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Economic and Monetary Affairs

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Resource Efficiency in European Industry

STUDY



DIRECTORATE GENERAL FOR INTERNAL POLICIES
POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY

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STUDY

Abstract

Resource efficiency has rightly become a priority in the EU. Evidence indicates that using resources more efficiently reduces material costs for companies and also opens new business opportunities (e.g. recycling industry) and improves competitiveness. While a number of low-hanging fruit opportunities exist, improving the efficiency of the European macro-economic system will also require structural change. Resource efficiency indicators are required to set quantifiable targets and measure progress toward absolute decoupling and a green economy.

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LIST OF ABBREVIATIONS

6EAP	6th Environmental Action Plan
CAP	Common Agricultural Policy
CIP	Competitiveness and Innovation Framework Programme
DEMEA	German Material Efficiency Agency
DG EFIN	Directorate General for Economic and Financial Affairs
DMC	Domestic Material Consumption
DMI	Direct Material Input
Eco-AP	Eco-Innovation Action Plan
EEA	European Environment Agency
EIO	Eco-Innovation Observatory
EIONET	European Environment Information and Observation Network
EIP	European Innovation partnership
EMC	Environmentally-Weighted Material Consumption
EREA	European Resource Efficiency Agency
FOE	Friends of the Earth
GDP	Gross Domestic Product
GHG	Greenhouse gas
HANNP	Human Appropriation of Net Primary Production
ICT	Information and communication technology
JRC	Joint Research Centre
LCA	Life Cycle Analysis
LEAC	Land and Ecosystem accounting
NISP	National Industrial Symbiosis Programme
NRW	North Rhine-Westphalia
OECD	Organisation for Economic Co-operation and Development
PPS	Purchasing power standards
RFID	Radio-frequency identification device
RMC	Raw Material Consumption
RMI	Raw Material Input
SME	Small and medium-sized enterprise
TMC	Total Material Consumption
TMR	Total Material Requirement
UNEP	United Nations Environment Programme
WEI	Water exploitation index

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EXECUTIVE SUMMARY

Resource efficiency has become a priority in the EU. It is not a concept restricted to just clean-tech or environmental industries, but rather a comprehensive strategy with economic and environmental benefits across the economy.

In general, efficiency is a concept that compares the inputs to a system with its outputs; it essentially means achieving “more with less”. As efficiency occurs across all levels of society, the system can refer to a production process (producing more with less) or an entire economy (achieving more utility with total input). A resource-efficient economy produces and consumes resources in a more sustainable way.

Fostering systems-wide resource efficiency thus paves the way for structural change in the prevailing macro-economic systems of production and consumption in the EU. It not only contributes to sustainable development, but also reduces dependence on imports, thereby reducing the burden shifting of environmental and social problems associated with extraction and production abroad, as well as enhancing material security for European business.

Measuring resource efficiency is the first step towards managing resources more effectively. Strong indicators are needed for target setting, especially to give markets a long-term orientation and trigger innovation in companies. The Resource Efficiency Roadmap¹ proposed using resource productivity, measured as GDP / DMC (domestic material consumption), as a lead indicator for resource efficiency, based on available data. The Roadmap also requires extending the scope of such a headline indicator to also account for indirect resource requirements of imports (and exports). The most comprehensive indicator of primary material use and its overall efficiency would be GDP / TMR (total material requirement), which measures progress toward decoupling of total resource requirements (including indirect flows and both used and unused extraction) from economic growth over time. The Roadmap's proposal for a dashboard of indicators on water, land, materials and carbon seems to reflect essential approaches developed in the scientific community. The available indicator concepts allow accounting of both domestic and foreign resource use associated with intra EU production and/or consumption activities. The data availability, of course, is still better for national processes, and needs to be improved for the foreign part of European resource use. Nevertheless, information on global supply chains is becoming more and more important, and data availability will improve, also when policy and industry demand more comprehensive indicators. The interactions between scale (micro to macro) toward fostering a resource-efficient Europe is an area in need of further research.

In general, the efficiency of resource use in the EU is increasing (more value is being created per tonne). However, these gains are mostly being offset by growth in absolute consumption. Dependency on imports from abroad is also increasing, with imports comprising 33% of the TMR in 2000 and 38% in 2007. On a Member State level, wide differences exist. The productivity of new Member States is around half that of EU-15 countries. Closing this gap would contribute to increased economic coherence and competitiveness of the European Union.

Precise and intelligible targets and timetables are needed to be able to identify priority areas, drive sectoral objectives and choose priority measures, as well as to begin policy integration. With the exception of water abstraction, concrete proposals for targets in each of the four resource categories have been suggested, and even implemented in the realms

¹ COM(2011) 571

of energy use and GHG emissions. Leading scientists have been advocating a reduction of overall resource consumption from a Factor 4 to 10.

Resource efficiency can be an opportunity for business to save material costs and develop new business models. A growing body of evidence reports on substantial saving opportunities, many of which are simple to implement measures requiring either no monetary investments or payback periods of around one year. Nevertheless, achieving a resource-efficient Europe will need to go beyond incremental improvements in the way things are done. The vision of Europe presented in the Resource Efficiency Roadmap² implies a restructuring of the current economic system in order to grow the economy in a way that respects resource constraints and planetary boundaries. This will have different consequences and implications for different sectors. Currently, five sectors (construction; food, beverages and tobacco; agriculture, forestry and fishing; electricity, gas and water; and coke, refined petroleum products and nuclear fuels) are responsible for 60% of the TMR, making efficiency, adaptation and modernisation in these sectors particularly crucial. Enabling technologies have been highlighted by the Commission³ as key to this transformation. For example, application of ICT in sectors like construction, energy and transport can lead to smart solutions. Nevertheless a combination of high-tech innovations as well as social innovations toward functionality and consumption are essential to any systemic change.

The flagship initiative “A resource-efficient Europe”⁴ in the context of Europe 2020 moved the extraction and use of natural resources into the centre of the political agenda of the European Commission. The most pressing next step is defining the right indicators and implementing targets and timetables. These should be based on total resource requirements. Indicators hereto exist and are already in use in some Member States. Firmly integrating resource efficiency across all EU policy areas, financial instruments and programmes is a challenging task, but nonetheless crucial. A basis could be “greening the EU budget”. A starting point may be EU Cohesion funding, linked to national green stimulus programmes.

In the short term, the first paradigm of a resource-efficient and recycling-based industry can be achieved with current political instruments and policy action. This includes, for instance, setting new resource efficiency standards for products and services on the market, stepping up green public procurement, and launching a public awareness campaign on the importance and opportunities of improved resource efficiency. Efforts could be co-ordinated by a European Resource Efficiency Agency, which would be an EU-wide network for research, technological development, and diffusion.

Over the long term, the transition to a resource-efficient economy requires revised and reinforced actions reflecting changed priorities as well as drivers and barriers. For example, by “getting the prices right” economic allocation mechanisms can be mobilised for a long-term transition of the European economy. More policy-oriented research is needed on integrated solutions to systemic challenges. Pragmatic, long-term resource-efficiency policies must be embedded in a comprehensive vision of a sustainable metabolism of industrial societies. Overall, resource efficiency is a strategy suitable to realising short-term achievements and long-term visions of a prosperous and green economy.

² COM(2011) 571

³ COM(2009) 512

⁴ COM(2011) 21

1. INTRODUCTION

KEY FINDINGS

- Resource efficiency describes the relationship between a valuable outcome and the input of natural resources required to achieve that outcome. It occurs across all levels of society; at the company level it can refer to optimising a production process (e.g. producing more with less) while at the macro level it describes how effectively economies use natural resources.
- In its aims, resource efficiency represents the core of concepts like the “green economy” or “sustainable production and consumption”. It differs in that it is more concrete and thus can be measured more easily.
- Increasing resource efficiency combines economic and environmental aims; it is a strategy to save costs, especially material costs in companies, and reduce primary resource use. It also enhances material security; increasing resource efficiency lowers Europe’s growing import dependency for raw materials.

1.1. What is resource efficiency?

Resource efficiency has become a priority in the EU. Europe 2020 established it as one of seven flagships for smart, sustainable and inclusive growth (EC 2010)⁵. The Roadmap to a Resource-Efficient Europe (EC 2011a)⁶ emphasised that it is an integral part of the EU’s agenda for global competitiveness.

As a relatively new concept on the political agenda, there seems to be some confusion as well as different understandings across Member States about what resource efficiency means. A recent EEA survey (EEA 2011a) on resource efficiency policies in 31 Eionet countries⁷ found that only 5 countries defined “resources” and none defined “resource efficiency”. Confusion exists especially on how resource efficiency relates to concepts like “sustainable consumption and production” and the “green economy”.

In general, efficiency is a concept that compares the inputs to a system with its outputs; it essentially means achieving “more with less”. As efficiency occurs across all levels of society, the system can refer to a production process (producing more with less) or an entire economy (achieving more usefulness with total input). In this sense, resource efficiency at the micro level is often associated with company improvements to produce their products more efficiently, e.g. using less raw materials to achieve the same or better output. There is a large potential for these types of improvements in companies across the EU (EIO 2012). At the macro level, resource efficiency is about optimising the flow of natural resources across the economic system of production and consumption. This means taking a life-cycle perspective and includes not only production-oriented processes, but also end-of-life considerations like re-use and recycling. A resource-efficient economy produces and consumes resources in a sustainable way (doing “better with less”); it is a green economy. The difference is that resource efficiency can be measured, enabling development of quantifiable targets and monitoring of progress (Schepelmann et al. 2006).

⁵ COM(2010) 2020

⁶ COM(2011) 571

⁷ Including the EU-27 except Luxembourg and Malta, as well as Croatia, The former Yugoslav Republic of Macedonia, Liechtenstein, Norway, Switzerland and Turkey

As regards resources, the Thematic Strategy on the Sustainable Use of Natural Resources (EC 2005)⁸ applies a wide definition. It includes raw materials such as minerals, biomass and biological resources; environmental media such as air, water and soil; flow resources such as wind, geothermal, tidal and solar energy; and space (land area). The International Resource Panel refers to resources as the natural resources used by economies, including abiotic materials (fossil fuels, metals and minerals), biomass, water, and land. In general, resources can be seen as 'gifts' of the natural system that can be used in the economic system, but which are not part of the economic system (EEA 2005).

Box 1: Related concepts: resource efficiency, intensity and productivity

Resource efficiency is an overarching concept. It can be achieved by reducing resource intensity or increasing resource productivity.

Resource intensity depicts the amount of natural resources used to produce a certain amount of value or physical output. It is calculated as resource use / value added or as resource use / physical output. For instance, a production process is more resource intensive the more material input (e.g. in weight) is needed to create one monetary unit (euro).

Resource productivity describes the economic gains achieved through resource efficiency. It depicts the value obtained from a certain amount of natural resources (value added / resource use) and is thus the inverse of resource intensity. For instance, a production process is more resource productive the more monetary output (euro) can be created with one physical unit of materials (e.g. in weight)

Source: O'Brien and Bringezu (forthcoming)

1.2. Why resource efficiency?

Resource efficiency is a strategy that combines economic and environmental agendas. It is not just restricted to clean-tech or environmental industries, but is rather a comprehensive strategy with economic and environmental benefits across the economy. Resource efficiency may pave the way for structural change in the prevailing macro-economic systems of production and consumption in the EU.

1.2.1. Saving material costs

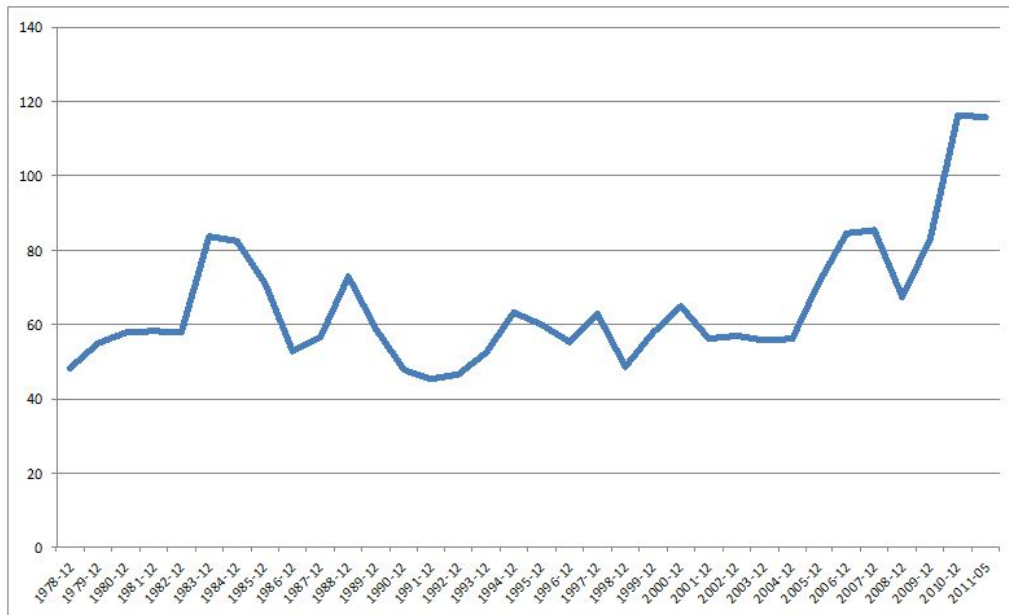
Resource efficiency leads to reduced material and energy use per unit output, and thereby also to reduced material and energy costs. The recent Eco-Innovation Observatory report (EIO 2012) argues that these savings are not only relevant for companies, but also aggregate to noticeable savings at the sectoral, economy and regional levels. Actual case study experiences with improving efficiency in the German manufacturing sector reveal that companies save around €200,000 euros on average, largely through small improvements to their manufacturing processes (see Box 3 and 6). EIO (2012) estimate that €50 billion could be saved annually in the EU-27 if all European manufacturing companies implemented similar scale improvements.

