolism" and "physical economy" are used here synonymously although in a strict sense "society" comprises not only economic activities but also non-commercial activities

physical stock of the economy must be confined to a level at which life sustaining and service functions of nature can be sustained. This level is still unknown. However, accounting the physical growth rate indicates the deviation from equilibrium between inputs and outputs.

- Intragenerational equity: A region should not seek development at the expense of others. This applies not only to regions but to individuals as well. Hence, the use and burden of the environment by resource use (materials extraction and land use), on the one hand, and the release of emissions and waste, on the other hand, should not be unequally distributed *on a per-capita basis*.
- Intergenerational equity: The opportunities of future generations resulting from the societal metabolism must not be impaired by the current use of resources, the resulting materials and energy throughput, and the physical growth of the technosphere. Clearly, this requirement is the most challenging. It implies developing the volume and structure of the societal metabolism towards a *dynamic as well as continuous flow equilibrium system*. Dynamic in that sense refers to the flow character and the required changes in technology and in the composition of the flows. Continuous means that we need to establish supply and waste management systems, which can be continued in the long run.

1.3 Strategies to sustain the societal metabolism

Historically, human beings started to solve material flow problems within a limited scope of time and space (e.g. handling sewage and water pollution). Later they proceeded to tackle long-term and wide-range issues (e.g. global warming). The principle of “dilution and diversion” in pollution control policy then aimed at the reduction of critical emissions and the substitution of hazardous substances. After conspicuous incidents as in Minimata and Seveso, control of ambient concentrations (“immissions”) and chemicals assessment became compulsory in the 1970s and 1980s. The *“detoxification”* of the societal metabolism effectively reduced selected hazards in a variety of industrial countries. In a wider sense, this strategy can be related to any substance-specific impact such as toxicity to human beings and other organisms, eutrophication, acidification, ozone depletion, global warming, etc. Regulatory governmental actions like banning substances and use restrictions represented first measures of environmental policy. Cleaner technology aimed primarily at the mitigation of critical releases to the environment. Pollution problems in the spatial-temporal short range could thus be solved. However, transregional and global problems, and the problem shifting to future generations, as well as the complexity of the industrial metabolism made it necessary to analyse the flows of hazardous substances, selected materials or products in a system-wide approach, i.e. from “cradle-to-grave”, and with respect to the interlinkage of different flows.

Since the 1990s, another complementary strategy has increasingly been propagated, namely the "*dematerialisation*" of the industrial metabolism. Huge amounts of resource requirements of industrial economies made the reduction of the global primary resource consumption a prerequisite for sustainability. Taking the needs of developing countries and the social objective of equity in resource use, as well as ecological and economic concerns into account, scientists of the Wuppertal Institute proposed an increase of *resource efficiency* by factors of 4 and 10 over the next 30 to 50 years[3] (Schmidt-Bleek 1994, Weizsäcker et al. 1995). Also methods were developed to measure the total material consumption of national economies (Bringezu 1993). The proposed strategies made use of the systemic linkage between inputs and outputs because a reduction of overall output requires a prior, or at least simultaneous, reduction of resource inputs. Meanwhile many international organisations and national governments[4] adopted the factor 4 to 10 goal. The factor 4/10 concept aims at the provision of increased services in the sense of utility as well as economic value added with reduced resource requirements[5].

The concept of *eco-efficiency* goes even further. It includes not only the major inputs (materials, energy, water, land) but also specific critical outputs to the environment (emissions to air, waste water, solid waste) and relates them to the products, services or benefits produced (EEA 1999, OECD 1998, WBCSD 2000). However, an increase in eco-efficiency does not necessarily mean an absolute reduction of resource requirements or emissions. Eco-efficiency is a relative measure and may grow with rising environmental pressure. But for the environment the reduction of the absolute impacts through material flows is

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3 In general, factor 4 is seen as a step towards factor 10; the former has been more related to energy productivity in industrial countries within the next 30 years and the latter more to materials productivity and the absolute reduction of primary resource requirements of industrial countries within the next half of the century.

4 At the Earth Summit+5, the 19th special session of the General Assembly (UNGASS 1997), for the first time the concepts of eco-efficiency and factor 4/10 targets were included in the conclusions at United Nations. As a key representative of industry the World Business Council for Sustainable Development (WBCSD 1998) adopted the factor 4/10 concept. The environmental ministers of OECD (1996) expected progress towards this end. Several countries included the aim in political programmes (e.g. Austria, Netherlands, Finland, Sweden; see also Gardener and Sampat 1998). In Scandinavian countries research was launched to test the broad feasibility of factor 4/10 (Nordic Council of Ministers 1999). In Germany, the draft for an environmental policy programme (BMU 1998) referred to a factor of 2.5 increase in productivity of non-renewable raw materials (to be attained beween 1993 and 2020). The environmental ministers of the European Union (1999) also regarded an increase in eco-efficiency as essential. The review of the Fifth (environmental) Action Programme (Decision No. 2179/98, EC) emphasises resource use and efficiency. The Sixth Environment Action Programme of the EU includes the increase of resource efficiency as part of sustainable resource management as one of four priority concerns (European Union 2001).

5 Dematerialisation of the economy may imply a reduction of all hardware products and thus the throughput of the economy as a whole, comprising the use of primary and secondary materials. However, dematerialisation may also be directed more specifically to the reduction of the primary inputs and final waste disposal.

essential. Thus, the quantity of human-induced material flows through the industrial system has to be adjusted to tolerable levels of exchange between economy and environment.

In the future, we will not only have to eliminate or reduce the flow of critical substances and reduce the total resource requirements by becoming as efficient as possible but we will also have to find out which material flows can and should be continued in the long run. We will have to find out down to what level dematerialisation on a macro-scale can and should be implemented. In other words, we will have to describe the future physical basis of (post)-industrial economies. This means developing a perspective of a future societal metabolism where its volume, structure and composition meet the basic requirements of sustainability.

In the long run we will have to approach a level and composition of the overall materials throughput which can be continued. The system-wide regeneration of resources will therefore come into perspective as a necessary prerequisite for a sustainable societal metabolism, along with detoxification and dematerialization. Regeneration goes beyond renewability and comprises the regeneration of biotic and abiotic resources by natural and technological processes, respectively.[6] So far, biomass production and waste recycling were optimised for selected flows only. In the future, a life-cycle or system-wide perspective will have to be applied to increase the regeneration rate of the whole resource basis of our economies, adjusted to local and regional conditions.

Before we attain that kind of fine tuning of the societal metabolism, overall steering through dematerialization seems to be a precondition to reduce the currently dominant non-renewable and non-regenerated resource requirements[7]. We may keep in mind that the above-mentioned concepts are no end in themselves but strategies to steer the societal metabolism towards a situation when resource inputs and residual outputs are compatible, or consistent, with natural functions of environmental processes.

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6 Renewability refers to possibilities of regrowing or recycling a resource. Regeneration describes the reproduction of a resource (input) reproduced through reintegration of waste (output) materials into the economic process.

7 Abiotic (non-regrowing) raw materials currently dominate the input structure of industrial economies, and the share of abiotic resources which can be recycled is rather low. For instance, in 1996, only 26% of the domestic abiotic raw materials extraction in Germany was potentially recyclable for the same purpose. In addition, the production, use and waste management of biomass is to a large extent associated with linear materials and substance flows rather than cyclical ones that lead to regeneration.

Interim conclusions

When we compare the requirements and strategies for a sustainable physical economy with the goals formulated in existing EU policy and especially within the 6EAP we find that

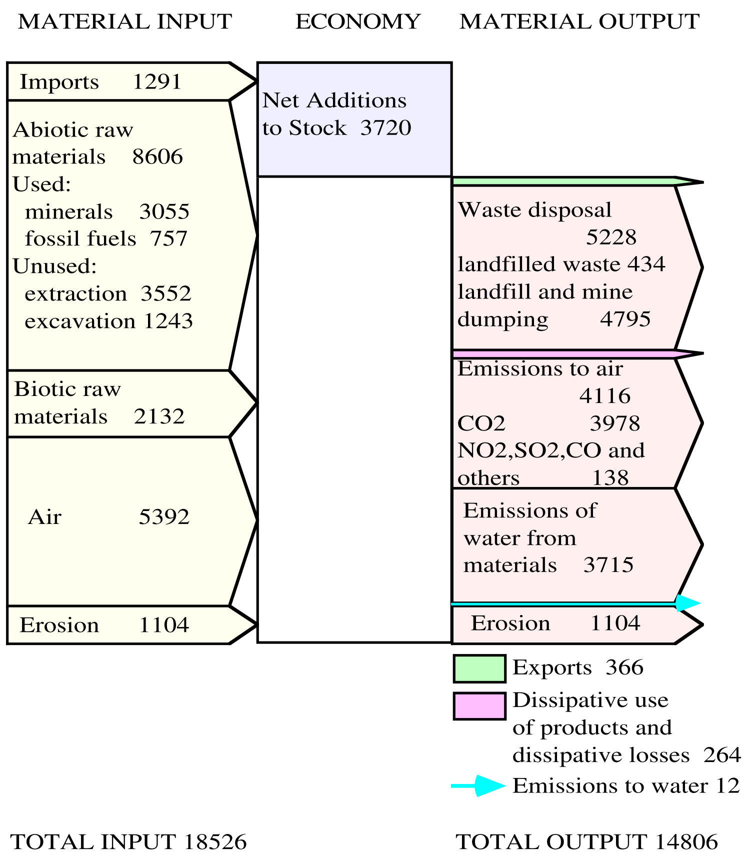
- the detoxification strategy is already well established in the form of pollution control and chemicals assessment regimes limiting the release of pollutants to air and water and controlling the use of hazardous substances; however, that approach is insufficient to manage the total material throughput and the linked flows of resources from and residuals to the environment in a sustainable way which prevents creeping hazards through a continuous irreversible change of the environment due to the unsustainable use of resources;
- European waste policy started from traditional waste management and progressed towards a waste policy hierarchy which regards waste prevention as a top priority; widening the perspective from safe disposal to waste prevention requires thinking in material flow terms; any effective prevention of waste coincides with the reduction of resource extraction; thus, waste prevention — and even more than this — prevention of all releases to the environment and the prevention of resource use are two sides of the same coin;
- the 6EAP has formulated the goal to increase resource efficiency; however, the remaining task is to define priority fields and concrete targets for implementation of resource efficiency policies;
- the limitation of the physical growth of the economy, or better its techno-sphere part, has not yet been formulated as a major goal;
- the regeneration strategy is also not yet considered in the context of sustain-able resource management.

2 The current situation

2.1 Material throughput and physical growth of the EU economy

Material flow balances allow to organise flow data in an integrated framework and to provide an overview on the domestic metabolism of an economy. As an example, Figure 2.1 presents the material balance for the EU-15 comprising all inputs and outputs besides water[8]. The input side comprises imported materials, materials harvested or extracted from the domestic

Figure 2.1: Material flow balance of the European Union 1996



Source: Bringezu and Schütz 2001b

8 The water included derives from materials (e.g. water which is evaporated from materials or formed as a result of combustion) and is mainly accounted for balancing purposes.

economy, and inputs of oxygen required for fossil fuel combustion and human and animal respiration. The physical growth of the economy is shown as net additions to stock. On the output side, the figure shows exported materials, outflows to land, air, and water.

Material flow balances are a necessary prerequisite for accounting the physical growth of the economy, and when provided over time they help to disclose flow shifts between environmental media (e.g. an increase of outflows towards the atmosphere which may result from reduced waste deposition). In addition, the balancing method allows the consistency of primary statistics to be checked as well.

The method of material flow balancing has been described in a methodological guide of Eurostat (2001). The guide was established in close cooperation with the Wuppertal Institute and shall assist the national statistical offices of Europe in setting up material flow accounts and derived indicators.

The material flow balance exhibits the current structure of the EU's physical economy:

- Abiotic resources exceed 4 times biotic (regrowing) resources: thus most of the material requirements are naturally non-renewable and contribute to the gradual depletion of geological deposits and continuous irreversible change of landscapes within the EU;
- Unused extraction exceeds 1.3 times used extraction: the so-called ecological rucksacks or hidden flows still constitute a significant share of the domestic resource extraction; these flows are not further processed nor do they have any economic value, instead they contribute to local environmental implications associated with the extraction, translocation, deposition and control of overburden, mining and quarrying waste;
- Biotic (regrowing) resources are associated with 0.5 tonnes erosion per tonne biomass: this net loss leads to a continuous reduction of fertile soil which threatens long-term agricultural productivity with significant variations between cultivation regimes and regions; a closer look reveals that erosion is especially significant in the southern regions of the EU;
- *Net additions to stock (NAS)* is 10 tonnes per capita: this is the average growth rate of the physical economy; this amount of material is stocked each year in additional buildings and infrastructures such as highways; NAS indicates that the EU's economy — like many other countries' — is still far from a physical flow equilibrium. In 1996 in the Member States NAS ranged between 7 and 28 tonnes per capita (Bringezu and Schütz 2001b). Between 1975 and 1996

the order of magnitude of NAS remained rather constant in countries such as Austria, Germany, Japan, Netherlands and the USA (Matthews et al. 2000).

- Landfill and mine dumping exceeds controlled waste disposal more than 11 times: the amount of rucksack flows is accounted on the input as well as on the output side of the balance; the data exhibit the relation of different waste flows; also as a consequence of such accounts environmental statistics increasingly consider mining waste;
- Emissions to air are dominated by carbon dioxide: a more disaggregated picture reveals that most of this carbon dioxide is of fossil origin and represents a massive shift of earth crust material into the atmosphere.

The material flow balance also exemplifies the inherent connection between resource input flows and subsequent outflows to the environment. The environmental burden associated with the volume of emission and waste streams cannot be reduced with continuously high resource inputs (if the input is not increasingly being stored). In addition, resource inputs have also impacts at the extraction side. Therefore, the data tentatively underpin the necessity of an absolute reduction of non-renewable resources, a dematerialisation and restructuring of the *physical* economy.

2.2 Total material requirements of the EU

Accounting for TMR

Sustainable resource management must consider the total resource requirements of an economy irrespective of whether the extraction takes place on domestic or foreign territory. Otherwise a shift of environmental burden would remain undiscovered. For instance, the EU increasingly imports electricity from other countries. If the associated resource requirements such as coal or oil extraction and the associated hidden or rucksack flows were not accounted for, the domestic material flow balance would indicate an improvement although in fact the overall burden to the environment may even have grown.

Material flow accounting may be used to differentiate and indicate the domestic and foreign resource requirements of an economy in a quantitative manner (Bringezu 2000, EUROSTAT 2001).

Total Material Requirement (TMR) comprehensively indicates the domestic resource extraction and the resource extraction associated with the supply of the imports. TMR thus measures the physical basis of an economy. It comprises raw materials which are further processed and have an economic value (= “used extraction”), as well as the so-called hidden or rucksack flows (= unused extraction). These latter flows which are not further processed and have no economic utility (e.g. mining waste and overburden) nevertheless burden the environment, especially in the local and regional surroundings of the extraction site (landscape changes, hydrological impacts, sometimes eco-toxic effects). Direct Material Input (DMI) is the part of TMR which comprises the domestic used extraction plus the mass of the imports.

> For instance, when lignite is mined in open pits such as in Germany the unused overburden which is extracted to get access to the coal exceeds the mass of the coal ten times. The resulting hole in the landscape would be significantly smaller if the overburden were not to exist. In reality, however, the overall extraction volume determines the extent of environmental (and social) impacts induced. Indicating the impact potential only based on the coal production volume would not be sufficient.

Analogous to the primary energy requirements, TMR measures the primary materials requirements. The former is quantified in Joule per time period. The latter is accounted for in tonnes per time period and comprises energetic and non-energetic materials.

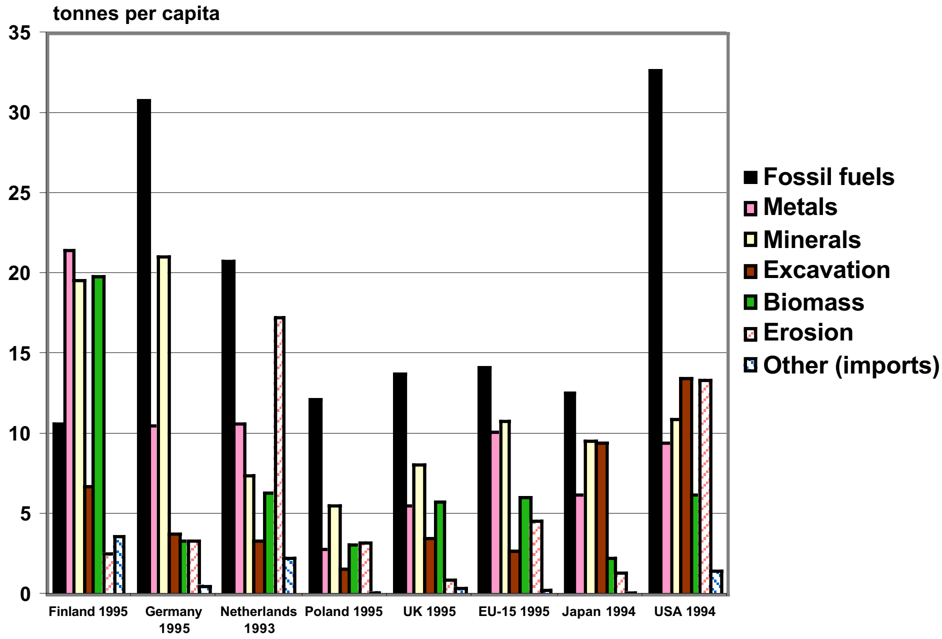
Composition of TMR

The structural analysis of TMR reveals similarities as well as differences in the countries investigated so far (Figure 2.2). The TMR of EU-15 was investigated and documented by Bringezu and Schütz (2001a). Similar to other single countries the major constituents of TMR are fossil fuels, minerals, and metals. Including hidden flows these natural resources represent almost three quarters (72%) of the European Union's TMR in 1995.

In the EU-15 fossil fuels contribute 29% to TMR of which nearly two thirds (63%) are from domestic resources. Coal, crude oil, refinery products and natural gas are the main components. 72% of the fossil fuels resource requirement are hidden flows. Metals hold 21% of TMR of which most (95%) are imported. The main components are ores and concentrates, metals, and products manufactured from iron, copper and other non-ferrous metals. Again, most (92%) of the total resource requirements for metals are hidden flows.

Minerals represent 22% of the EU's TMR most of which (91%) are domestically extracted. The main components are construction minerals, in particular sand and gravel, natural stones, and clays, as well as a variety of industrial minerals like salts, phosphates, diamonds and other precious stones. In contrast to metals and fossil fuels, a much smaller portion (24%) of the minerals resource requirement is due to hidden flows.

Figure 2.2: Composition of TMR in selected countries



Source: Bringezu and Schütz (2001b), Bringezu and Schütz (2001a) Chen and Qiao (2000), Mäenpää and Juutinen (1999), Schütz et al. (2000), Adriaanse et al. (1997).

Biomass accounts for 12% of the TMR of EU-15. The level of 6 tonnes per capita is similar in the USA. Most of the biomass stems from agriculture. Finland is an exception. Its input of biomass amounts to 23.5% of TMR and is dominated by forestry, a significant basis for the Finnish exports. The proportion of regrowing resources in Finland is almost twice the level of EU-15.