The relevance of increasing efficiency has also grown with rising commodity prices. While the 20th Century was largely characterised by falling prices, the last decade has seen sharp price increases in many commodities (see Figure 1). With a relatively high import dependency in Europe, price volatility especially exposes European companies to risk and uncertainty. A 2010 survey revealed that 87% of European companies in the manufacturing, construction, agriculture, water and food services sectors expect material

⁸ COM(2005) 670

cost increases in the next 5 to 10 years. Around 45% of companies ranked high material prices as a very important driver for innovation (EC 2011d). The savings opportunity associated with resource efficiency is explored in Chapter 5 in more detail.

Figure 1: Commodity price index for the euro area



Source: Bundesbank (2011)⁹ cited from HWWI (Hamburg Institute of International Economics) Commodity Price Index, accessed 2nd of April 2012. Based on €, total index excluding energy.

1.2.2. Reducing primary resource consumption

Global resource extraction and use increased from around 38 billion tonnes in 1980 to approximately 68 billion tonnes in 2008 (SERI 2011). Without policy intervention, global extraction could reach more than 100 billion tonnes in 2030 (Lutz and Giljum 2009). This data only comprises used extraction (resources which are further processed, see Section 3.1), while the unused extraction in mining, quarrying, agriculture, forestry, fisheries and construction would add 2 to 3 times this volume (Bringezu 2009). A number of environmental assessments (EEA 2010, UNEP 2011, WWF et al. 2010, SERI et al. 2009) show that already at today's level of global consumption, the natural resource base societies are built on is in danger of overexploitation. The planet has reached its tipping points for a number of Earth systems, beyond which the fear of overshoot and possibly collapse becomes relevant (Rockström et al. 2009, EEA 2010, Meadows et al. 2004).

While overconsumption does not manifest itself as a straightforward and visible problem, like pollution or toxicity, it is contributing to enhanced environmental pressure and problem shifting (for example shifting the negative impacts of production abroad). Moreover, even though consumption of different resources leads to different environmental impacts, Van der Voet et al. (2005) have shown that on the macro level, negative environmental impacts per capita are correlated with high levels of per capita consumption. As a general rule of thumb, the more resources a country requires, the deeper the impact on the environment is (Schepelmann et al. 2006).

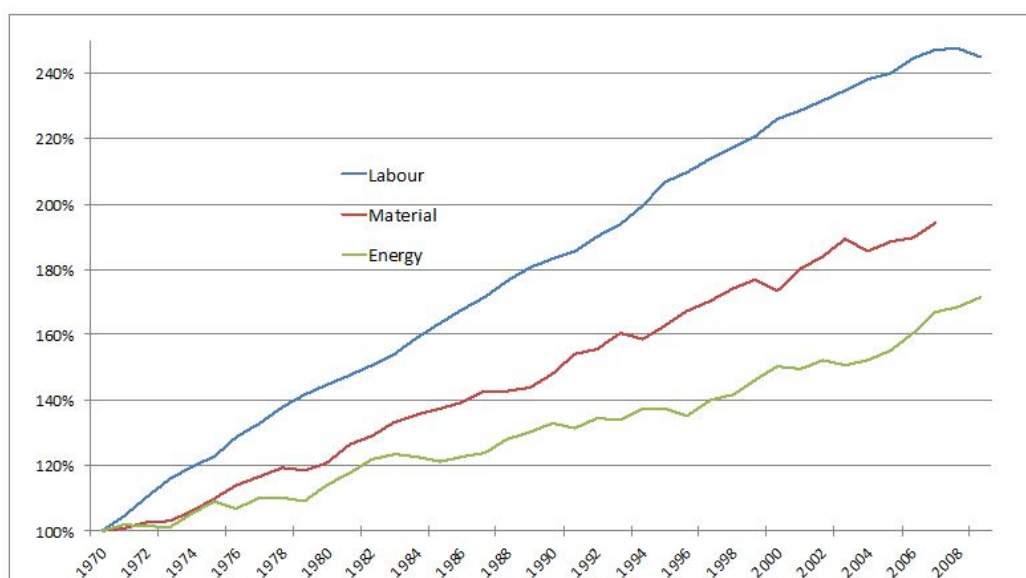
The World Business Council for Sustainable Development (WBCSD 2010) estimates that by 2050 resource efficiency will need to increase 4 to 10 fold, with significant improvements needed already by 2020. This efficiency will not only improve value chain management

⁹ http://www.bundesbank.de/statistik/statistik_zeitreihen.php?func=row&tr=iuw501&year=

from extraction to consumption, but also the re-use and recycling of materials to improve the efficiency of the entire system. The aim is to reduce dependence on primary resource extraction, while still enabling business to deliver value to their customers.

Historical trends reveal that efficiency improvements can go hand in hand with growing business. However, these experiences refer mostly to labour. Between 1970 and 2007 productivity per unit of labour increased by 144% in the EU-15, compared to 94% and 69% increases in productivity per unit of material and energy input respectively. The main driving force behind the better historical performance of labour has been the relative pricing of labour, materials and energy in tax regimes (EEA 2010; ETC/SCP 2011). This indicates two things. First, there seems to be scope for improving efficiency in the use of natural resources. Second, leading thinkers and scientists have proposed capitalising on the price effect for stimulating efficiency by shifting the burden of taxation from labour to material and energy use (e.g. Bringezu 2009, Schmidt-Bleek 2008, Weizsäcker et al 1997, 2009).

Figure 2: Development of European labour, material and energy productivity in the EU-15*, 1970 - 2008

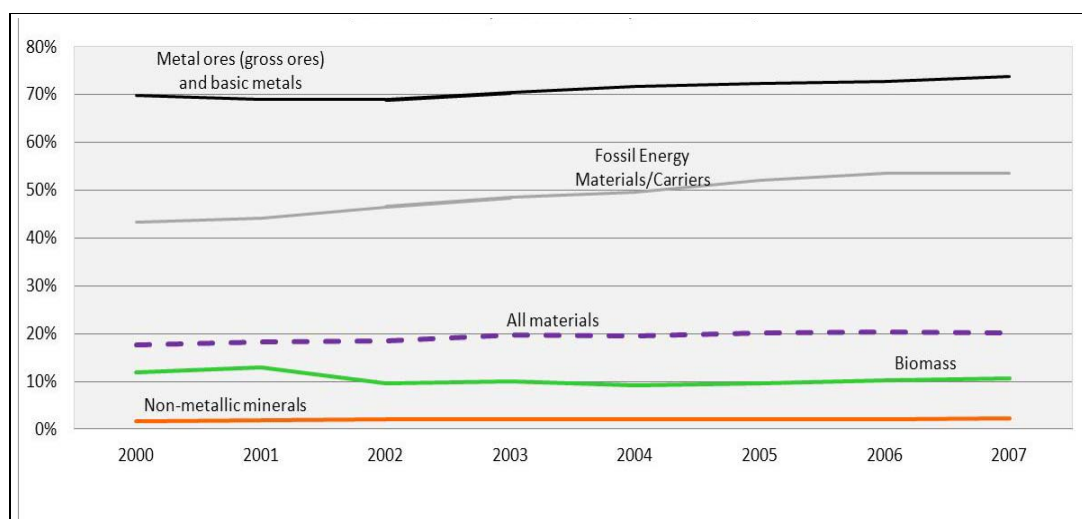


Source: EEA (2011)¹⁰, *Labour productivity: GDP per annual working hours, material productivity: GDP per DMC, energy productivity: GDP per total primary energy supply

1.2.3. Increasing material security

Europe has a high and increasing dependency on imports. Of all world regions, the EU has the highest net imports of resources per person (EEA 2010, SERI et al. 2009). Figure 3 shows that especially Europe's dependence on imports of metals and fossil fuels is increasing. Around 70% of metals are imported and dependency on fossils has risen sharply over just 7 years, from 43% to 53% (ETC/SCP 2011).

¹⁰ <http://www.eea.europa.eu/data-and-maps/figures/growth-in-the-productivity-of>

Figure 3: Share of imports in the EU-27's direct use of materials

Source: ETC/SCP 2011

Moreover, there are concerns over Europe's almost complete dependence on a number of rare metals, which are key to high-tech industries and environmental technologies. According to Roskill (2007), China provided 90 to 95% of global use of rare metals between 2000 and 2007 and will only be able to meet its domestic needs for several rare metals in 5 to 10 years, if it adheres to its production limits.

Resource efficiency is key to reducing resource use and enhancing European material security. However, it will be very challenging to achieve resource efficiency improvements that are capable of offsetting current patterns of growth in absolute consumption and the on-going depletion of European stocks (ETC/SCP 2011).

1.3. Aim and methodology of the study

This study reviews major reports and key studies on resource efficiency to provide a general overview on the state and potential of resource efficiency in the EU. It starts with a synopsis of major policy initiatives and instruments to support resource efficiency and foster a resource-efficient Europe. After that it considers the state of research for measuring resource efficiency and focuses on the economic relevance of resource efficiency in European sectors now and in the future.

Chapter 2 focuses on policies for resource-efficiency, taking a brief look at EU policies towards resource efficiency and the political challenge cross-cutting consistency and policy integration. Chapter 3 summarises the state-of-discussion surrounding the preliminary objectives and indicators put forth in the Roadmap and explores the indicators already existing at the European level through Eurostat, pointing out gaps and needs for improvement highlighted in literature. Chapter 4 applies these indicators to look at trends in Europe as a whole as well as in individual Member States. It also presents preliminary targets, depicting the scope of the challenge for resource efficiency. Savings potentials and future competitiveness in European industries are examined in Chapter 5. It especially considers visions of resource-efficient sectors and highlights potential enabling technologies for inducing more sustainable patterns of production and consumption. Chapter 6 concludes this report by highlighting key policy actions and making recommendations for fostering resource efficiency.

2. RESOURCE EFFICIENCY IN POLICY

KEY FINDINGS

- The flagship initiative “A Resource-Efficient Europe” moved resource efficiency into the centre of the political agenda. Because coupled economic growth and resource use have been an essential part of industrial history, the flagship initiative seems to introduce something new and even revolutionary.
- Headline or cross-sectoral targets on overall resource use are needed for medium to long-term orientation. These may then serve to derive sector specific action targets, timetables and mix of governance modes to foster the transition to a resource-efficient Europe. Coordinated action of research development, economic stakeholders and political decision makers across all levels of governance is needed.

2.1. Review of EU actions toward resource efficiency

In 2006 we explained in a study for the EP environment Committee: “In 2002 the European Commission set up the 6th Environmental Action Program (6EAP) as a strategic and long-term framework of its environmental policy. Concrete targets, timetables and an implementation plan were not set in the action programme itself, but intended to follow in so-called “Thematic Strategies” which were due approximately five years after the formulation of the 6EAP. Instead of presenting targets, timetables and an implementation plan the European Commission presented in 2005 a Thematic Strategy on the Sustainable Use of Natural Resources (...)” (Schepelmann et al 2006). This was the starting point of an on-going strategic development process that is now continued under the Roadmap for a Resource Efficient Europe. Now at the conclusion of the 6EAP a clear definition of targets and timetables and an implementation plan across all concerned policy departments is still under construction.

The **flagship initiative “A resource-efficient Europe” in the context of Europe 2020** moved the extraction and use of natural resources into the centre of the political agenda of the European Commission. The strategy is the seventh and last of the Europe 2020 flagship initiatives which aim at building smart, sustainable and inclusive growth for Europe. It establishes resource efficiency as the guiding principle for EU policies on energy, transport, climate change, industry, commodities, agriculture, fisheries, biodiversity and regional development. The flagship initiative connects policies related to resources such as the Roadmap for a resource efficient Europe and the Raw Materials Initiative. In the Communication on the Flagship Initiative the European Commission states that “indicators are needed to cover issues such as the availability of natural resources, where they are located, how efficiently they are used, waste generation and recycling rates, impacts on the environment and biodiversity. The Commission is working to ensure that appropriate indicators are available for monitoring and analytical purposes on the basis, for example, of the sustainable development indicators”¹¹.

¹¹ COM (2011) 21

One of the building blocks of the flagship initiative “A resource-efficient Europe” is the European Commission's **Roadmap for a resource-efficient Europe**¹². It builds upon and complements the other initiatives under the resource efficiency flagship, the 2005 Thematic Strategy on the Sustainable Use of Natural Resources and the EU's strategy on sustainable development. It sets out a vision for the structural and technological change needed to put Europe on a path to resource efficient and sustainable growth by the year 2050 and defines milestones to be reached by 2020.

Similar to the Thematic Strategy, the Roadmap proposes ways to increase resource productivity and decouple economic growth from resource use and its environmental impact. The Commission proposes to launch a joint effort with stakeholders to work on defining the right indicators and targets for guiding actions and monitoring progress until 2013. The European Commission intends to use a combination of environmental indicators. “Resource Productivity” shall be the lead indicator. It shall be supported by indicators on land and water use, and GHG emissions as a proxy for negative impacts on the environment. Global indicators will be added when available, together with indicators on natural capital and environmental impacts, to complete a comprehensive “resource efficiency dashboard”.