In total (including excavation for buildings and infrastructure, and soil erosion from agricultural land), non-regrowing materials account for 78% of the TMR of EU-15. The greater part of TMR (60%) are hidden flows. More than one third of total resource requirements (37%) come from foreign resources.

The conclusion is that the current composition of TMR is not sustainable in the long run, owing to the non-renewable character of extraction and the various impacts of producing and using these resources.

TMR and economic growth

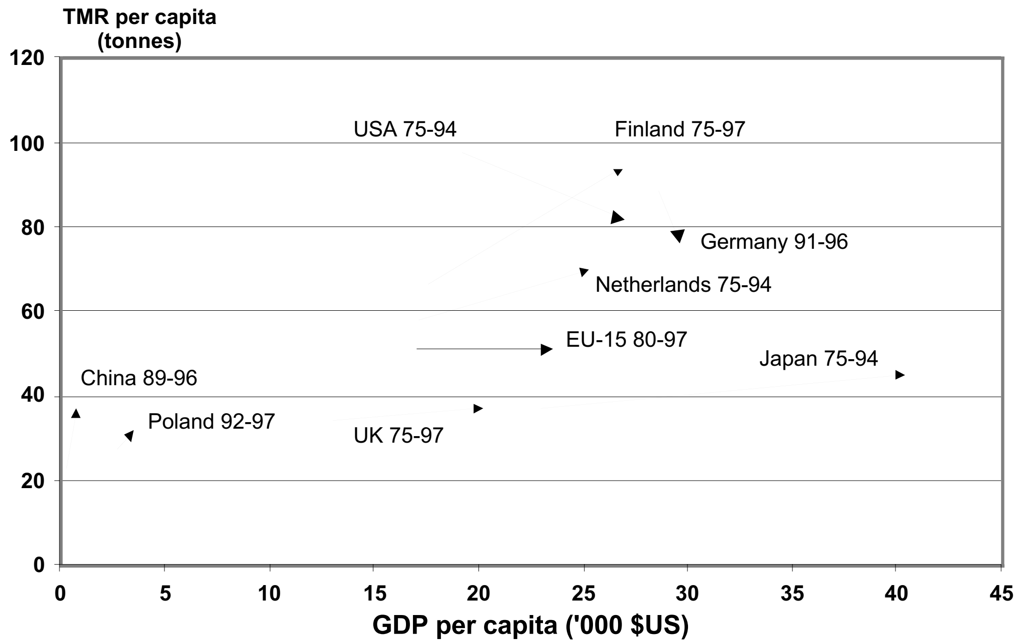
In general absolute levels of TMR are increasing with economic growth (Figure 2.3). There are exceptions. For instance, in the case of the USA a declining trend started from a particularly high level. The same applies for Germany after re-unification. In those countries where TMR is significantly lower, like in Japan or the UK, the absolute level of TMR is either slowly increasing or constant.

The decreasing trend in the USA resulted from a successful governmental programme to reduce erosion on arable land (Adriaanse et al. 1997). In Germany the declining tendency of TMR resulted primarily from closure of lignite mines in the eastern part, and was thus a result of technological conversion after the reunification of Germany in 1990. In the Federal Republic of Germany, the western part, TMR had been rather constant between the middle of the 1970s and 1990 (Bringezu and Schütz 2001a).

In accession countries such as Poland one may expect that the level of TMR will increase when joining the European Union through associated technological convergence. In China economic development is at an even lower level, although TMR has already reached 35 tonnes per capita. It is unlikely that this level will not be exceeded with future development.

The data thus suggest that business as usual will not lead to a reduction of the TMR of the EU and may be expected to contribute to an increase of TMR in accession countries.

Figure 2.3: Development of Total Material Requirements and GDP



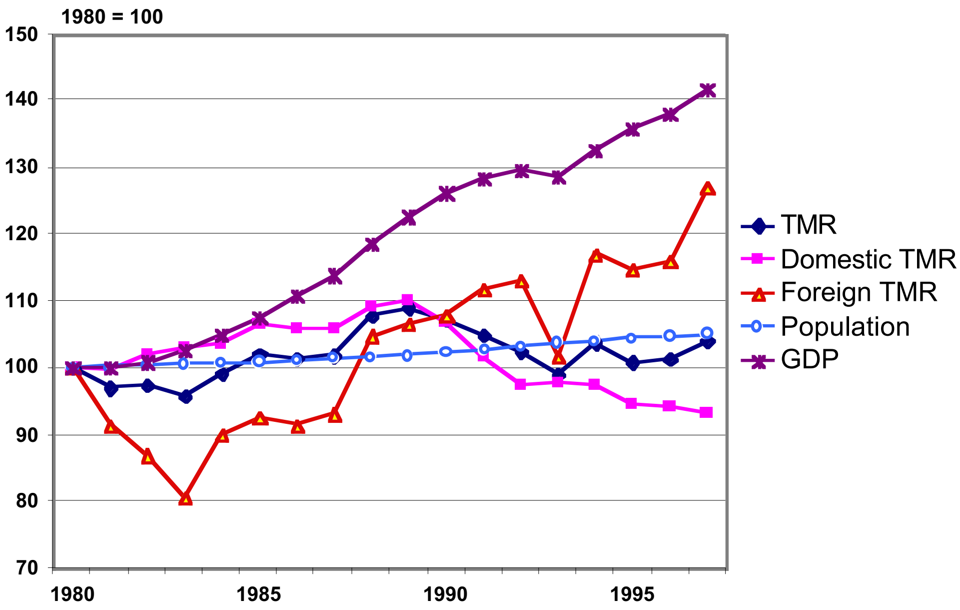
Source: Bringezu and Schütz (2001b), Bringezu and Schütz (2001a) Chen and Qiao (2000), Mäenpää and Juutinen (1999), Schütz et al. (2000), Adriaanse et al. (1997)

Burden shifting between regions

The European Union increasingly relies on foreign resources. As a consequence the environmental burden of resource extraction is shifted to the exporting regions. The domestic resource extraction within EU-15 has been slowly curtailed whilst resource requirements are to a growing extent supplied through imports from foreign countries (Figure 2.4).

Some of the European mineral deposits, for example iron ore mines, have been depleted for a long time. Nevertheless, some other mining activities continue, also for metal resources, within European countries. However, resource extraction within the EU is more resource efficient (in terms of the ratio of unused to used extraction) than resource extraction abroad for export to the EU (Table 2.1). Only for energy supply does domestic resource extraction per unit of raw material exceed that of the imported energy carriers.

Figure 2.4: Domestic and foreign resource extraction of the European Union



Source: Bringezu and Schütz 2001a

Table 2.1: Ratio of unused to used extraction for domestic and foreign resource requirements of the European Union, 1995 (raw materials only)

	Domestic	Foreign	Total
Fossil fuels	3.44	1.41	2.49
Metals	0.94	9.91	6.49
Minerals	0.22	5.71	0.30
Agricultural Biomass	0.62	8.90	0.84
Total	0.92	3.50	1.59

2.3 Arguments for impact assessment

Trying to find out those flows of the metabolism of an economy which are most critical for the environment is a difficult task with respect to the different material flows and the various impacts. As indicated in chapter 1.1. the impacts comprise material specific effects on the one hand, and systems specific effects which are independent from material properties on the other hand. For instance, ecotoxic effects are material specific (they are already subject to chemicals regulation and pollution control regimes). Systems specific effects, for example, relate to the capacity of regeneration of resources within a certain region. The extraction of non-renewable resources continuously diminishes this capacity, and the associated risk is largely determined by turnover volumes of non-renewables (policies for sustainable resource management are still lacking).

Considering the structure of the EU's metabolism, the following aspects seem critical for the assessment:

- The economy of the EU is growing not only in economic but still in physical terms; i.e. the technosphere (buildings, infrastructures) is expanding at the expense of natural and reproductive land; in Germany the current increase in built-up land is about 450 km^2 each year; continuing at this rate, in less than 700 years the country would be totally covered by buildings and highways; however, Germany and the EU as a whole will require most of its land area for sustainable supply with renewable resources from agriculture and forestry; in the future man-made assets will reach a certain level which is maintained by primary materials input for rebuilding, refurbishment and repair; the construction of new buildings or roads will be balanced by dismantling and retrofitting of old ones; thus, the current rate of physical growth will have to be diminished when approaching a sustainable condition of the economy;
- Most of the current EU resource requirements stem from non-renewable mineral deposits. Even in case of regular rehabilitation of abandoned extraction sites, the continuous change of landscapes contributes to the loss of reproductive land. Although Germany may not be regarded as a country heavily depending on the primary sector, the current domestic resource extraction directly transforms an area of about 40 km[9] each year; however, indirect effects (e.g. groundwater depletion) affect a much larger area around the extraction site[10]; and subsequent effects due to the movement, transformation, mobilisation and dispersion of extracted material affect all

9 Gwosdz and Lorenz (2000) estimate 33 km^2 of direct extraction area; considering also hard coal and on-site disposal of un-used extraction, 40 km^2 seems to be a reasonable estimate for direct landscape change

10 Another effect is the subsidence of land as a consequence of underground mining; in the Ruhr region about 75000 ha would be flooded if water inflow to land lowered by mining were not pumped out continously

environmental media from local to global scale; each ton extracted will be released to the environment sooner or later as waste or emissions, in various forms and at different locations; therefore, an absolute reduction of the extraction of non-renewables seems a necessary pre-requisite for sustaining supply of resources and waste management;

- Also most of the renewable (regrowing) resources used in the EU are not sustainably cultivated; especially erosion will lead to a continuous degradation of fertile soil; a large part of agricultural area is characterised by an overload of nutrients such as nitrogen through mineral fertilisers and/or manure; in 1998 organic farming area in the EU was still around 2% but is going to increase significantly since the EC regulation 2092/91 defining organic farming practices was established[11]; in future, supply with resources and regeneration of waste will primarily depend on biomass production, and thus sustainable agriculture and forestry practices will gain widespread attention;
- The emission of fossil based carbon dioxide dominates the releases to the atmosphere; this flow represents a massive disequilibrium of flows between the earth's crust and the atmosphere; those emissions are linked to the extraction of fossil fuels which are also coupled to an enormous amount of resource extraction, most of which is unused (ecological rucksacks);
- The EU economy is increasingly sourcing from other regions, the associated environmental burden is shifted from domestic resource extraction to foreign resource extraction; the increased share of imported resources is a symptom of a growing globalised market; besides the economic costs and benefits, the social and environmental repercussions are not fully understood; however, there are clear indications that increasing global disparities in access to resources and in environmental burden sharing are contributing to socio-cultural rifts, and increased danger of war and possibly terrorism; dependency on foreign resources may be significantly reduced by domestic increase of resource efficiency; any policy designed to foster sustainable resource management will have to consider these problems, aiming to reduce the further shift of environmental burden to other regions and securing sustainable domestic supply through addressing the use of primary resources by domestic extraction *and* via imports.

Interim Conclusions

The current status and actual development of the metabolism of the EU economy is characterised by unsustainable properties, especially

[11] Nic Lampkin and Peter Midmore (1999): Organic Farming in the European Union. Memorandum of Evidence to the House of Lords Select Committee on the European Communities Sub-Committee D (Agriculture, Fisheries and Food). http://www.aber.ac.uk/wirwww/organic

- physical expansion of the technosphere;
- composition of total material requirements largely based on non-renewables;
- shift from domestic to foreign resources;

In assessing the metabolism, a reduction of volume and composition of total resource requirements seems to be necessary in order to

- control the creeping hazards of resource extraction and net addition to stock, especially the continuous decline in the capacity to produce renewables;
- reduce the amount of outflows to the environment;
- change the unsustainable properties mentioned above.

3 Looking into the future: outline of a Target Material Flow Balance

There are some basic considerations on what a sustainable metabolism should look like. Let us look 200 years ahead and focus on the essential prerequisites of continuous supply and management of materials and energy in the EU. For a first sketch which provides only the rough outline of the metabolic structure, the minimum requirements comprise three basic elements:

1. The material supply will largely rely on sustainably cultivated biomass. For a first estimate we assume that the order of magnitude of current biomass production can be sustained (i.e. biomass input = const.).

   Also in future, basic human requirements for materials and energy will have to be met by sufficient and high quality food and feedstuff. In addition, renewable raw materials such as timber and fibres will have to be produced by forestry and agriculture. To a limited extent there will be some production facilities where highly valued biomass products such as vegetables are generated in containments such as glasshouse towers with high energy throughput and significant technological measures to cycle nutrient flows and control critical substances. However, most of the mass flow biomass products will be generated in open fields and forests in order to maximise the use of natural functions for the reproduction of biomass. Agriculture and forestry will become part of an integrated resource and waste management. The aim should be to integrate the use of biowaste residuals into the reproduction cycle, use the residuals of biowaste also for energy supply (e.g. through biomass fermentation and biogas production), and contribute to the continued generation of clean (ground) water. Cultivation practices will be applied which can be continued, which essentially contribute to maintaining natural functions and biodiversity[12] and allow to maximise the use of a diverse and multi-functional landscape for society (e.g. for recreation).

2. The physical growth of the technosphere will come to an end and evolve towards a flow equilibrium of construction and deconstruction (i.e. NAS = 0).[13]

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[12] See e.g. Weiger und Willer (1997)

[13] A reduction in NAS must not be interpreted as a reduction of improved living conditions because the technology we use is expected to provide these conditions (incl. adequate living room) with significantly less resources in the future (especially by dematerialised methods of construction)

The main reason is that an unlimited physical growth in material terms is associated with a continuous expansion of built-up land[14] which would increasingly cover an area needed for renewable supply. For the purpose of sustainable biomass supply, sufficient land area will be required. Maintaining the current order of biomass production within the EU, allowing sustainable cultivation practices to be applied throughout agriculture and forestry (and fisheries), and contributing to an increased share for non-food renewable raw materials, will require about 80% of the EU's area. From 1985 to 1994 the share of EU-15 land area (3.13 mill. km^2) which was used for biomass production in agriculture and forestry was reduced from 83.5% to 82.0%[15]. The absolute land use for the consumption of agricultural and forestry products within the EU may be expected to be even higher. For instance, if the imports and exports are considered, the absolute land use for the supply of agricultural products consumed in Germany exceeds the agricultural area within that country (about half of the territory) by 1.3 times (Loske et al. 1996).

Land is also required for the purpose of nature conservation and recreation. Assuming at least another 10% of the EU's territory to be reserved for that purpose, this would leave 10% for settlements and transport infrastructure. In 1991, at least 6.5% of the land was built-up in the EU-15 (EEA 1995 lists one third of Member States with data for 1980). In the same year in a large Member State such as Germany, building and transport area covered already 11.5%. In 1998 in Germany the share had grown to 12.2%. Between 1993 and 2000 the average rate of increase of built-up area was 123 ha/day. In 2000 it was 129 ha/day or 15m^2 per second (Statistisches Bundesamt 2001). If the rate continues, this would lead to double the extent of built-up land within about 90 years. Therefore, the degree of freedom for decisions to diminish the physical growth of the technosphere is already limited and declining rapidly.

3. The use of naturally non-renewable resources will be minimised (i.e. abiotic raw materials input will decline by 90% + x).

   The future metabolism will minimise inputs also in order to minimise residuals' output to the environment (emission to air and water, waste disposal). Industries involved in the supply of raw materials will increasingly shift towards the management of cycles within the economy and the use of secondary raw materials and renewable energy. Each ton of avoided extraction of non-renewables is also an avoided ton of waste and/or emission.

[14] Currently NAS and built-up land grow in a linear fashion; even if constructions tend to grow more towards the vertical dimension in the future, a long-term continuing net addition to stock will be associated with a certain increase of built-up area (we will preferably use solar radiation for lighting and passive and active energy supply of buildings which demands predominantly above-ground constructions which require solid foundations for static reasons).

[15] Using actual FAO data on arable land and permanent crops and permanent pastures and forest and woodland (http://apps.fao.org)

The use of mineral resources such as fossil fuels, metals and construction minerals is associated with a variety of different environmental (and social) impacts along the route from extraction to final disposal. The reduction of primary inputs and resulting outputs to the environment will also reduce *creeping hazards* of slowly but continuously changing living conditions. Here one of several aspects is the gradual depletion of the capacity of sustainable reproduction of renewables. Although the actual share of extraction land is relatively low, one has to consider that mining and quarrying activities can extract minerals only once on the same spot. Continued extraction of non-renewables always affects additional area and leads to a total devastation of the sites during the course of extraction. Reclamation of abandoned mining and quarrying sites — if it occurs — often does not allow for agricultural production (e.g. if a lake is established or soil or ground water contamination is still too high), and a reestablishment of farming may require soil excavation from other sites (not to speak of the financial resources needed). In general, the extraction of non-renewables steadily contributes to the degradation of natural and reproductive land.

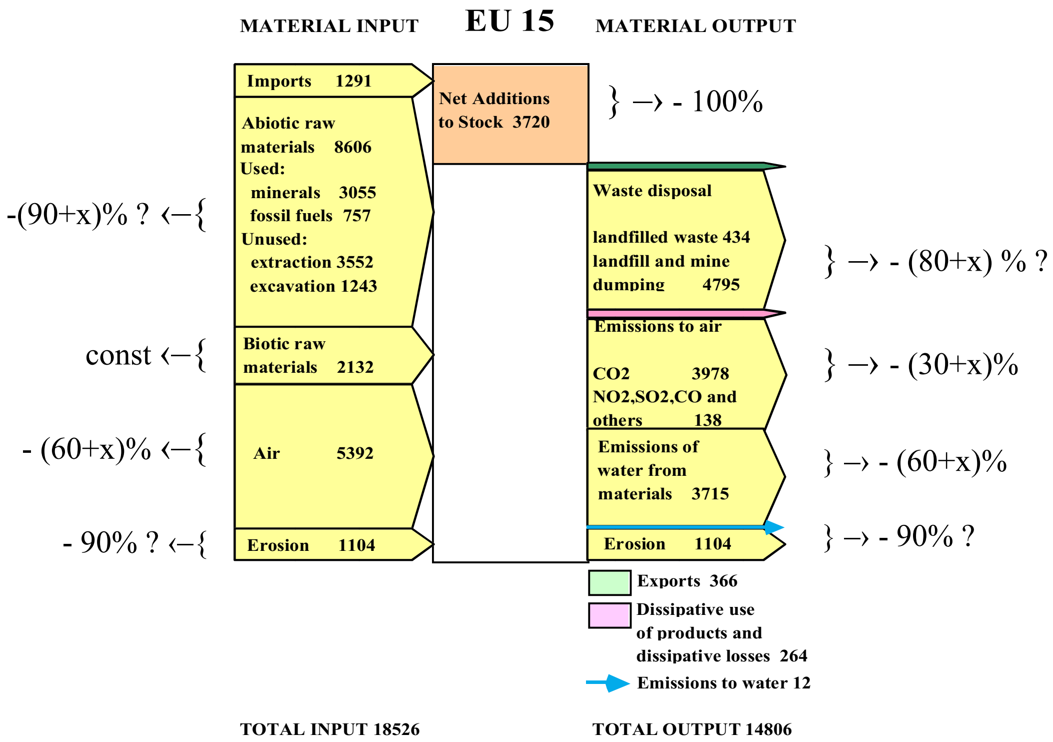
Those three main elements provide a first outline of a so-called target Material Flow Balance (t-MFB) of the European Union (Figure 3.1). Based on the situation in 1996, a reduction of the abiotic input by 90% is applied to domestic extraction and imports as well, affecting fossil fuels, metals, construction and industrial minerals altogether, based on their current proportions. The corresponding changes of the other major input and output flows have been estimated based on stoechiometric calculations assuming *ceteris paribus* conditions. Assuming also a transition towards sustainable cultivation schemes, the amount of erosion linked to agriculture is also reduced by 90%.