In its conclusions of December 2011 the European Council “invites the Commission to continue to work in close cooperation with Member States and all other relevant stakeholders and to develop by 2013 a proposal for an appropriate set of resource efficiency indicators, taking into account the life-cycle perspective, potential environmental burden-shifting to other regions or between resources, and social aspects, as well as the work done by, among others, the EEA, OECD and UNEP, and to define a process for considering potential resource efficiency targets in close cooperation with Member States and other relevant stakeholders”.

In February 2012 the European Commission proposed to set up a **European Innovation Partnership) on raw materials**. According to the European Commission¹³ the partnership will bring together Member States and other stakeholders (companies, NGOs, researchers etc.) to develop joint strategies, pull together capital and human resources and ensure the implementation and dissemination of innovative solutions within Europe. The EIP on raw materials will tackle the entire value chain of raw materials. As such the EIP addresses all aspects including exploration, extraction, refining and processing, sorting, collecting and recycling, as well as substitution. The Partnership is supposed to help develop technologically driven solutions as well as non-technological options including the use of demand-side instruments (e.g. public procurement, standards). Once the Partnership becomes operational, a Strategic Implementation Plan will be developed. This plan is foreseen to be adopted by early 2013. To speed this process up, the Commission proposes concrete targets to be achieved by 2020 at the latest, which also relate to the generation of intelligence and indicators on sustainable minerals extraction, including European standardised statistical instruments for the survey of resources and reserves, a 3-D geological map as well as a dynamic modelling system linking trends in supply and demand to a full life-cycle analysis.

The resource policies of the emerging policies under the roof of Europe 2020 and their data needs are supported by the regulation on **European Environmental Economic Accounts** of November 2011, which makes Economy-wide Material Flow Accounting mandatory in the EU-27. The new legislation requires EU countries to harmonise national reporting data on air pollution, green taxes and raw material flows in order to build up Europe-wide “environmental economic accounts”. For their material balance sheets, Member States are

¹² COM (2011) 571

¹³ http://ec.europa.eu/enterprise/policies/raw-materials/innovation-partnership/index_en.htm

asked to produce statistics on solid, gaseous, and liquid materials, except for flows of air and water, measured in mass units per year. As described above, the new regulation represents an important step forward. However, mandatory data provision by statistical services will not suffice to record the transboundary resource use of the EU and the resource efficiency of its primary sectors (i.e. the relation of used and unused extraction). For that purpose, monitoring efforts should be improved to enable more informed policy-making.

2.2. The challenges of overall orientation and policy integration

There will be no “one-size-fits-all solutions” for guiding all EU policies and economic sectors towards a resource efficient Europe. However, overall orientation is needed to guide sectoral implementation. The right targets, timetables and mix of governance modes will differ from sector to sector, depending on the natural resource, stakeholders and regimes. For example, a transition to more resource efficiency in the context of the Common Agricultural Policy will look different than in the context of the chemical industry or the iron and steel processing industries. Nevertheless, coordinated action of research, development, economic stakeholders and political decision-makers on all levels of governance is needed. For that purpose, also headline or cross-sectoral targets for overall resource use are needed for orientation and as a reference for priority setting, evaluation of policy outcomes and for derivation of sector specific targets and measures.

According to the European Commission¹⁴, in 2009, 10% of the total EU budget was allocated for environmental purposes. Around 80% of this money was spent in Regional and the Common Agricultural Policy (CAP). In 2009, CAP spending was around around €60 bn. From 2007 onwards, half of the EU budget was dedicated to structural interventions in the framework of EU Regional Policy. According to the European Commision, between 2007 and 2013 the total amount of Structural and Cohesion funds allocated to environment activities has doubled compared to the previous funding period to around €100 bn (30% of the total spending). Half of this investment will be devoted to end-of-pipe technology, nature protection and risk prevention. The other half will be spent on indirect investments with an impact on areas such as transport and energy systems, eco-innovation, environmental management for business, urban and rural regeneration and eco-tourism. As Schepelmann et al. (2009) have outlined, EU Regional Policy could boost overall resource efficiency especially in resource intensive Central and Eastern European industries. However, most of the budget is still primarily dedicated to end-of-pipe environmental protection.

The cross-cutting approach of the Flagship Initiative for a Resource Efficient Europe seems to reflect the findings of the latest state of the environment and outlook report of the European Environment Agency which reveals an “enhanced understanding of the links between environmental challenges combined with unprecedented global megatrends. This has allowed a deeper appreciation of the human-made system risks and vulnerabilities which threaten ecosystem security, and insights into the shortcomings of governance” (EEA 2010). Finally, the EEA and the European Commission seem to turn away from incremental environmental analysis and repair towards a deeper investigation of root causes and eventually a system transition of the EU economy. The fact that the flagship initiative is not only launched by the environmental General Directorate, but by the President of the Commission who has announced initiatives across different policy-areas seems to be a promising start. It remains to be seen whether the European Commission can actually muster the necessary competences and leadership resulting in a resource efficient Europe. The ultimate proof will be whether the EU will actually manage to decouple resource use

¹⁴ http://ec.europa.eu/regional_policy/activity/environment/index_en.cfm

from economic development to such an extent that it decreases the pressure on the global environment in absolute terms. So far, the various EEA assessments of the State of the Environment have revealed that the European Union has developed consumption and production patterns which impose unsustainable levels of pressure on ecosystems in Europe and other parts of the world. The flagship initiative promises to “define medium and long-term objectives and means for achieving them with the main aim to decouple economic growth from resource use and its environmental impact”¹⁵. The coupling of economic growth and resource use has become an essential part of industrial history and thus the way of life and economic development as we know it. Thus, the flagship initiative seems to introduce something new and even revolutionary.

¹⁵ COM (2011) 21

3. MEASURING RESOURCE EFFICIENCY

KEY FINDINGS

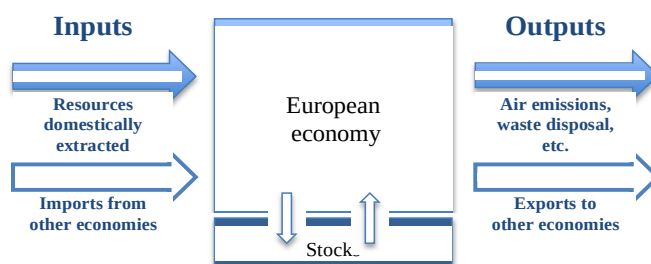
- Operational indicators for measuring resource efficiency already exist and are in use in some Member States. Data quality needs to be improved and wider integration is called for across member states and at the European level.
- Measures of resource efficiency must account for total primary resource use, if used and unused resources shall be considered as well as resources "embodied" in trade.
- Major assessments seem to be in agreement that dedicated indicators covering materials, land, water and GHG emissions are needed. Work on the methodology and specific indicators is on-going.
- A challenge is making macro level indicators and targets operational also at the level of companies.

3.1. Taking a systems perspective: Economy-wide material flows analysis

Because efficiency is a comparison between the inputs and outputs of a given system, defining the systems boundary is the first step. At the level of economies the concept of the industrial metabolism provides a framework for analysing resource efficiency. Similar to the metabolism of a human body, the industrial metabolism is a perspective that focuses on the input and output flows that power the economy. Figure 4 depicts this perspective, showing how resources are extracted and used in society, and then disposed of in the form of waste and emissions.

This simplified perspective forms the framework for deriving indicators in the arena of resource efficiency. The efficiency of the whole system can be measured with economy-wide material flow analysis. Parts of the system can also be assessed within this framework. For instance, input-output analysis can be used to study the throughput of materials in specific sectors, life-cycle analysis (LCA) focuses on the environmental impacts associated with specific products across the system, and material system analysis looks at the flows of individual materials (Eurostat 2001, 2009; OECD 2008; UNEP 2011; Bringezu et al. 2009).

Figure 4: Scope of material flow analysis



Source: Based on Eurostat 2009

Basically, economy-wide material flow analysis accounts for resource consumption by adding domestic extraction plus imports minus exports. Whether indirect flows and unused extraction are taken into account determines how comprehensive the indicator set is. Indirect flows are the up-stream material requirements of imported or exported products which are used as material inputs along the production chain, but do not cross national borders. They are also known as the ecological rucksacks of these trade flows. Unused extraction is not further processed as such, although it may be used in landscape modelling when roads are constructed, or it becomes a “left-over” in the extractive processes. It includes for instance the overburden of soil and rock in mining, harvest residues in agriculture and forestry and the by-catch in fishing. As resources become more difficult to access, unused extraction grows, indicating that also environmental pressures related to e.g. mining waste volumes and water discharge, among others, might increase. Dittrich et al. (2012) found that while global trade increased around 3.5-fold between 1960 and 2005, the ecological rucksacks of those traded goods multiplied by a factor of nearly 4.8. Table 1 describes these input indicators, as well as related consumption indicators, in more detail.

Table 1: Economy-wide input and consumption indicators: derivation and related policy questions

Type of indicator	Name	Derived by	Policy questions
Input	Direct Material Input (DMI)	Domestic extraction used + imports	How many environmental resources are used in domestic production and consumption?
Input	Raw Material Input (RMI)	DMI + ecological footprints	How much primary material is directly used in domestic production and consumption?
Input	Total Material Requirement (TMR)	RMI + unused domestic extraction + resource requirements of imports	How much primary material is required globally by domestic production and consumption?
Consumption	Domestic Material Consumption (DMC)	DMI - exports	How many environmental resources are used for domestic consumption?
Consumption	Raw Material Consumption (RMC)	RMI – exports (incl. ecological rucksacks)	How much primary material is directly used for domestic consumption?
Consumption	Total Material Consumption (TMC)	TMR – exports – indirect flows associated with exports	How much of the global primary material requirement is associated with domestic consumption?

Source: Based on Bringezu et al. 2009

Eurostat, based on its guidelines from 2001, has been monitoring and publishing data on material flow accounts since 2002. While Eurostat reports on domestic consumption, it does not yet report on the total resource consumption of economies. To account for the overall

use of primary material resources, Total Material Requirement (TMR) is an appropriate indicator, as described in the indicator framework from Eurostat (2001) and OECD (2008). It is used in EEA reporting (e.g. already by EEA 2001), and is available for the EU-27 (ETC/SCP 2011). As it is still a relatively new concept, the number of national economies for which TMR data is available is still limited, although growing (See Annex 1 for an overview of data availability for countries and regions). Data on unused extraction and indirect flows associated with trade has been mainly provided by research institutes and is not yet well developed in official statistics, hindering diffusion of the indicator. New legislation (European Environmental Economic Accounts, see also section 2.2) makes a basic version of economy-wide material flow accounting mandatory in the EU-27 and requires EU countries to harmonise national reporting data. By December 2013, and every 3 years thereafter, proposals shall be made, if appropriate, for introducing measurement of unused extraction¹⁶. The mandatory provision of a core data basis to monitor the more simple indicators such as DMI and DMC is a further step towards an improved data basis, and will also benefit the more medium-term goal of measuring the TMR. Progress towards this end, however, will critically depend on the demand voiced by parliaments, industry and NGOs, in order to enhance efforts and speed up the process of data provision and harmonisation. Otherwise, indicators with restricted information value might unintentionally contribute to problem shifting to unaccounted areas.

3.2. Towards a headline indicator: resource productivity

In the Resource Efficiency Roadmap the Commission proposed using resource productivity, measured as GDP / DMC, as a lead indicator. It also requests the stepwise enlargement of the scope of this indicator, and invites all key stakeholders to propose a new supplementary indicator on 'natural capital and environmental impacts of resource use' by the end of 2013.

Table 2: Economy-wide resource productivity indicators and their related policy questions

Name	Derived by	Policy questions
Direct Material Productivity	GDP / DMI	Is there a decoupling of material use from economic growth over time?
Total Resource Productivity	GDP / TMR	Is there a decoupling of total resource requirements from economic growth over time?
Material productivity (proxy resource productivity)	GDP / DMC	Is there a decoupling of material consumption from economic growth over time?
Resource productivity	GDP / TMC	Is there a decoupling of total resource consumption from economic growth over time?

Source: Based on Bringezu et al. 2009

Measuring resource productivity with GDP / DMC is insufficient. First, it does not take into account total primary resource demand (see above discussion of ecological rucksacks and unused extraction). Second, it relates GDP just to the consumption of national economies, rather than to consumption and production activities. For these reasons, GDP / TMR is the

¹⁶ OJ L 192, 22.7.2011, p. 5

most comprehensive indicator for measuring resource efficiency at the economy-wide level. However, because data is currently lacking for some Member States, GDP / DMC is currently standing in as a “proxy indicator” for comparing country performance. Current trends are depicted with this indicator in Chapter 4, where progress toward relative and absolute decoupling is discussed.

The use of resource productivity as a lead indicator has been criticised for not taking into account the environmental impacts associated with consumption of different resources (e.g. acid rain and eco-toxicity). This seems to be one of the reasons behind the Commission's decision in 2005 to develop a lead indicator on eco-efficiency, with the aim of combining decoupling of resource use and the environmental impacts of resource use into one indicator. To allow for time to develop this indicator, development of targets and timetables were postponed 5 to 10 years. However, as Schepelmann et al. (2006) pointed out at that time in a study commissioned by the European Parliament, introducing a second objective (decoupling specific impacts from resource use) adds layers of unnecessary complexity, which are subject to methodological weaknesses, and which delay policy action and hinder concrete orientation for the actors in consumption and production systems. It is unclear whether any new lead resource efficiency indicator will incorporate the concept of eco-efficiency or not. The links between material flows and environmental impacts should be further studied. There is no material flow without impact and substitution between materials and resources often leads to problem shifting. The LCA based methods for the assessment of environmental impacts are still somewhat biased towards a selection of few impacts which can be quantified, and the basic assumptions behind often become obscure when different impacts are combined into a single index, which again depends on certain weighing assumptions. In contrast, one can be rather sure that given a certain structure of the socio-industrial metabolism a reduction of primary input might reduce input as well as output related impacts. Thus, decoupling of economic growth from resource use and an increase of resource productivity is a key action in and of itself, and a necessary, although not sufficient condition for sustainability. Operational indicators already exist. In this sense, further development and diffusion of the indicator TMR seems to be a key action towards measuring total resource efficiency.

3.3. Towards a dashboard of indicators: materials, water, land and carbon

The Roadmap (EC 2011a)¹⁷ states that “because this provisional lead indicator only gives a partial picture, it should be complemented by a 'dashboard' of indicators on water, land, materials and carbon and indicators that measure environmental impacts and our natural capital or ecosystems as well as seeking to take into account the global aspects of EU consumption.”

In their recent assessment of resource efficiency indicators and targets, Bio Intelligence Service et al. (2011) together with the Commission recently proposed a shortlist of basket indicators. These were analysed against the RACER (Relevant, Acceptable, Credible, Easy, Robust) framework. The suggested basket includes a set of 16 headline indicators on level 1 dedicated to four resource use categories: material use; energy use and climate; water use; and land use. These level 1 indicators are supported by level 2 indicators, which address specific questions within each resource category. The idea behind this division is that level 1 indicators can be used to set overall policy targets for aggregated resource use while specific policy measures can be linked to and monitored with level 2 indicators.

¹⁷ COM(2011) 571

Table 3 depicts these suggested Level 1 indicators. As shown, indicators are grouped in resource-use indicators and to environmental impact indicators. The first grouping is intended to allow for monitoring issues such as resource scarcities, access to resources, import dependencies, increased competitiveness, and international distribution and global fair shares. The second grouping is intended to monitor negative environmental impacts associated with resource use, including climate change, ecosystem quality and biodiversity, and toxicity, among others. They further split the indicator basket into short and medium-term indicators. While the short-term indicators primarily measure environmental pressures or impacts stemming from activities within the EU territory, medium-term indicators are intended to consider global environmental pressures and impacts related to EU consumption. All short-term indicators listed already exist and several are already in use. Indicators on land-use accounts, environmentally-weighted material consumption and human appropriation of net primary production are under development. As regards medium-term indicators, some are being tested with pilots (e.g. RMC, Actual Land Demand, Footprints) whereas others are new suggestions. Especially the development of land use indicators seems to be in need of development over the medium term.

Table 3: Basket of 16 “headline” indicators

	Resource use-oriented indicators		Env. Impact-oriented indicators	
	Short-term (1 year)	Medium-term (2-5 years)	Short-term (1 year)	Medium-term (2-5 years)
Material use	Domestic Material Consumption (DMC)	Raw Material Consumption (RMC)	Environmentally-Weighted Material Consumption (EMC)	Life-Cycle Resource Indicator* (by JRC)
Energy use and climate	Gross inland energy consumption	Actual primary energy consumption (incl. energy flows “embodied” in trade)	Territorial GHG emissions (UNFCCC/Kyoto)	Carbon Footprint (incl. GHG emissions “embodied” in trade)
Water use	Water abstraction (only blue water)	Water Footprint (blue and green water)	Water Exploitation Index (only blue water; territorial)	Global Water Consumption Index (blue and green; incl. “embodied” water)
Land use	Domestic Land Demand	Actual Land Demand (incl. land use “embodied” in trade)	Human Appropriation of Net Primary Production (HANPP)	eHANPP, LEAC and other indicators on ecosystem quality

Source: BIO Intelligence Service et al. 2011.

*The Life-Cycle Resource indicator is developed by JRC and not only covers material use, but also provides information on the life-cycle wide environmental impacts of other resource categories, which are not covered by the suggested set of indicators, such as water pollution. With regard to the impacts related to traded goods, it is, however, based on a rather limited selection of products (Lundie et al. 2011).

In their Briefing Paper on the Roadmap, Friends of the Earth (FOE 2012) urged the European parliament to adopt four indicators based on the consumption of key natural resources:

- Water footprint (in litres)
- Land footprint (in hectares)
- Carbon footprint (in tonnes CO_{2eq})
- Material footprint (in tonnes).

They argue that such footprints are transparent because they are based on real physical quantities and that a consumption approach that takes into account indirect resource use is needed to provide a complete picture of the overall scale of European resource consumption. Friends of the Earth (FOE 2012) also stress the need for developing and adopting more land-oriented indicators. Such indicators should be taken into account in target setting and policy making, especially as regards biofuels and renewable energies.

Table 4: Suggestions and availability of key indicators from the national and global perspectives for materials, land, water and GHG emissions

	Territory or national perspective		Global supply chain or international perspective	
Materials	Domestic extraction (used and unused), DMI, DMC*	Available for all EU Member States	TMR and TMC	Available for the EU-27 (aggregated) and some Member States
Land	Artificial land or built-up area (km ²)	Available with restrictions in time series	Direct and Indirect land use / "embodied" land for consumption of biomass-based products focussing on cropland (ha)	Available for the EU-27 (aggregated)**
Water	Water exploitation index*** (WEI, %)	Available with restrictions on completeness of data and regional / temporal resolution (river basin / intra-annual variations)	Water footprint or "Embodied" water	In need of improvement; In need of development
GHG Emissions	GHG emissions (t)	Available	Direct and indirect GHG emissions (both carbon and non-carbon emissions)	Available for selected Member States through statistical offices and for all countries from scientific sources

Source: own compilation

*DMI and DMC do not apply the territory principle, but account for the nationality of actors

** See Bringezu et al. (2012)

*** This indicator has limitations; e.g. it aggregates different water resources, it does not take into account the nature of the water use after abstraction, the commonly used threshold values are under discussion. The Commission is exploring alternatives, which are however not yet fully available. Awaiting improvements, the WEI will be further used.

In general, there seems to be broad agreement on the need to cover these 4 resource categories, as well as on the need for linking European consumption to global supply chain effects. While indicators on the national perspective in these resource categories appear to be more generally available, indicators addressing the global perspective seem to be in need of further development. Table 4 depicts this perspective more fully. In the big picture, considerations of global resource use need to be put into perspective of global trends and resource limits in order to address the question of whether European consumption is leading to an overexploitation at the global level. For instance, Bringezu et al. (2012) have accounted for the annual amount of cropland needed to supply Europe's consumption of agricultural goods, finding that 1/3 more cropland is needed than the globally available cropland per capita. Recent research on planetary boundaries (e.g. Röckström et al. 2009) may be built-on toward developing targets for acceptable levels of resource consumption to trigger resource efficiency.

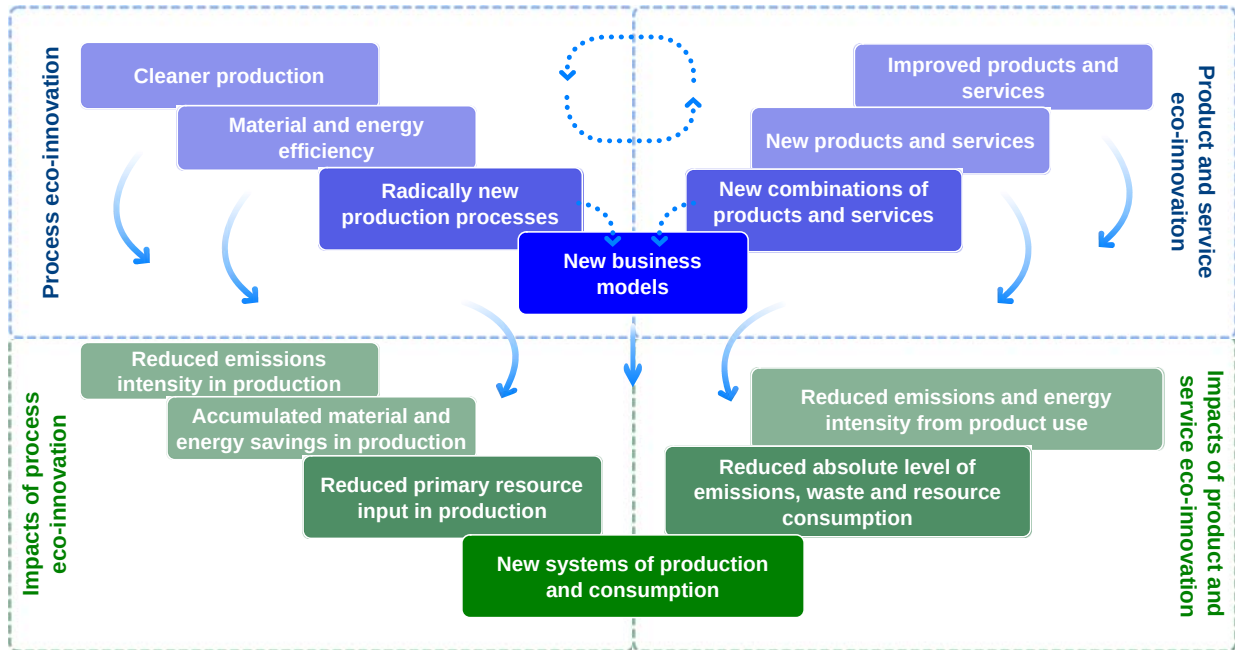
The Roadmap also mentions a development of third level indicators to monitor progress towards existing targets in other sectors. For instance, the iGrowGreen indicators from DG ECFIN represent a complementary additional set of indicators which focus on the policy response. Because they are still focussed on energy and climate issues, these indicators may be amended by resource-oriented categories to also reflect considerations of resource efficiency.

3.4. A question of scale: measuring progress from the macro to micro level

A policy challenge is translating macro level targets to the level of companies in an operational way that fosters greater systemic-wide resource efficiency. To foster a resource-efficient Europe, not only material and energy efficiency improvements in companies will be necessary, but also a more structural shift in the way companies do business (e.g. a shift toward better utilisation of “waste”, more resource-efficient services, etc.). Figure 5 depicts how different stages of change at the business level, in both how the company operates internally and what they sell, relates to impacts at the macro level.

Tools to assess the resource intensity and the environmental impacts of products and goods at the micro level exist. For example, Material Input per Service Unit (MIPS) can be used to compare the material and energy requirements of functionally comparable goods and services (and thus provide the data for TMR, water consumption and basic information of air input which usually corresponds to carbon dioxide output). Life-cycle assessment can be used to compare the impacts associated with all life stages of similar, competitive products.

The eco-design directive requires producers of specific appliances to measure energy efficiency. However, for overall resource efficiency there is not, yet, a framework at the micro level to allow labelling of *radically* different goods or services against *prevalent* goods and services. This means that certification and labelling of “green” products may inadvertently foster incremental improvements rather than radical changes and thus limit the success of EU resource efficiency policies. In general, governance and interactions between different scales for managing a transition towards a resource-efficient Europe is an area in need of further research.

Figure 5: Pathways to systemic change

Source: EIO 2012

Box 2: A need for integration: toward one indicator set?

The Lisbon Strategy was adopted in March 2000, aiming to make the EU the world's most competitive, knowledge-based economy, with sustainable economic growth, more and better employment opportunities and greater social cohesion. It was accompanied by a set of 79 'structural indicators'. With its conclusion in 2010, these indicators are being progressively frozen in the context of Eurostat's structural indicator data tables. However, most indicators are still being reported in the context of sustainable development indicators.

In 2005, the European Commission adopted a set of more than 100 sustainable development indicators. These are used to monitor the EU Sustainable Development Strategy.

In 2010, The European Commission presented Europe 2020, a 10-year strategy for smart, sustainable and inclusive growth. Eurostat reports on a handful of headline indicators toward achieving 5 headline targets. Many of these directly overlap with sustainable development indicators. Currently, resource productivity is included in sustainable development indicators, but not in Europe 2020 indicators.

From a citizen perspective, the existing overlap between the indicator sets of these three overarching strategies is confusing. From a policy perspective, it may be adding more layers of complexity rather than moving towards simplicity of a single political agenda. It would seem that one comprehensive and overarching strategy and indicator set for (sustainable) social, economic and environmental development would be desirable. This indicator set could merge short and medium-term targets (e.g. Europe 2020) with long-term targets (sustainable development).

4. RESOURCE EFFICIENCY IN THE EU: TRENDS AND TARGETS

KEY FINDINGS

- In general, the efficiency of resource use in the EU is increasing (more value is being created per tonne of directly used material). However, these gains are being offset by growth in absolute consumption. Especially industrialised countries, with high rates of consumption, are the most efficient in terms of value gained per resource input.
- The total material requirements (resource footprints) of Europeans are more than double direct material inputs and are increasing at a higher rate than direct inputs. This heightens the likelihood of negative environmental impacts induced through trade.
- An efficiency gap exists between old and new Member States. Closing this gap would contribute to increased economic coherence and competitiveness of the European economy.
- EU legislation seems to drive climate change, energy and waste (recycling) targets in EU Member States, indicating a potential for strong EU leadership in the setting of material consumption targets. In order to prevent an outsourcing of production activities, targets must focus on the absolute decoupling of total material requirements from economic growth. Suggestions ranging from a 'Factor 4' to 10 have been made by scientists and have been adopted in a general manner on the policy programme level of various countries.