There are some interesting insights from this first outline. Because resource flows for construction constitute a significant share of the current resource requirements and are mainly used for the expansion of the technosphere, the reduction of these non-renewable flows by 90% coincides with a situation of zero NAS.

The reduction of waste disposal could range between 80 and 90%. This is still far from targets such as the zero waste deposition aim of the German environmental minister (however sensible this may be from a perspective of sustainable metabolism). Here, however, this results from the fact that in this first outline no further assumptions were made, for instance, on the reduction of non-renewable inputs (through efficiency gains, etc.) below the level of a flow equilibrium of inflows and current outflows. In addition, the question whether and how these remaining non-renewable flows could sustainably be provided is not considered yet. Neither are the dynamics of the stock of buildings and infrastructures regarded with respect to a possible increase of construction waste volume. If these aspects were to be considered, comprehensive dynamic modelling would be required based on differentiated physical data.

Although the reduction of fossil fuel input would reduce the fossil CO_2 also by 90%, the overall emissions to air (mainly CO_2) would only be diminished by 30-40%. Most of the remaining emissions will result from the complete oxidisation of biomass (either through respiration or incineration).

Figure 3.1: Outline of a target Material Flow Balance of EU-15. Target rates of change are based on the situation in 1996.



The production, use, disposal and regeneration of biomass would be a continuous cycle driven by renewable energy. Regenerated carbon would be the major constituent of this materials cycle. Even with a complete phase-out of fossil fuels, a sustainable societal metabolism would not be "decarbonised" as is sometimes advocated. Considering the biological regeneration cycle of cultivated biomass, the metaphor of "carbocycling" seems more compelling.

For this first sketch, the figures of the dissipative use of products and the emissions into water have not yet been changed, although a sustainable metabolism will also require a reduction of those flows and an appropriate fitting of the biowaste residuals and their nutrient content used for fertilisation purposes on the one hand and the biomass generated on the other hand. More detailed analysis is required to outline future scenarios in that respect.

Interim conclusions

Looking to the future, a significant change of the structure of the EU's metabolism towards the implementation of sustainability criteria will require:

- limitation of the expansion of the technosphere in the form of additional buildings and infrastructures (especially roads and highways) until an equilibrium of new constructions and deconstruction of old ones;
- a significant reduction of the share and absolute amount of non-regrowing resources used, of energetic and non-energetic non-renewables, i.e. fossil fuels, construction and industrial minerals and metals;
- shift of agriculture and forestry towards sustainable biomass cultivation (including reduced erosion and the recycling of biowaste nutrients).

4 Looking into more detail: major non-renewable resource flows and their implications

We will now look at those flows which significantly contribute to the current resource requirements of the EU. The question is which primary materials contribute major potentials to possible gains in resource efficiency, and are expected to be substituted (by recycled materials) or avoided (through resource efficient technologies) in the course of sustaining the EU's metabolism.

Long-term SRM will have to consider total resource requirements. Thus, the question arises which flows contribute most to the current TMR of the EU and especially to the non-sustainable part of it. Therefore, a focus on naturally non-renewables (incl. erosion) seems appropriate (not implying the current biomass production meets sustainability standards).

> Although all the different material flows have their own specificities (in terms of chemical composition, ways of extraction, use and disposal, known hazards and possible long-term effects), the trend of the mass turnover of primary materials indicates the generic impact potential for a variety of environmental and social problems. On the aggregation level of a national economy or for the EU as whole, the turnover of resource flows may be interpreted quite in the same way as the total requirements of primary energy, i.e. the lower the requirement, the lower the environmental impact potential (especially for a given mix). Thus, these turnover based indicators fairly complement the substance specific risk assessment of the chemicals regulations[16]. The indicators also cure a deficiency of local environmental impact assessment which in practice allows only for finding site or production alternatives with *relatively* lower environmental burden, but which is not capable of portraying the overall development resulting from a variety of different production sites.

[16] For interpretation of turnover based indicators of environmental impact potential see Bringezu (2000, 2001)

In 1997, non-renewable resource requirements of the EU were dominated by fossil fuels (29% of TMR), metals (23%), and construction minerals (19%). Table 4.1[17] lists those resource flows contributing at least 10 mill. tonnes per year to the EU's TMR. A closer look at the major flows reveals the following *top ten* categories (excluding biomass):

- Fossil fuels: lignite, hard coal, oil
- Metals: precious metals, copper, iron
- Construction minerals: sand/gravel/stones, limestone/calcareous stone
- Others: excavation, erosion

Those 10 flow categories comprise 76% of the EU's TMR. The share of domestic extraction varies significantly between the different resource flows. For instance, it is highest for limestone and lignite, and lowest for precious metals and iron. The rucksack or hidden flows represent that part of the resource extraction which is not used for further processing and which predominantly burdens the environment near to the extraction sites. The proportion of hidden flows is highest for raw materials such as precious metals, and lowest for raw materials such as oil and sand/gravel/stones. Flows such as excavation and erosion are completely hidden flows per definition.

Ores and concentrates of precious metals comprise gold, silver and platinum-group metals. They have been grouped according to Combined Nomenclature (CN) classification and due to lacking information in the specific shares. Here the available information is used to provide a minimum estimate based on the hidden flow ratio of gold. Clearly further data is required to quantify the resource flows of precious metals, ores and concentrates more precisely. For semi-manufactures of gold, silver and platinum, separate CN classes do exist. Further research should also reveal the production and consumption and waste management processes which take up these raw materials.

[17] Notes of Table 4.1
(1) domestic extraction of metals: subcategories of metals here are not yet corrected for other possible values from original databases like from Finland, whereas the total for metals is corrected; therefore the subcategory "other metals" which is obtained by the total minus the named categories may not exactly represent the mass of metals excluding all the named ones.
(2) the distinction of industrial and construction minerals needs further refinement; due to insufficient and inconsistent databases (UN, EMY, USGS) these differentiations can not yet be made for the entire time series. Consequently, industrial minerals are here under-, construction minerals over-estimated.
(3) TMR of diamonds and other precious stones is determined by hidden flows of diamonds because hidden flows of other precious stones have not yet been considered
(4) domestic extraction of construction minerals: needs further refinement, only very rough allocation of EU-data, not yet corrected for specific UK, etc., data.
(5) imports: for the 2nd level data (lignite, etc.) direct statistical data of EU-15 are available for 1995 to 1997. Data of EU-15 for 1980 to 1994 are only available for the higher aggregation level (fossil fuels, etc.).

Table 4.1: Components of the Total Material Requirements of EU-15, 1997

EU-15	TMR													Foreign TMR (5)					
1997	Absolute					Share domestic	Proportion of HF	Trend		Trend		Trend		Trend		Trend		Trend	
	million t	%	Rank	%	Rank	%	%	80-97	Rank	92-97	Rank	95-97	Rank	80-97	Rank	92-97	Rank	95-97	Rank
Fossil fuels	5489	29%	1			62%	72%	-14%	8	-6%	6	-2%	36	17%	3	8%	3	5%	16
Lignite	2447			12,7%	1	99%	90%					-8%	39					-4%	35
Hard coal	1577			8,2%	4	36%	83%					1%	23					3%	21
Oil	787			4,1%	9	21%	13%					2%	18					3%	20
Gas	367			1,9%	16	60%	15%					20%	2					42%	2
Electricity	280			1,5%	17	0%	100%					9%	7					9%	10
Other fuels	32			0,2%	33	65%	15%					-39%	44					-62%	45
Metals (1)	4360	23%	2			4%	93%	31%	2	26%	2	15%	4	41%	2	29%	2	17%	5
Precious metals (ores and concentrats not further specified)	1773			9,2%	2	0%	100%					65%	1					65%	1
Copper	773			4,0%	10	8%	95%					6%	12					4%	17
Iron	542			2,8%	13	7%	67%					-10%	41					-9%	41
Tin	420			2,2%	14	0%	100%					3%	16					3%	19
Gold	370			1,9%	15	2%	98%					-18%	43					-19%	44
Silver	130			0,7%	21	21%	91%					-11%	42					-8%	40
Platinum	90			0,5%	23	0%	100%					7%	9					7%	12
Aluminium	70			0,4%	24	40%	75%					2%	20					5%	15
Titanium	62			0,3%	27	0%	98%					11%	5					11%	9
Zinc	39			0,2%	32	26%	69%					-2%	33					-3%	33
Nickel	27			0,1%	35	9%	90%					-5%	38					-4%	34
Molybdenum	20			0,1%	36	0%	100%					-1%	30					-1%	30
Lead	13			0,1%	38	25%	73%					0%	27					1%	23
Other metals	29			0,2%	34	11%	25%					-43%	45					-1%	32
Industrial minerals (2)	555	3%	7			38%	67%	4%	6	-32%	8	9%	8	-8%	7	-50%	8	12%	7
Diamonds a.o. precious stones (3)	232			1,2%	20	0%	100%					19%	3					19%	4
Phosphate	69			0,4%	25	0%	85%					3%	15					3%	18
Industrial sands	63			0,3%	26	96%	2%					3%	17					6%	14
Potash	57			0,3%	28	68%	71%					0%	29					-5%	36
Industrial clays	45			0,2%	30	77%	62%					2%	19					11%	8
Salt	43			0,2%	31	96%	3%					4%	14					21%	3
other ind. Minerals	48			0,2%	29	67%	25%					0%	26					-12%	42
Metals and Industrial minerals	4915					8%	90%												
Construction minerals (2,4)	3491	18%	3			99%	18%	17%	3	0%	4	-1%	31	0%	5	0%	5	-7%	37
Natural stones	1423			7,4%	5	96%	19%					1%	22					-8%	39
Sand and gravel	1198			6,2%	7	100%	13%					-4%	37					0%	24
Limestone, calc. Stone	760			4,0%	11	100%	25%					1%	21					14%	6
Clays	110			0,6%	22	100%	22%					-8%	40					0%	24
Minerals	8406					46%	60%												
Excavation and dredging	1231	6%	6			100%	100%	7%	5	-7%	7	-1%	32	0%	5	0%	5	0%	24
Excavation	975			5,1%	8	100%	100%					-2%	35					0%	24
Dredging	256			1,3%	18	100%	100%					0%	28					0%	24
Biomass	2327	12%	4			93%	0%	8%	4	8%	3	6%	11	-10%	8	-13%	7	-7%	38
Biomass from agriculture: from harvest and processing	1331			6,9%	6	93%	0%					5%	13					-13%	43
Biomass from agriculture: from grazing	735			3,8%	12	100%	0%					10%	6					0%	24
Biomass from forestry	247			1,3%	19	77%	0%					1%	25					2%	22
Biomass from fishing, hunting	14			0,1%	37	71%	23%					1%	24					8%	11
Erosion	1646	9%	5	8,6%	3	66%	100%	-5%	7	-1%	5	-2%	34	6%	4	5%	4	-1%	31
Other (imports)	110	1%	8			0%	20%	175%	1	61%	1	6%	10	175%	1	61%	1	6%	13
TMR	**19209**	**100%**				**61%**	**62%**	**5%**		**2%**		**3%**		**27%**		**13%**		**11%**	