4.1. Trends

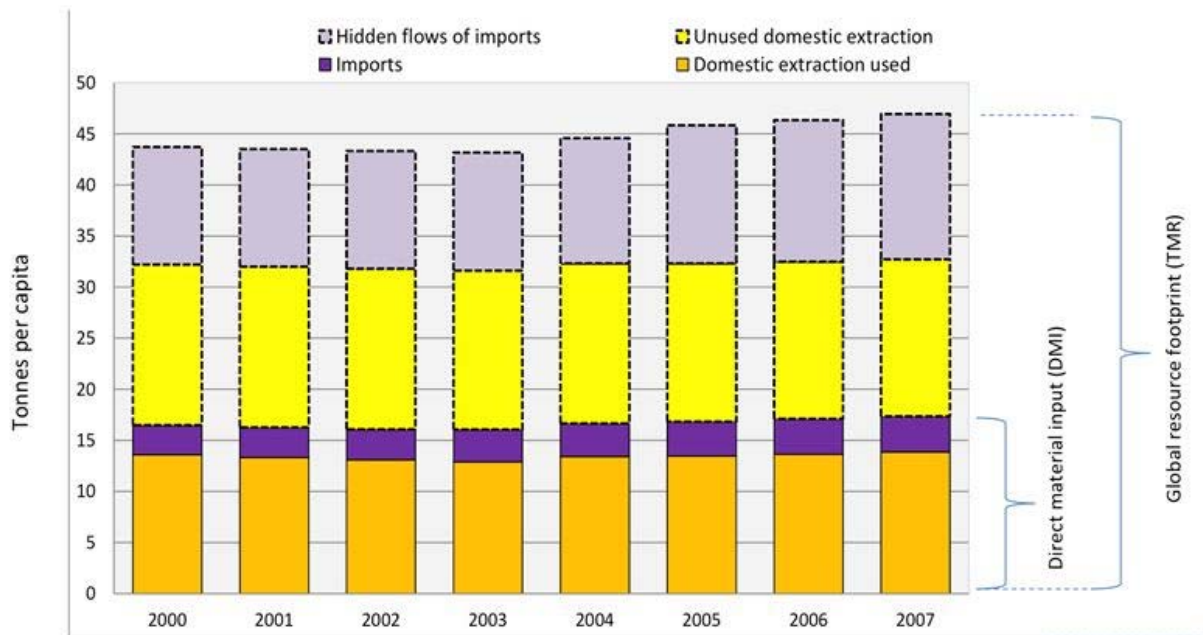
4.1.1. Resource inputs

Around 50 tonnes of primary resources are required per capita in the EU-27 (TMR). Around one-third is used directly, whereas around two-thirds consist of unused extraction and ecological rucksacks of imports. Between 2000 and 2007 direct material input (DMI) increased by around 5%, whereas the total material requirement (TMR) increased by 7% (Figure 6). This means that the resource footprints of Europeans are more than double direct material inputs, and that footprints are growing more rapidly than direct inputs.

Increased extraction and use of minerals and energy carriers are responsible for most of the growth in European footprints. The hidden flows associated with biomass imports have also increased. While used and unused biomass extraction in the EU has been reduced, sharp increases in cereal imports (+264% between 2000 and 2007) and beverage crop imports (+14% between 2000 and 2007) and their associated hidden flows imply that Europe's land demands on the rest of the world are increasing with potentially negative consequences for high-value nature areas and biodiversity¹⁸. As Figure 6 reveals, dependency on imports from abroad is increasing overall, with imports comprising 33% of the TMR in 2000, up to 38% in 2007.

¹⁸ Results from Bringezu et al. (2012) using the approach of Global Land Use Accounting corroborate these findings.

Figure 6: Trends in per capita resource requirements of the EU-27, DMI and TMR (2000 - 2007)

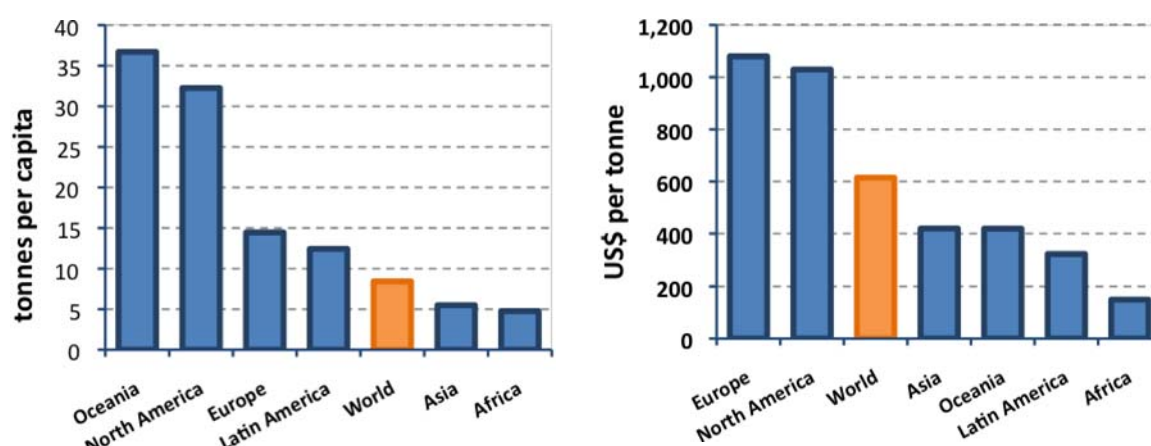


Source: ETC/SCP 2011

4.1.2. Resource consumption and efficiency, global perspective

Measured with the indicator Raw Material Consumption (RMC, see Section 3.1), around 14.5 tonnes of natural resources were consumed per capita by Europeans in 2000. This is less than e.g. North Americans (32 tonnes), but more than Asians (around 5.5 tonnes) and Africans (less than 5 tonnes) (Giljum et al. 2011).

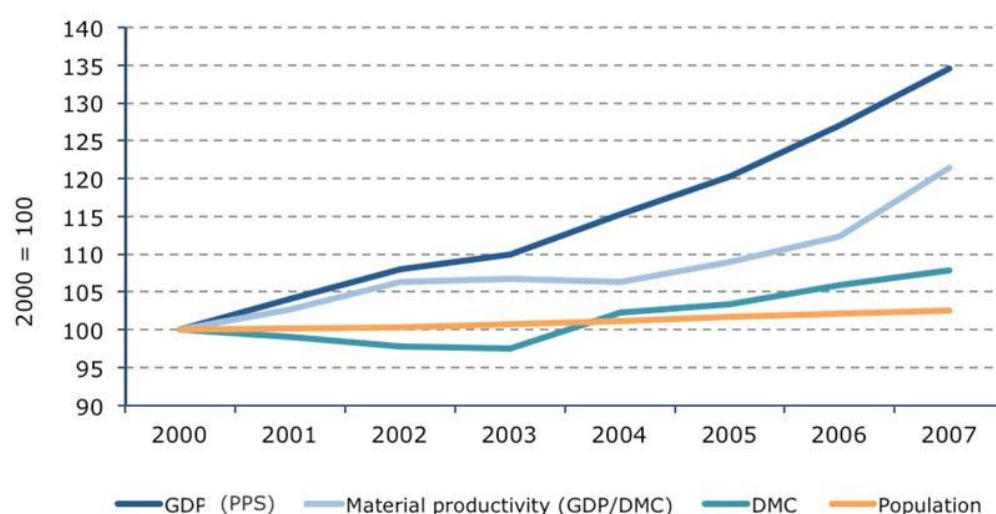
Dividing GDP by RMC for these world regions reveals that Europe and North America produce output of more than 1,000 USD with one tonne of material, whereas all other world regions produce output of around 400 USD or less per tonne. This indicates that efficiency is also strongly related to a country's economic structure and levels of GDP. In most cases, the countries that extract and consume the most are also the most efficient. As such, efficiency as measured by GDP over RMC (or DMC) is not a strong indicator of sustainable development alone.

Figure 7: Resource consumption and efficiency of different world regions, RMC (2000)

Source: Giljum et al. 2011, EIO 2011

4.1.3. Resource consumption and productivity, EU perspective

Between 2000 and 2007 the European economy grew by 35% and population by 2.6%. Also material consumption, measured with DMC¹⁹, increased by 7.8%. This implies a relative decoupling—24% more economic value was extracted from a tonne of material consumption in 2007 than in 2000—but not an absolute decoupling. On average, resource productivity (measured with the proxy indicator of GDP/DMC) grew by 3.2% over this period (Figure 8). However, these numbers should be used with caution. If GDP were expressed in exchange-rate values instead of purchasing power standards, resource productivity would be 2.2% per year. If total material consumption (TMC) instead of domestic material consumption (DMC) were used, Europe's material productivity would decline (EIO 2011).

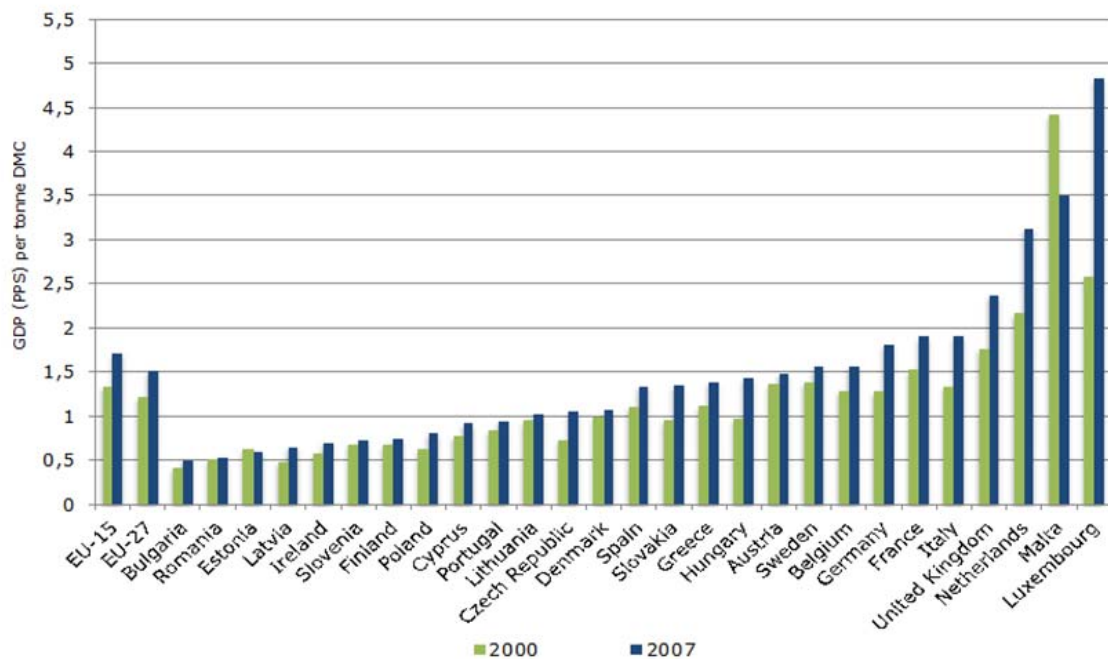
Figure 8: Trends in DMC, GDP and material productivity in the EU-27 (2000-2009)

Source: EIO 2011 based on Eurostat MFA database

¹⁹ DMC is currently the most available indicator and is thus used here; TMR would provide a more comprehensive picture (see Section 3.1).

EU-wide trends as a whole mask vast differences between EU Member States. In general, there is an efficiency gap between EU-15 countries and new Member States. In 2007, EUR 1,715 of GDP was produced per tonne of DMC in the EU-15, whereas productivity in new Member States was around half of this (EUR 798 on average). This difference can mainly be traced back to the sectoral composition of these economies. New Member States are still relatively more focused on industrial and extractive sectors, with less mature service sectors. According to EEA (2010) countries with a high share of service sectors (e.g. financial services in Luxembourg or the UK) and small countries with high imports and low domestic extraction (e.g. the Netherlands, Malta) have the highest productivities. Also EU-15 countries with relatively important material processing sectors have relatively low productivities, e.g. timber production in Finland or milk and dairy production in Ireland and Denmark. Nevertheless, it should be noted that service sectors may indirectly stimulate higher levels of consumption. In any case, the large efficiency gap between EU Member States also indicates room for improvement. Reducing the productivity gap among Member States would contribute to increased economic coherence and competitiveness of the European economy (Schepelmann et al. 2006).

Figure 9: Material productivity in Member States, GDP (PPS) / DMC (2000, 2007)



Source: EIO 2011 based on Eurostat MFA database

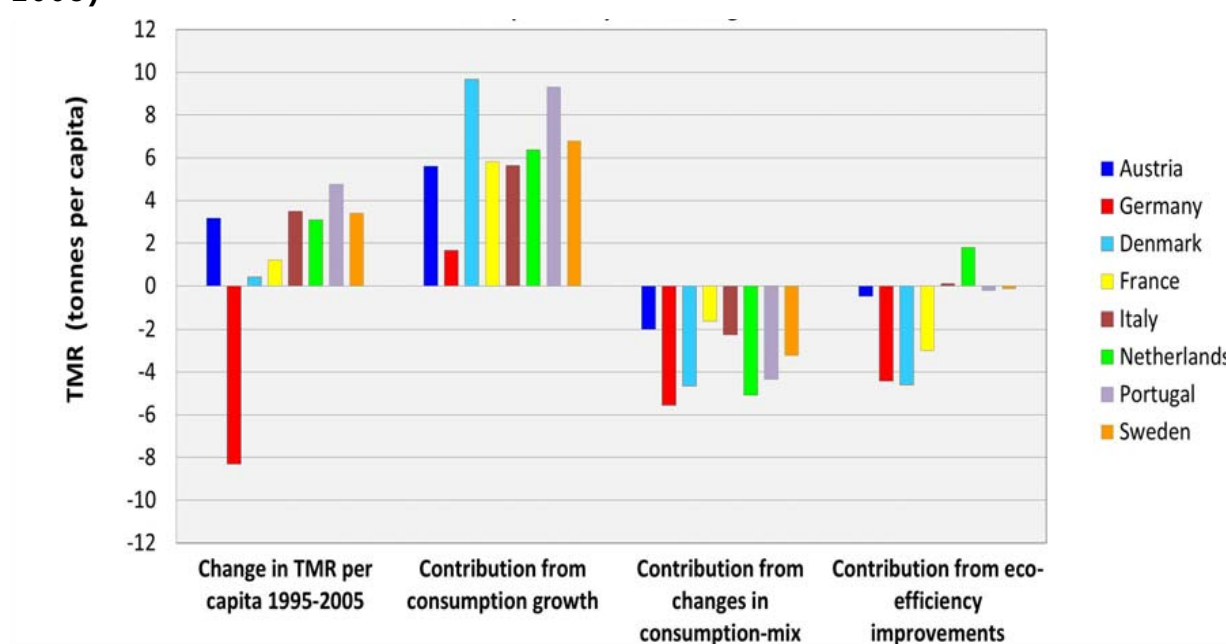
4.1.4. Relative and absolute decoupling

In general, while the efficiency of resource use seems to be increasing in Europe, these gains are being offset by growth in the absolute consumption of resources. Relative decoupling is occurring in the EU, meaning that the rate of resource use increase is lower than the rate of economic growth. However, decoupling will only lead to absolute reductions in resource use when the growth rate of resource productivity is higher than the growth rate of the economy (UNEP 2011).

Data on total material requirement is available for 8 EU countries. Figure 10 depicts the change in TMR per capita for final domestic consumption, i.e. Total Material Consumption

(TMC)²⁰, between 1995 and 2005 and how 3 factors have influenced this development: changes in consumption expenditure (consumption from growth), change in the consumption mix of Europeans and changes in the resource intensity of individual product groups. It shows that all countries saw a relative decoupling, but only Germany achieved an absolute decoupling (comparing the two left-hand groups of bars). Germany's absolute reduction is mainly due to a significant decrease in the consumption of construction and coal mining products (ETC/SCP 2011). Changing the share of product types in the shopping basket contributed positively to decoupling in all eight countries, while reducing the resource intensity of product groups contributed to decoupling in a handful of the countries examined. Overall, stronger changes in both will be needed to bring about a substantial change in the absolute consumption of natural resources.

Figure 10: Contributions to changes in the global resource use caused by domestic final use of products (Changes in TMR per capita, 8 EU countries, 1995-2005)



Source: ETC/SCP 2011

4.2. Targets

Only a few indicators have been used to set concrete, qualitative targets. Bio Intelligence Service et al. (2011) found that most targets on resource use seem to be rather general in nature, with the exception of GHG emissions and renewable energies. EU legislation seems to drive climate change, energy and waste (recycling) targets in EU Member States, indicating a potential for strong EU leadership in the setting of material consumption targets. To date, however, Japan has been the most advanced and successful in setting targets for resource productivity (BIO Intelligence Service et al. 2011). In the EU, Austria, Germany, Italy and Sweden have specific objectives for material consumption and resource productivity grounded in material flow analysis. Furthermore, Sweden, Finland and France have set waste reduction targets.

Little political consensus for setting targets could partly be due to a lack of undisputable scientific evidence on all of the planet's sustainability thresholds. Nonetheless, while science can provide the background information for an informed political discussion, the setting of

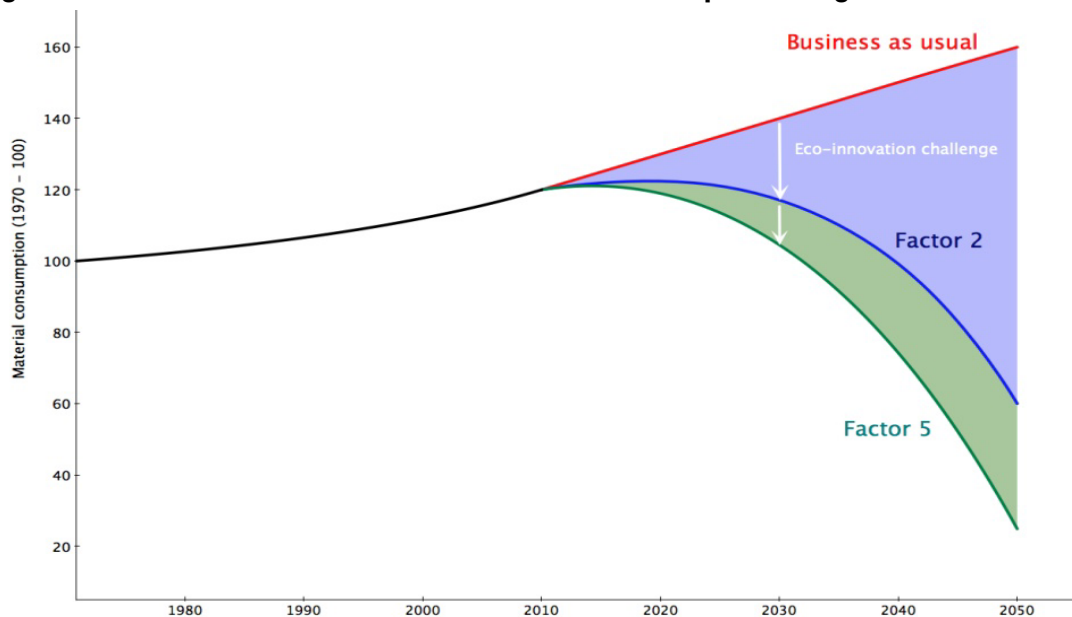
²⁰ TMC equals TMR minus exports including their TMR_{req}.

targets is a normative and political procedure. Leading thinkers have proposed specific targets based on existing knowledge about carrying capacity, unsustainable practices and future scenarios (von Weizsäcker et al. 1997, 2009; Schmidt-Bleek et al. 1993; Ekins et al. 2009; Bringezu 2011).

Proposals include e.g. a Factor 4, or a doubling of income while reducing material consumption by 50% (von Weizsäcker et al. 1997); a Factor 5, i.e. an 80% increase in resource productivity (von Weizsäcker et al. 2009); a Factor 10, or a ten-fold reduction in material consumption in industrialised countries (Schmidt-Bleek et al. 1993). In order to prevent a dislocation of domestic material and energy intensive parts of the economy abroad, resource targets should be based on comprehensive indicators. For instance, 6 to 10 tonnes per capita of total resource use (including unused material resources) has been suggested by Bringezu (2011) and Schmidt-Bleek (2008); Ekins et al. (2009). Figure 11 visualises Factor 2 to Factor 5 targets for resource consumption. The “eco-innovation challenge” is depicted as the difference between business-as-usual and achieving targets. This implies a combination of innovations improving resource efficiency in companies, across material value chains and in the consumption behaviours of consumers, as well as greater transformative change toward resource efficiency at the systems level.

Based on existing knowledge about links and plausibility, BIO Intelligence Services et al. (2011) generated potential targets for each of the four resource categories; material use, energy use and climate, water use, and land use. These are presented in Table 5. With the exception of water abstraction, concrete proposals could be made in all categories.

Figure 11: Factor 2 to Factor 5 resource consumption targets



Source: EIO 2011

Table 5: Targets for material, energy, water and land use in relation to 2005

Material use	DMC 2020: -30% 2050: -70%	EMC 2020: > -30% 2050: > -70%
Energy use and climate	Gross Inland Energy Consumption* 2020: -20% 2050: -50%	GHG emissions** 2020: -20% 2050: -95%
Water use	Water Abstraction (indicator development)	Water Exploitation Index 2020: <20% 2050: <10%
Land use	Actual Land Demand 2020, 2050: zero net demand of foreign land	Human Appropriation of Net Primary Production 2020: stabilisation at 50% 2050: reduction to 40%

Source: BIO Intelligence Service et al. 2011

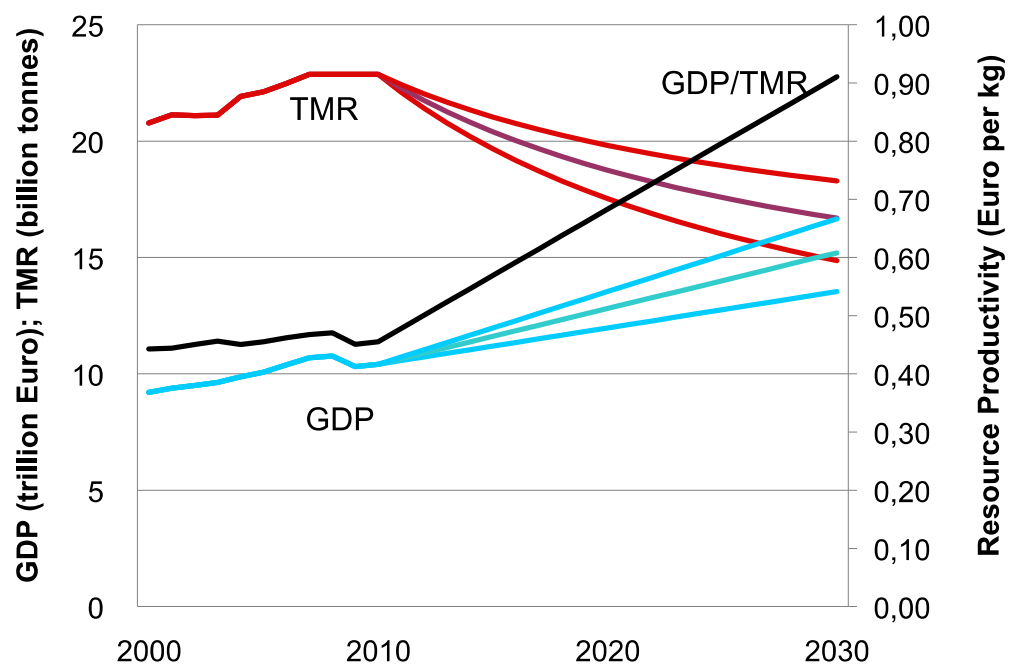
* Current energy efficiency target is set in relation to the reference year 2000. Originally set as primary energy consumption, it is tracked in gross inland energy consumption.

** The current GHG targets are set in relation to the reference year 1990. In the 2011 Roadmap to a low carbon economy (EC 2011c), 80% reduction of GG is set at the target for 2050.

As sharp reductions of direct material input as measured by DMI and DMC might enhance the trend to reduce the domestic resource extraction and shift towards the import of prefabricated goods outside the EU, any discussion on targets should reflect on the possible side effects. The shift to foreign resources may be avoided by targets which comprise both domestic and foreign resources extracted for the economic activities within the EU. This, again, underlies the importance of more comprehensive indicators such as TMR (for total resource productivity) and TMC (for absolute total material consumption per capita). Moreover, as these indicators comprise both used and unused extraction and represent higher nominal values, the potentials to realise such significant changes of a 70% reduction is much higher than for direct material use as depicted by DMI or DMC. Figure 12 shows the possible trends of GDP and TMR if a policy target of doubling total resource productivity (GDP/TMR) between 2010 and 2030 were to be realised. The subsequent table indicates that a more moderate economic growth would be favourable to reach an absolute reduction of material resource use.

Altogether, sufficiently comprehensive and intelligible indicators should be used for the derivation of targets and timetables which are needed to provide medium to long-term orientation and to be able to identify priority areas, drive sectoral objectives and choose priority measures.

Figure 12: Potential trends in resource productivity and GDP growth related to a policy target of doubling total resource productivity (GDP / TMR)



GDP average growth p.a.	1.5%	2.3%	3.0%
TMR reduction (2010-30)	35%	27%	20%

Source: Bringezu (2010)

5. SAVINGS POTENTIALS IN KEY EUROPEAN INDUSTRIES

KEY FINDINGS

- Resource efficiency can be a business opportunity leading to saved costs and new business models. Pay-offs may not only contribute to enhancing competitiveness of individual companies, but also aggregate to sectoral and economy-wide savings.
- Only a handful of product groups constitute the majority of resource demand: construction, food and energy products were identified as responsible for around two-thirds of primary resource consumption. Case study examples reveal that the potential for reducing resource consumption and saving money at the same time is high in these sectors.
- There is a correlation between competitiveness and resource productivity at the macro level. The impacts of resource efficiency on sectoral competitiveness are less well understood. In the future, enabling technologies are expected to help modernise EU industries and foster competitiveness while enhancing resource efficiency. More research is needed not only on high-tech applications, but also on creative low-tech solutions to foster a smart transition to a resource-efficient Europe.