The long-term trend from 1980 to 1997 shows that especially the import of finished goods is growing significantly. Metal resources and construction minerals also show an increasing trend. Slightly diminishing trends can be observed for fossil fuels and industrial minerals.

The shift to foreign resources is a long-term trend especially for fossil fuel and metals. From the top ten non-renewable resources, the following categories show a higher increase or lower decrease of the imports between 1995 and 1997: lignite, hard coal, oil, iron, precious metals, and erosion[18].

These data indicate that an effective strategy to reduce the use of non-renewables cannot only aim at the reduction of domestic extraction but should also *aim at the reduction of the demand* for primary materials in the production and consumption chain. Otherwise the domestic resources would only be substituted by imports. This has to be considered for instance in the case of hard coal, the extraction of which is subsidised in Member States for social reasons. If the subsidies were to be cut without adequate measures to reduce the demand for electricity from coal (e.g. through efficiency programmes), the only result would be a shift towards the import of coal from other countries. The environmental burden would be transferred to other countries, and may be even increased (e.g. when hard coal from open pit mining is used).

Interim conclusions

- The top ten of non-renewable resources can be addressed with regard to their contribution to total material requirements; all of them are associated with different environmental impacts;
- However, a policy design aiming at the reduction of selected flows will be at the risk of inducing a shift to other flows with another bundle of impacts; instead, the combined resource use of fossil fuels, metals and construction minerals should be significantly reduced;
- An effective strategy to reduce the amount of resource flows should aim at the reduction of the demand for primary resources. Otherwise environmental burden would only be shifted between regions.

[18] The absolute imports of limestone can be neglected, although the imports are also increasing

5 Towards a policy framework for sustainable resource management

Where should policies for SRM start and what measures should be taken? Any energy oriented policy will set targets for the non-renewable or renewable energy supply volume and for the mix of the different energy carriers. Analogously, the question arises whether or to what extent a sustainable materials management policy should not only set targets for the total material requirements of renewable and non-renewable primary materials but also indicate the preferred materials mix in the future. With a limited number of energy carriers the task seems manageable. However, with a huge variety of material resources the question is whether it makes sense to decide which resources should be preferred over others and, if so, on the basis of which criteria. Substance- or material-specific hazards should be approached by chemical and pollution control measures, and for that purpose, regulations are already in place in the EU and the Member States. However, a targeted and integrated approach to foster a sustainable structure of the societal metabolism which guarantees a sustainable supply with materials and energy is lacking.

Any policy action should aim at certain priorities in order to be effective and efficient as well. Here, the question is whether priority setting for sustainable resource management should orientate towards selected resources. For instance, in the case of metals, primary copper may be regarded of prior importance due to its significant contribution to TMR and to various pollution problems associated with copper mining. If targeted measures were designed to reduce the use of primary copper we should expect a contribution to reduced environmental burden. We may also expect that copper will be substituted by other metals. Depending on the required technological properties and prices, for instance, aluminium, nickel, palladium, silver and other metals could probably be used instead of copper for a variety of uses. If, as a result, the use of these metals were to increase, the volume of other resource flows would grow, along with different pollution effects, and there would be no reason to assume that the environmental burden would be reduced. Thus, policy design should minimise the possibilities of burden shifting between potentially substitutable resource flows.

5.1 Policy design for balanced material flow management

Within the material flow system different points of leverage are possible. There are existing instruments to control certain flow sections, but as such they are not sufficient to sustain the metabolism of the EU economy as a whole. Nevertheless, the development of an integrated policy framework for SRM does not need to start from scratch but can be based on existing regulations and measures which can be supplemented by, combined with and in the future possibly substituted by new instruments.

Basically three major leverage points or rather target areas can be distinguished with respect to the materials metabolism (Figure 5.1):

- the entry of primary resources
- the product system (comprising production, consumption and recycling)
- the exit of waste residuals

Historically, policies aiming at the materials flow system started with the exit. Final disposal of waste was first regulated by technical standards aiming to control hazardous effluents and emissions. In the second half of the 1990s, land fill taxes were increasingly used as an incentive to reduce final waste disposal. These leverages have been successful in some Member States in reducing the amount of waste deposition. However, they have not been sufficient to reduce the generation of waste and the demand for primary materials.

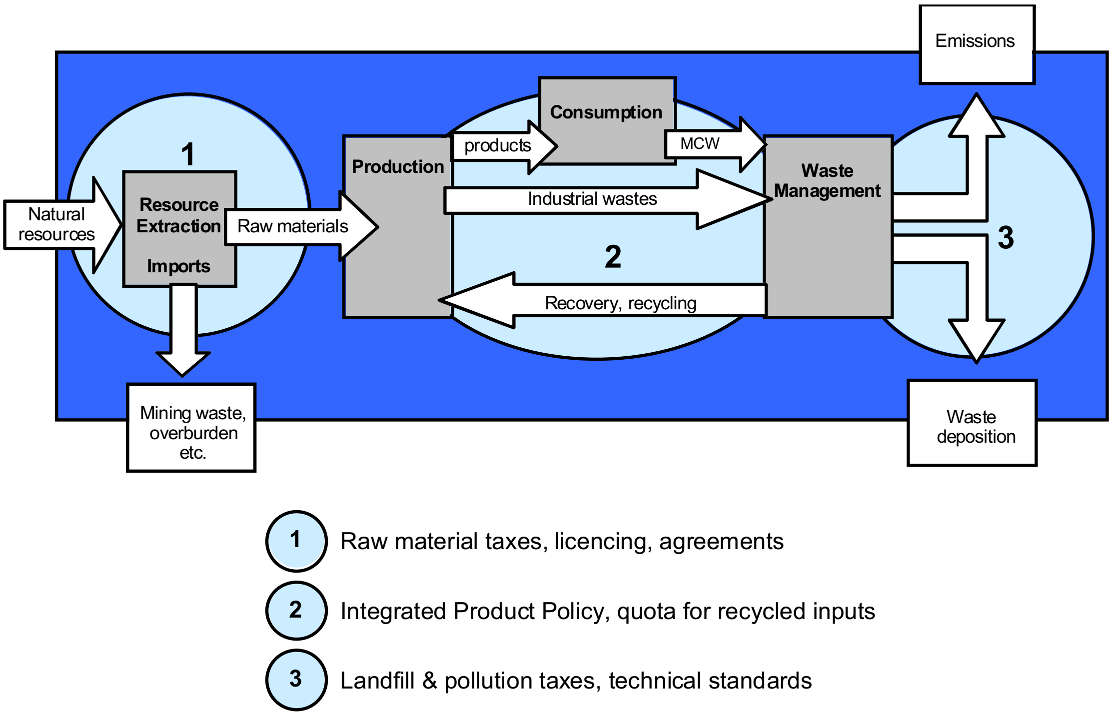
Recycling quotas were introduced for selected waste flows such as packaging materials to enhance the substitution of secondary materials for primary ones. Some voluntary agreements of industry, for instance, to recycle construction and demolition waste were successful to further reduce waste disposal. However, large product flows are still associated with extended flows of primary resource inflows and waste outflows. Selected product groups are now subject to considerations on how to design and enforce an Integrated Product Policy (IPP), extend producers' responsibility for products and widen the use of take-back systems. The aim is to foster materials cycling, increase life-cycle-wide materials and energy efficiency, reduce the generation of waste and the demand for primary materials.

However, there is a variety of different product groups with various specificities, and if the policy approach were to arrange detailed regulations or agreements for each product group, the effort for policy design and implementation would be tremendous. Nevertheless, the IPP approach is indispensable. The measures of IPP will have to be designed also to effectively reduce the life-cycle-wide demand for primary resources.

Here a basic impediment pops up. The price of primary resources is usually much too low to provide an effective incentive for substitution and increase in resource efficiency in the manufacturing sector. This purpose can be achieved by supplementary measures such as raw material taxes and restrictive licensing policies for the extraction sector.

Policies aiming at only one of those three basic leverage points will probably fail. An effective policy for SRM will be based on a material flow management which balances the pressures on the different actors and combines upstream and downstream incentives. A balanced flow system for sustainable supply, use and waste management will require an appropriate mix of instruments aiming at all three stages along the material flow.

Figure 5.1: Main target areas for a balanced material flow policy with examples of selected measures[19].



[19] For a better overview, the emissions from extraction, production and consumption have been omitted

5.2 Making resources more precious

The implementation of raw material taxes in several Member States of the European Union started in the 1990s.

In Sweden the Tax on Natural Gravel was introduced in July 1996 to encourage the conservation of natural gravel. The Geological Survey of Sweden had calculated that Sweden will run out of natural gravel within 20 years in some 40 municipalities, assuming production at the 1996 level[20]. The objective of the tax was to achieve proportions of 70/30 between the use of crushed rock and natural gravel. A target was set: by 2010 the extraction of gravel in the country shall not exceed 12 million tonnes per year and the proportion of reused materials shall represent at least 15% of the ballast used (Ministry of Environment 2000). The tax rate is 0.58 EUR per tonne sand and gravel. The forecasted revenue for the year 1999 was 11.6 million EUR. Tax revenue is used for the general budget.

In Denmark the tax on waste and raw materials is regulated in the Raw Materials Act of 1997. The act applies to both raw materials and waste. It uniquely defines the distinction between recovered waste on the one hand and primary raw materials on the other hand. Focus is laid on construction minerals on the input side and construction and demolition waste on the output side (Ecotec 2001). The purpose of the tax is to reduce resource use and to support the Danish waste hierarchy. It is to ensure that exploitation of raw material deposits is based on the principles of sustainable development. The supply of raw materials to the society shall be ensured in the long term, and the raw materials are to be used according to their quality, i.e. materials of high quality shall not be used where low grade materials are available. Furthermore waste products shall be used to the greatest possible extent as a substitute for primary resources. The tax rate is 0.67 EUR /m^3 for natural raw materials such as stones/gravel/sand, clay, limestone, chalk, peat, top soil, and similar materials. Exemptions are, for instance, extraction for seaside protection. Revenues are used for general budget.

In the United Kingdom the Aggregates Levy will be introduced in April 2002 (Ecotec 2001, HM Customs and Excise Information Service 2001). It will apply to sand, gravel and crushed rock commercially exploited, including aggregate dredged from the seabed. The objective is to address the environmental costs associated with quarrying operations (noise, dust, visual intrusion, loss of amenity and damage to biodiversity) in line with the UK Government's strategy of, over time, shifting the burden of taxation from "goods" such as labour, to "bads" such as environmental pollution and resource use. It further aims to reduce demand for

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[20] Pers. communication between J. Hellberg and S. Moll, 8/2001

virgin aggregate and encourage the use of re-cycled materials. The levy will apply to extraction in the UK as well as imports. Exports will be exempted as well as recycled aggregates. There is a comprehensive range of exemptions for other quarried or mined products such as coal, metal ores, industrial minerals, etc. The tax rate will be £ 1.60 (EUR 2.53) per tonne. The levy will raise around £ 380 (EUR 601.9) million per year — all of which will be returned to business through a 0.1% point cut in employer NICs (social security contributions) and a new Sustainability Fund aimed at delivering local environmental benefits to areas subject to the environmental costs of aggregates extraction. There will be no net gain to the Exchequer from this reform. The Government will be consulting on how the new Sustainability Fund can best be used to deliver local environmental benefits.

As regards the effectiveness of those resource taxes, the first experiences are interesting. In Sweden the levy increased the price of gravel by about 10 percent and led to a reduction of gravel in the same order of magnitude, corresponding to about 6 million tons. As intended by the government the material was substituted by crushed rock. Therefore, the tax contributed to the conservation of gravel, but only at the expense of an increased use of another resource and the associated environmental burden.

The Danish landfill tax significantly reduced deposition of demolition waste. However, based on a much lower levy per tonne, the raw materials tax did not halt the increase of the use of construction minerals which can be observed in Denmark since the mid-nineties. Obviously the level of the tax was not sufficient to induce dematerialised modes of construction with a reduced demand for aggregates. The level of the envisaged aggregate tax in the UK is significantly higher than in Denmark, and it will be interesting to monitor the effectiveness.

Altogether, an effective reduction of resource extraction will only be reached if the applied instruments lead to a reduced demand for the resources within the production/consumption system. For that purpose, final demand will have to be met by new approaches to provide the utilities and services needed. Technologies must be further developed which allow resource efficient ways of production and reduce life-cycle-wide resource requirements of products (incl. constructions). A balanced policy framework will rely on an appropriate combination of resource, product and waste oriented incentives which complement each other in driving innovation towards SRM.

5.3 Strategies and instruments to manage major resources

When we look at the major resource flow categories of naturally non-renewables we can describe those strategies, target groups and potential measures which should be considered within a policy framework for SRM (Table 5.1).

There are three main strategies common to managing fossils, metals and industrial minerals, and construction minerals and excavation within a framework of effective SRM:

- The prevention of primary resource requirements through diminishing the demand for additional products by an improved use of “brainware” — i.e. information — and existing hardware.
- The increase of resource efficiency on a life-cycle-wide basis, including reuse, remanufacturing, and recycling.
- The shifting towards renewable resources as far as the life-cycle-wide resource requirements will not be increased.

The first strategy is clearly the most challenging. The reader will note that the aim is not to reduce total demand in economic terms but to substitute know-how for primary resources; this fits to the second strategy where welfare should be increased and people should be provided by improved services in the sense of utility functions with a minimum of resource requirements. Recycling may contribute significantly to a reduction of primary resource requirements, especially in the case of metals. However, it is not an end in itself, and recycling which requires more primary resources than the original primary production or alternative routes should be abandoned.

The third strategy relies on the effect of the first and second. A mere shift towards renewables is not possible without reducing the total resource requirements (because there is not enough land available, see chapter 3). Of course, biomass should also be used as efficiently as possible throughout the whole life cycle of products.

All three strategies are expected to relieve the environmental burden, guarantee the supply with materials and energy in the long run, and increase competitiveness of industry through innovation. Driving eco-innovation towards sustainable technologies is perceived as a major task for industry (Fussler 1996). Governments are expected to contribute towards that aim by setting the appropriate incentive structure. However, policy often has a retarding tendency in conserving out-dated resource intensive technologies, e.g. coal incineration, through subsidies and end-of-pipe pollution control. Instead public budget could be invested into measures of sustainable resource management.

The current development which still lacks policy guidance nevertheless has already embarked on the road towards decoupling of economic performance and total resource requirements (chapter 2.2). Those industries which fall behind this trend put their competitiveness at risk. Any policy which aims to conserve resource intensive industries will even increase that risk, and the risk of hidden unemployment as well. In the Ruhr area, which had been characterised by coal mining and heavy industries until the 1970s, the unemployment rate is higher in those areas where industry did not change resource productivity over decades (Bringezu 2000). When we proceed towards SRM the risk of becoming unemployed grows with the resource intensity per worker. The necessary changes within industry towards SRM technologies can only be met with significant investments in education and training. This will be one of the outstanding challenges for policy.

The list of potential measures provides the most important instruments which should be considered further. Some of them are already practised in Member States (e.g. taxes on energy consumption) but harmonisation is lacking within the EU. Some are already implemented at least to a certain extent (e.g. extended producer responsibility and take-back systems for cars). However, other proposals might require a paradigm shift within certain ressorts (e.g. with regard to the necessary reduction of the expansion of built-up land).

For most of the policy measures, considered legal instruments and responsible institutions do already exist. Thus, transaction costs could be minimised when using the existing instruments within a SRM policy framework. For instance, R&D programmes can be reviewed to underpin the requirements of resource efficient technologies, especially in the construction sector. Here an integrated consideration of energy and material and land resources is required. Existing subsidies should be reviewed. For instance, if the Commission has to decide on subsidies for coal extraction in a Member State, the agreement could be bound to commitments of investments leading to significant energy saving within that country. Tax credits for private construction activities could be qualified by standards for energy and materials efficiency .

The SRM policy measures range from hard to soft instruments. One major task of policy is to provide the framework incentives for the market which then can find optimal solutions. Economic instruments such as taxes are going to play an increasing role in the future, and the effectiveness of resource taxes should be checked for a variety of different options.

Policy is beginning to play an increasing role as information facilitator. Decision makers and operators need appropriate information on resource efficient technologies, the resource intensity of base materials, best management practices, etc., to implement SRM. In North Rhine-Westphalia, the most populated of the

16 Länder in Germany, the government established an efficiency agency which fosters information exchange between science, consultancies and industry in order to facilitate information transfer, development and implementation of resource efficient technologies.

Engineers and designers also require better information on resource intensity of base materials and processing technologies. Publicly available databases are required to assist the sourcing of industry and the establishment of material flow accounts for integrated environmental and economic accounting as well. Supply managers in companies and traders should know about resource intensity of globally traded commodities. Statistics which do not consider material flows linked to foreign trade will not be able to monitor shifts of environmental burden and thus fail to report an essential aspect of SRM.

The curricula of engineers and economists, planners, natural and social scientists should be supplemented by programmes on SRM. New study courses are required and even new diploma titles may become necessary. And the education and training of workers must be improved as well.