5.1. Scope of Saving Potentials

Available knowledge indicates large, often untapped potential for saving costs and materials across the EU (EIO 2012). A number of studies have identified economic savings associated with efficiency measures

- on the European level and on the level of selected countries or sectors (Table 6);
- on the level of companies (Table 7).

Especially opportunities for “low hanging fruits”, which are simple to implement measures requiring either no monetary investments or having payback periods of around one year, are documented and widespread. For instance, at the global level McKinsey (2011) estimates that 30% of total resource demands in 2030 could be met through resource productivity in land, water and materials²¹. This would equate to \$3.7 trillion (€2.65 trillion) of savings; 20% of this opportunity is estimated to be readily available. However, the study emphasised that these measures alone will not be enough and are insufficient to halting climate change at 450-ppm carbon dioxide equivalent.

This seems to be true for most of the examples presented in Tables 6 and 7, which seem to be focused more on incremental changes than path-breaking innovations. While low-hanging fruits represent an easy win-win opportunity, they are only the first step. EIO (2012) estimated €50 billion worth of savings at the European level if similar-scale measures achieved in around 100 German manufacturing companies were implemented across Europe (see the first column of Table 6). The scale of change needed to achieve a Factor 5 target (an absolute reduction of consumption by 80%) would require efforts more than 40 times higher than those assessed by the EIO. Studies that focus on the dynamic potential of incremental innovations, as well as the potential impacts of more disruptive

²¹ Through the implementation of more than 130 resource productivity measures and without subsidies for energy, agriculture and water and an assumed price per carbon tonne of \$30.

change, are needed to improve understanding about the economic potential of eco-innovation at different scales and scopes.

Many of the studies dealing with resource efficiency take a case-study oriented approach. They scale-up the resource-saving potential shown to work for some companies to the level of sectors and economies. Surveys also seem to be a common method for generating data on the resource efficiency opportunity. Other studies use expert judgment with combinations of statistical sources and literature to estimate potential savings. Only one study (Meyer et al. 2012) is based on modelling. This means that results presented in Tables 6 and 7 should be used cautiously.

More comprehensive assessments and modelling work are needed to quantify the likely economic, environmental and social implications of large systemic shifts. Key aspects to consider include rebound effects due to resource efficiency increases, spill-overs of material input reductions across sectors and along value chains, resource prices and material substitution options as well as impacts of demand changes due to changes in consumer behaviour and life-styles (EIO 2012).

Meyer et al. (2012) have undertaken a comprehensive approach to consider sectoral interlinkages through modelling. Using two macro-econometric models which include information on resource use in physical units along with monetary economic data, Meyer et al. quantified the economy-wide costs and benefits from material saving efforts in different sectors. The models took into account that material reductions in one sector reduce demand and employment in other sectors, as well as decrease domestic material extraction and imports. Altogether, modelling revealed that most material input savings can be realised with positive impacts on aggregated GDP and thus make sense not only for environmental reasons, but also from the perspective of macroeconomic development and competitiveness.

Table 6: Studies reporting about resource efficiency savings potential on the European and country levels

Study	Savings potential	Scope and method
EIO (2012)	€50 billion	• Annual savings possible due to the implementation of a similar system to demea* (material efficiency measures) in all companies from all manufacturing sectors in the EU-27. • Estimation on the basis of extrapolation of micro savings of companies (N=92) from five German manufacturing sectors (food and beverages, rubbers and plastic, fabricated metal products, machinery and equipment, furniture and other products).
Schröter et al. (2011)	€48 billion	• Yearly savings possible due to material efficiency efforts in companies from the manufacturing industry in Germany. • Estimation and extrapolation on the basis of a survey (questionnaire, 2009, N=1,484) in companies from the manufacturing industry and data for manufacturing companies in Germany.

Study	Savings potential	Scope and method
Oakdene Hollins, Defra (2011)	£23 to 33 billion (€27 to 38 billion)	• Yearly savings possible due to implementation of no cost / low cost resource efficiency measures (£23 billion) and measures with payback greater than 1 year (£33 billion) targeting energy, waste, water, raw materials in each business sector within the UK. • Estimation on the basis of changes in resource efficiency by using consumption and waste statistics and literature reviews in each business sector.
COWI (2011)	€22.5 billion	• Annual savings possible due to implementation of a similar system to PIUS-Check (cleaner production methods) in SMEs from industrial production for EU-27, assumed that all SMEs will accept the PIUS check* (€776 million are possible if the same percentage of SMEs as in NRW accept PIUS check). • Estimation on the basis of extrapolation of micro savings of SMEs (N>500) from the German industrial production sector (particularly metal processing and finishing, food industry).
COWI (2011)	€1.4 billion	• Over the first five years savings are possible due to implementation of a similar system to NISP* (sustainable resource management solutions) in all companies in all sectors in the EU-27 (€187 million are possible within the UK). • Estimation on the basis of extrapolation of micro savings (N=1,340) of British companies of all sizes and sectors.
Mudgal et al. (2011)	15% to 28% of all non-energy materials	• Future feasible savings possible due to recycling, waste prevention and eco-design for the EU-27. • Estimation on the basis of material flow accounts, waste and production statistics, literature, case studies, expert judgment.
Meyer et al. (2012)	Positive GDP effects	• Savings possible due to material input reducing efforts (input reduced about 1 %) for 17 EU countries. • Estimation on the basis of macro-econometric modelling (with E3M3, GINFORS) of a general material input reduction and its effects on GDP and TMR. Development of short and long run cost abatement curves.

*See Box 3

Box 3: The German Material Efficiency Programme (demea) and similar programmes targeted at enhancing resource efficiency in companies

The German Material Efficiency Agency (demea) was launched in 2006 by the German Federal Ministry of Economics and Technology in order to provide financial means and contextual support for German companies (in particular SMEs) from the manufacturing sector interested in improving their material efficiency. The efficiency programme not only targets the materials that are consumed in the products themselves, but also those materials that are needed in the production process (operating and cleaning supplies, water, energy, etc.).

Demea offers a pool of more than 200 experts able to analyze material flows and identify material saving potentials within companies. The demea consultancies last between two and nine months and the demea reimburses costs (including expenditures for analyzing, advising, coaching and training; excluding material efficiency investment costs) up to 33%, and to a maximum of €100,000 in certain cases. In 2011 the programme changed slightly (amongst others €80,000 maximum value instead of €100,000).

So far, the programme has been proven to be very successful. More than 1,000 proposals have been approved (IDW 2011). Several studies (Schmidt and Schneider 2010 and EIO 2011) reported about the material savings that the demea programme was able to achieve. But neither in the German-wide nor in a European-wide context the idea of informing and supporting business via politically induced programs is unique. Related initiatives in the EU-27 that likewise advise companies on resource efficiency potentials include:

- **PIUS-Check:** The PIUS-Check is a Cleaner Production-instrument stemming from the Efficiency Agency (EFA) North Rhine Westphalia (NRW) in Germany which has been helping SMEs in NRW to improve their business resource efficiency since 2000. More than 500 checks have been initiated and have led to considerable savings, see Table 6.
- **NISP:** The British National Industrial Symbiosis Programme is a free business opportunity programme assisting member companies of all sizes and from all business sectors to improve their resource efficiency. Since its start in 2005, the programme has enabled thousands of business to become more resource-efficient, see also Table 6.
- **Követ:** The Hungarian Követ Association for Sustainable Economies has developed several tools to assist businesses on their way to more sustainable development. Within the programme “Money back through the window” Követ has analyzed more than 50 companies of all sizes since 2002 from and found evidence money that being spent in environmental measures is a good investment and not “money thrown out of the window”, see also Table 7.
- **ENWORKS:** ENWORKS is a three-years programme that helps businesses in the North West of England to improve their resource efficiency and thus converts environmental pressures into competitive advantages. ENWORKS offers practical advice, awareness-raising, on-site support and training, see also Table 7.

Table 7: Studies estimating resource efficiency savings potential per company on the sectoral level

Study	Yearly savings potential per company	Scope, method and other results
Schmidt and Schneider (2010: 158f.)	€210,000	• Results stem from demea which analysed and consulted companies (N=569) in the German manufacturing sector regarding material efficiency measures. • Saving potential per employee: €3,000 Savings related to annual turnover: 2.1 %
EIO (2012: 15ff.)	€196,000	• Results stem from the demea which analysed and consulted companies (N=92) in five the German manufacturing sectors (food and beverages, rubbers and plastic, fabricated metal products, machinery and equipment, furniture and other products) regarding material efficiency measures • Saving potential per employee: €3,000 Savings related to annual turnover: 2.3 % One-off investments: €129,000 Annual operation costs: €2,000 Average payback: 13 months
Követ ²² (2012)	€134,000 to €412,000	• Results stem from KÖVET which analysed and consulted companies (N=56) in the Hungarian manufacturing sector regarding reduction of materials, energy, waste and pollution • “Washed fruits on the table” (€134,000 savings) One-off investments: €0 Annual operation costs: €3,000 Average payback: immediate • “Low hanging fruits” (€181,000 savings) One-off investments: €200,000 Annual operation costs: €16,000 Average payback: 14 months • “High hanging fruits” (€412,000 savings) One-off investments: €3,100,000 Annual operation costs: €26,000 Average payback: 97 months
BIS (2010: 1ff.)	depending on the sector: £19,000 to £52,000	• Results stem from an analysis of ENWORKS²³ data and case studies (basing on existing data from stakeholder networks, internet research) regarding resource efficiency savings (energy, waste and water) for companies (N=403) from a couple of commercial and industrial sectors in the UK. • Results for Sector of Environmental Technologies: Annual savings per opportunity: £27,000 Annual savings per business: £50,000 Capital Investment of annual savings: 13 % Average payback: 2 months

²² More information about Követ available under <http://www.environmental-savings.com/>

²³ More information about ENWORKS under <http://www.encyclopedia.net>

5.2. Sectoral perspective

Few studies on savings potentials at the level of sectors exist. Considering that the sectoral composition of countries is crucial to the structural make-up of economies, better understanding on how to improve resource efficiency in a smart way catered to specific sectors is crucial to the transition toward resource-efficient economies and the EU as a whole. Data on the resource requirements and intensity of different sectors is becoming more robust. Sectoral analysis is subject to a number of ongoing research projects funded by the Seventh European Framework Program. For example, the project “Environmental Macro-Indicators of Innovation” (EMInn) aims at generating deeper insights into the role of innovation in decoupling resource use from economic growth²⁴. The FP7 project DESIRE (DEvelopment of a System of Indicators for a Resource efficient Europe) will develop and apply a set of indicators to monitor European progress towards resource-efficiency and its implications capturing the EU, country, sector and product group level, and the production and consumption perspective including impacts outside the EU. Once this data will be available it can be used to identify hot spots for resource use, as well as to compare sectoral performance in different countries. Examples of good practices and potentials for resource efficiency highlight the potential for considerable savings and underscore the need for more knowledge and knowledge diffusion on the level of sectors.

5.2.1. Resource requirements

Recent calculations from the Wuppertal Institute (ETC/SCP 2011) show that there are five product groups with especially high TMR and DMI shares (Figure 13):

- construction,
- food, beverages and tobacco,
- agriculture, forestry and fishing,
- electricity, gas and water,
- coke, refined petroleum products and nuclear fuels.

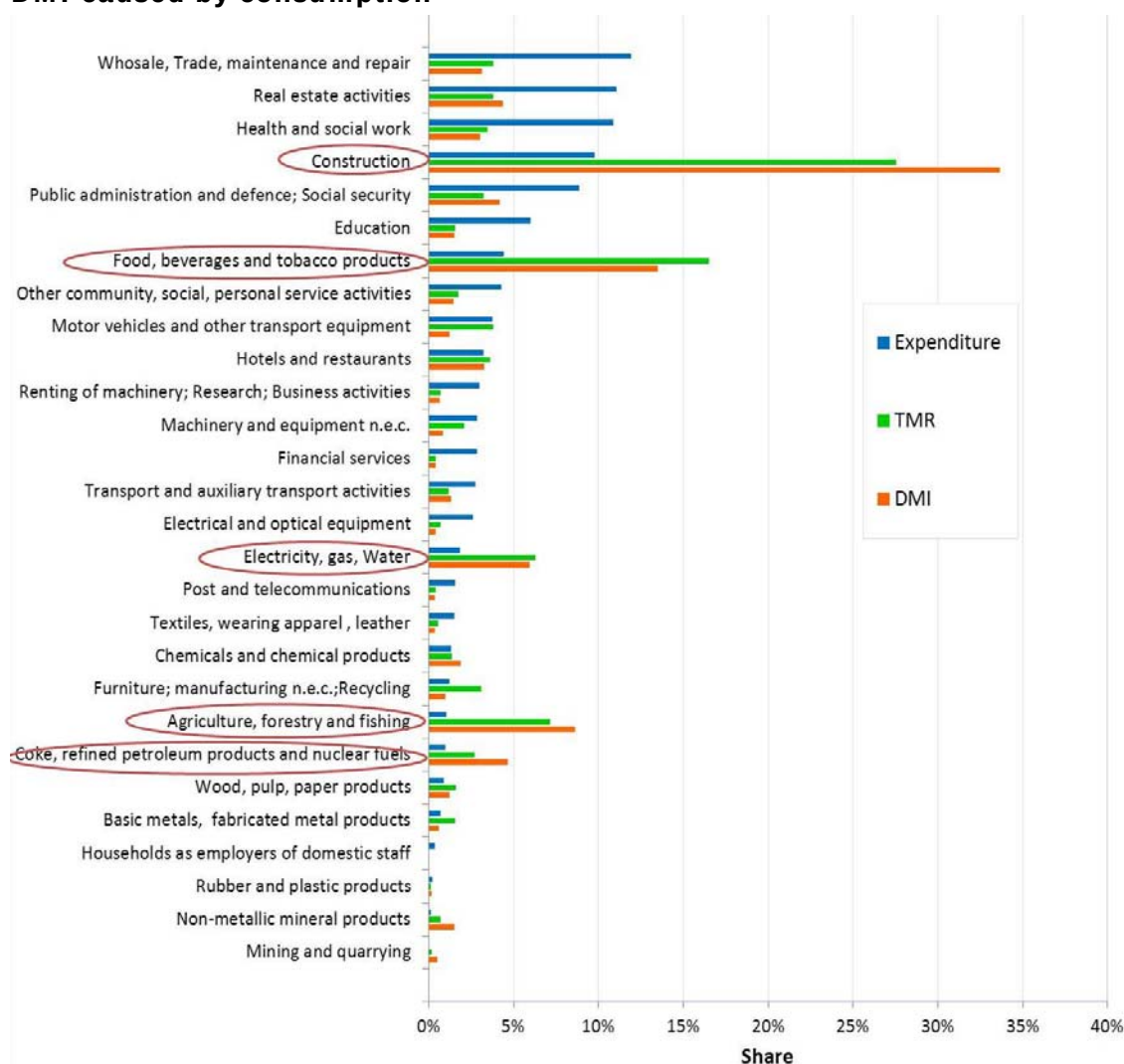
These findings are supported by other studies listing construction, agriculture, and food and beverages as main material consuming sectors (SERI et al. 2009, BIS 2011). Regarding their economic performance, the identified five product groups represent altogether 18% of the consumption expenditure (ETC/SCP 2011) and are responsible for two thirds (60% of the TMR and 66% of the DMI) of resource use at the final consumption end. This also makes them some of the most resource-intensive product groups.