If we proceed towards SRM, beneficial policies should be strengthened and counterproductive policies must be abandoned. For instance, we will need a certain shift of paradigms with respect to the future construction policy. We will have to review the role of public investments in infrastructures and the subsidisation of private construction activities. In the light of sustaining the physical basis of our economies, improving their competitiveness and securing long-term employment, we will have to review our structural and regional economic policies. Of course we will have construction activities also in the future, but they will differ from the current activities; renovation and refurbishment will require improved know-how; re-use and facility management will need increased services where repair and maintenance and reconstruction become an integrated part.

We will need a policy framework which effectively controls the net increase of built-up area (by roads and buildings), and allows for compensation between regions and communities (e.g. by land use certificates) .

It is the nature of policy to integrate various requirements. To this end, the major goals and strategies must be harmonised in order to allow for predictable and reliable action towards a sustainable future. We must expect certain discrepancies between the goals and strategies of different policy departments, i.e. directorates, and the goals and strategies required for SRM. Many if not most of them should be reconciled based on targets with a long time horizon. However, before it comes to harmonisation, any significant discrepancies should be revealed and explicated between the involved departments. For that purpose the European institutions will have to develop a procedure to evaluate the existing regulations with regard to their impact on SRM, to foster beneficial elements and to abandon counter-productive effects (e.g. when directives are updated). The decisions of nearly all directorates have impacts on the metabolism of the EU economy. Thus SRM requires an integrative effort of all departments significantly involved in relevant policy development. Basic policy guidelines will have to be developed to ensure that each directorate contributes to SRM within its own responsibility. And there will probably be a need for a regulation to lay the ground for sustainable resource management in the EU.

Table 5.1: Target material flows, strategies, addressees and possible measures within a framework of sustainable resource management

Target flows	**Strategies**	**Target sectors or groups**	**Potential policy measures**
Fossil fuels	(1) Reduction of energy demand (2) Increasing energy- and materials-efficiency (3) Changing energy mix towards renewables	Private households, construction industry, architects and civil engineers, facility managers Energy supply Transport	Taxes on energy consumption, harmonisation of Member States eco-taxes Technical standards for energy (+ material) saving buildings, cars and other machines Market introduction programmes for combined heat and power generation, and technologies using renewable sources in an energy- and materials efficient way, Reviewing subsidies on fossil fuel extraction and use (gradual phase-out of coal) and reviewing subsidies on fuels (especially those used for freight transport) R&D programmes on integration of materials and energy efficiency and use of renewables
Metals and industrial minerals	(1) Reduction of (primary) materials demand Service (function) orientation Dematerialised product design Product management which extends producers' responsibility (2) Optimising production processes with regard to life-cycle-wide primary resource requirements, including new technologies re-use, remanufacturing, and recycling	Designers and engineers Industry Private households	Campaigns for dematerialised product design, review of engineering standards, R&D programmes on resource efficient technologies and on use and substitution of precious metals Fostering metal recycling through quota for input of secondary raw materials (e.g. end-of-life vehicle regulation) Extended producer responsibility by compulsory take-back regulations for all major durable goods (e.g. cars, "white, brown and black" goods) Taxes on first domestic use of primary metals and industrial minerals Levies on products designed for dissipative use (e.g. mineral fertiliser) Databases and guidelines for engineers and operators to plan and conduct production with respect to primary resource requirements of material supply (incl. recycled materials)

Target flows	**Strategies**	**Target sectors or groups**	**Potential policy measures**
	(3) Substitution by renewables (e.g. biowaste for mineral fertiliser; biopolymers for semiconductors) as far as sensible with regard to life-cycle-wide primary resource requirements		
Construction minerals and excavation	(1) Reduction of (primary) materials demand Diminishing the amount of additional infrastructures/buildings Provision of (new) housing and mobility functions through improved use of existing infrastructures/buildings Extension of life-span of buildings (2) Optimising production processes with regard to life-cycle-wide primary resource requirements, including new construction technologies re-use, refurbishment and modernisation, and recycling (3) Substitution by renewables (e.g. wood, fibres) as far as sensible with regard to life-cycle-wide primary resource requirements	Policy makers Service sector (facility management), Construction sector, Transport sector, Planners, architects, civil engineers, Private Households	Transport policy: changing paradigm towards prevention of additional infrastructures; reviewing public investment policies Policy programmes to foster exchange of flats and houses according to actual age and group specific demand; Change of policy paradigm to prevent additional buildings at a balance between new construction and demolition, Reviewing subsidies for public and private construction Resource-input-tax, land-use tax, incentives for recycling of demolition waste, quota, voluntary agreements, Educational programmes (e.g. amendment of curricula for architects and civil engineers), R&D programmes to enhance resource efficiency in construction Campaigns for dematerialised construction, review of civil engineering standards, R&D programmes on resource efficient construction technologies Campaigns to improve quality of housing and living conditions in abandoned or run-down city areas Industry guidelines to improve renovation of buildings and remanufacturing of construction components Databases and guidelines for architects and civil engineers to plan and construct buildings and infrastructures with reduced primary resource requirements Programmes to improve qualification of workers for construction and utilities

5.4 Target setting

While various measures are expected to contribute to SRM, leaving open also a certain flexibility to adjust measures over time, the aims must nevertheless be clear and binding by agreement between involved parties, and the effect of policies must be measurable in terms of distance to target.

Before any management measures are taken, the first measure required is the setting of targets and milestones. Both must be based on indicators. The indicators are not necessarily the parameters where management measures set the leverage. However, they must allow to monitor the overall development with regard to resource use. And they must sufficiently reflect necessary conditions for SRM.

Therefore the EU should set targets to

- reduce the growth of built-up area,
- reduce the use of non-renewable resources,
- increase productivity of non-renewables and renewables[21],
- shift towards sustainable cultivation modes in agriculture and forestry, and
- combine this with the targets to reduce climate gas emissions.

For that purpose, concepts such as factor 4/10 may provide some kind of "leitmotiv" or goal, but they are not yet sufficient for target setting. For that purpose, concrete target parameters and schedules have to be defined.

For instance, in Germany the environmental ministry drafted an environmental policy programme (BMU 1998) which contains a number of limited targets. Progress towards these targets is regularly monitored and reported also by the economic ministry (Bundesministerium der Finanzen 2000) and the Federal Statistical Office (Statistisches Bundesamt 2001). The German targets comprise

- a reduction of the growth of built-up land to 30 ha/day until 2020 (currently over 120 ha/day),
- an increase of energy productivity by a factor of 2 (1990–2020)

[21] This relates to the ratio of GDP to total resource requirements (TMR) and/or direct material input (DMI); as regards the productivity increase of renewables it does not aim at an intensification of biomass production per hectare but to increase the efficiency of biomass use in industry and households

- an increase of non-renewable raw materials[22] productivity by a factor of 2.5 (1993–2020)
- a reduction of CO_2 emissions by 25% (1990–2005)
- an increase of the share of organic farming land to 20%[23] (until 2010, from 2.5%)

Certain progress is seen with respect to all targets, besides the built-up area expansion, although further action is required to meet the targets.

[22] Based on a definition which equals DMI minus biomass; thus changes in efficiency due to hidden flows of imports or to changes in biomass use are not captured

[23] The original target of 10-15% (BMU 1998) has recently been revised by the minister of the environment

6 Recommendations

A policy framework for SRM should be developed to secure the materials and energy supply of the economy and the natural resource basis in the long run. Developing a framework which considers key aspects of SRM will require

- target setting for land use (especially built-up land), absolute material requirements and productivity of materials use, and the share of sustainable cultivation practices in agriculture and forestry;
- a mix of instruments influencing the materials flow through the economy in a balanced manner aiming at the stepwise but significant reduction of all non-renewable primary resource requirements of fossil fuels, metals, industrial minerals, and construction minerals and excavation;
- policies effectively reducing demand for those primary resources, which seem also necessary to counteract the current trend of resource and burden shifting to non-EU regions;
- effective measures to control the expansion of built-up land;
- policies to support a continuous shift to sustainable cultivation practices in agriculture and forestry;
- an integrated effort of various ressort policies mainly to qualify existing measures and regulations;
- an increased use of soft policy instruments and probably new institutions to generate knowledge and to facilitate information exchange on SRM.

In order to develop such kind of policy framework for SRM, a policy debate is needed supported by additional scientific advice concerning the following main questions:

- Up to which level shall built-up land (for buildings and infrastructures) increase within the EU? The effect on the long-term supply capacity of regrowing resources will have to be considered as well as the interrelations with foreign trade (especially of agricultural and forestry products); technological and economic potentials and challenges should be explored for agriculture and forestry as well as for construction and transport.
- Which level of non-renewable resource use of the EU economy is acceptable in the mid-term and long-term future? The environmental and social implications of that use will have to be considered, the risks for secure and sustainable supply, as well as the systemic linkage of resource input and waste

and emission output; the role of resource efficiency will have to be regarded with respect to the interdependence of incentives, innovation, technological change and competitiveness; future scenarios should be developed with regard to different levels of EU demand, domestic or foreign supply and evaluated in terms of ecological, economic and social implications, and especially with regard to interregional burden shifting.

Further research seems necessary to determine the capacity of biomass (re)production in the EU if organic farming practices become the rule in agriculture and forestry. What increase of productivity per hectare can be realistically expected under that regime? And, will it be necessary to revise some of the certification requirements for better integration of the production into the whole societal metabolism and to improve the reproduction cycle (e.g. to ensure nutrient cycling also via organic household residuals)?

Acknowledgements

The author would like to thank Helmut Schütz for data analysis, Stephan Moll for essential input on resource taxation, both of them for helpful discussions and comments to the draft version and Melanie Krause for technical support. Valuable comments came also from Peter Bartelmus, Frans Vollenbroek, Maria J. Welfens, and Dirk Wolters. Support by EUROSTAT and the Department for Environment, Transport and the Regions to provide the TMR data of the EU and the UK, respectively, which became a basis of this paper, is highly appreciated.

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