Box 4: Recycling: saving resources and creating jobs

According to the EEA (2011b) recycling creates more jobs at higher income levels than landfilling or incinerating waste. Between 2000 and 2007 overall employment related to recycling increased 45% in European countries. FOE (2010) estimate that if a recycling target of 70% of key materials was met at the EU-level, it would create up to 322,000 jobs, with knock-on effects creating an additional 241,300 jobs in other sectors.

The environmental benefits are also considerable. Recycling currently contributes to a reduced need of 313 to 886 Mt of materials in the EU; if targets and best practices are achieved, up to 1,015 Mt of materials could be saved annually (mostly in construction). According to Mudgal et al. (2011), construction material recycling is the most important activity for material savings, while metal recycling is key for substituting intensive upstream processes related to mining and refining (recycling 1 kg of copper saves in general around 20 kg of copper ores).

²⁴ <http://www.eminnn.eu>

Figure 13: Share of product groups in consumption expenditure and in TMR and DMI caused by consumption

Source: ETC/SCP 2011: 25, *Expenditure, TMR and DMI induced by domestic final use, 9 EU countries (Austria, Czech Republic, Germany, Denmark, France, Italy, Netherlands, Portugal, Sweden), 2005

5.2.2. Resource intensity of sectors varies by country

Taking a closer look at the TMR-intensity of the identified resource intensive product groups in Germany, France and Italy reveals that on a national level, the resource-intensity of sectors varies, sometimes significantly (Table 8):

- In Germany, the most resource intensive products are from forestry, followed by agriculture and basic metals. The TMR-intensity of food and beverages and construction lie below the average (1.5 kg per Euro).
- In France, again products from the forestry and agricultural sectors are the most resource-intensive, followed by basic metals and coke and refined petroleum products. Food and beverages are below the TMR-intensity average of all product groups (0.9 kg per Euro).
- In Italy, basic metals are the most resource-intensive sector, followed by products from the agriculture and electricity, gas and water sectors. Coke and refined petroleum products and food and beverages lie slightly above the average TMR-intensity of all product groups (1.1 kg per Euro). Construction is the only sector that lies below the Italian TMR-intensity average of all product groups.

As regards economic potentials, the different performance of sectors in different countries would seem to indicate a potential for improvement to close this gap. Nonetheless, one must also consider that different natural conditions may affect efficiency potentials in different countries. More studies are needed to assess the potential and trade-offs of resource efficiency in sectors of the EU.

Table 8: Sectoral contribution to resource use in 2005 in selected countries (measured by TMR-intensity of products and services produced domestically)

Products and services	Germany (kg per Euro)	France (kg per Euro)	Italy (kg per Euro)
Products of forestry	13.7	8.1	<1.1
Products of agriculture	11.8	8.0	6.2
Basic metals	8.4	7.0	9.9
Coke, refined petroleum products	4.5	3.3	2.9
Electricity, gas and water	3.1	1.5	3.7
Fabricated metal products	1.7	2.1	2.9
Construction	1.1	1.9	0.6
Furniture	1.2	0.8	2.6
Food and beverages	1.4	0.5	1.4
Chemical products	0.7	0.6	1.3
Other non-metallic mineral products	1.0	1.0	1.1
All product groups	1.5	0.9	1.1
TMR (millions of tonnes)	6,017	2,858	2,686

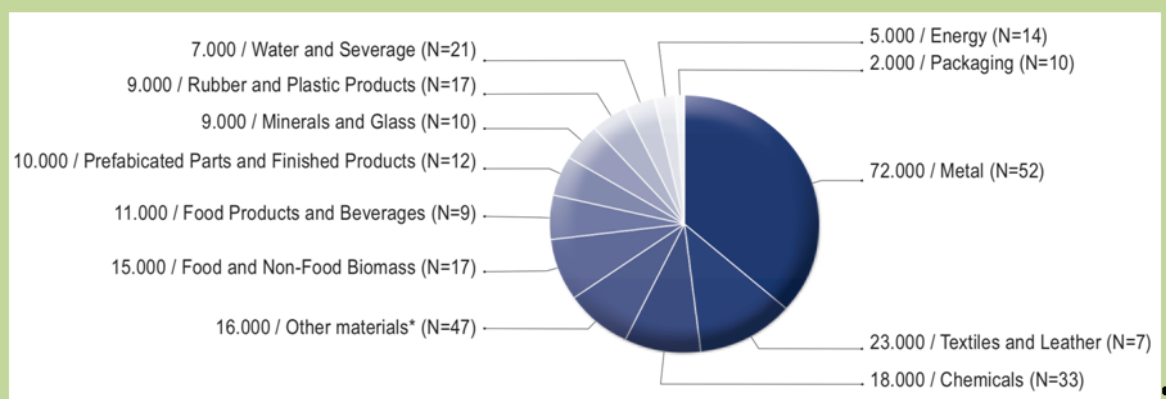
Source: Wuppertal Institute FG3, 2011: Acosta-Fernández and Schuetz, - calculations based on MFA data and external trade data from Eurostat and WI-MFA data set.

Box 5: Savings from reducing food waste

World-wide, around one-third of edible food is lost or wasted annually. Roughly 40% of food losses in industrialised countries occur at retail and consumer levels whereas more than 40% of food losses in developing countries happen at post harvest and processing levels (FAO 2011). Pressure on land, water, nutrients, and energy could be substantially lowered by reducing food loss and waste. FAO (2011) estimate that consumers in Europe and North America waste 95-115 kg/year. This is 10-15 times more than consumers in Sub-Saharan Africa and South/Southeast Asia waste. Studies from the UK reveal that around one-third of the food purchased is thrown out, leading to an estimated 5.3 million tonnes of avoidable food waste in the UK annually. This corresponds to an estimated £12 billion per year, or £480 for an average household, with an impact of 20 million tonnes of CO_{2eq} emissions (Defra 2010; WRAP 2009). Education and food waste prevention campaigns, such as WRAP¹ in the UK, are policy options for tackling the food waste problem in Europe. Anecdotal information from WRAP suggests that when food-waste collections are introduced, there is a reduction in the amount of food-waste generated. Separate food-waste collections also diverts organic waste from landfills so that it could be used for energetic purposes. Knowledge sharing and encouragement for infrastructure development could help to reduce post-harvest food loss in developing countries.

Box 6: Sectoral material savings in demea cases

A deeper analysis (EIO 2012) of efficiency savings from demea-advised companies has shown that metal is a material with high savings potential. 52 companies (from 92) were able to achieve yearly average cost savings of €72,000 due to the reduced use of metals. But also reductions of food products, beverages and non-food biomass were able to generate yearly savings of €26,000.

Figure 14: Share of average material savings (in €) realised per company

Source: EIO 2012: 22

N=92

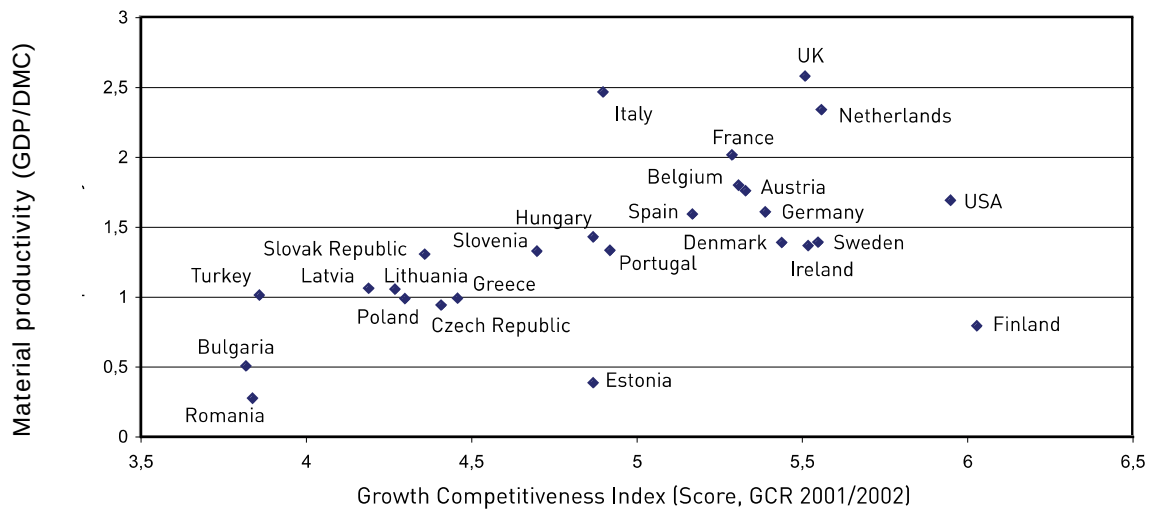
*other materials include auxiliary and operating materials, tools and mixed materials

A breakdown of the average cost savings from the metal products fabricating companies reveals that 70% of their savings were realized through the input reduction of basic metals. Also, companies from the machinery and equipment sector achieved more than 60% of their cost savings via the reduced use of basic metals. Cost savings of the food and beverages sector were half of the reduced input of water, electrical energy and sewage / refuse disposal services and one third of the reduced costs could be associated with a reduced use of agricultural products (EIO 2012). These findings show that the implementation of resource efficiency measures can contribute massively to resource reductions in upstream and high resource use sectors. Nevertheless, empirical findings about sectoral savings due to resource efficiency measures are rare and require more research.

5.3. Future competitiveness: enabling technologies transforming sectors

At the macro level, there seems to be a correlation between competitiveness, as measured by the Competitiveness Index of the World Economic Forum, and material productivity, as measured with GDP/DMC (Figure 15). Bleischwitz et al. (2009a) argue that resource productivity results in a competitive advantage due to high cost-saving potentials in material purchasing and transformation, waste handling and energy consumption.

At the level of sectors, more research is needed on the potential of resource efficiency to contribute to increased competitiveness. Case studies in section 5.2 revealed that the potential for cost savings is certainly high, which would seem to give resource-efficient companies a competitive cost-advantage at both the meso and macro level. The question is, how resource efficiency can contribute to maintaining competitiveness in the future.

Figure 15: Material productivity (GDP/DMC) versus competitiveness

Source: Bleischwitz et al. 2009a

The Roadmap outlines a vision of Europe in 2050:

"By 2050 the EU's economy has grown in a way that respects resource constraints and planetary boundaries, thus contributing to global economic transformation. Our economy is competitive, inclusive and provides a high standard of living with much lower environmental impacts. All resources are sustainably managed, from raw materials to energy, water, air, land and soil. Climate change milestones have been reached, while biodiversity and the ecosystem services it underpins have been protected, valued and substantially restored." (EC 2011a)²⁵

Realising this vision implies a restructuring of the current economic system. This will have different consequences and implications for different sectors. Enabling technologies are expected to play a role in the shift to a resource-efficient economy and the corresponding restructuring of industrial processes needed to modernise EU industry and foster competitiveness (EC 2009)²⁶.

Information and communication technology (ICT) has, for instance, been highlighted as a key enabling technology area. Application and adaption of ICT in construction, energy or transportation sectors has already led to radical innovation in the ways things are done (EIO 2012). It is estimated that ICT can help to mitigate around 13% of man-made GHG emissions resulting from transport by e.g. reducing travel needs, influencing travel choices, changing driver and vehicle behaviour, increasing network efficiency and increasing vehicle load factor (OECD 2010). In the future, innovations like the internet of things, machine-to-machine communication and radio-frequency identification devices (RFID) could be used in collaboration with other sectors to develop new and creative applications.

For example, RFID pads could be used to tag products, like cars and buildings, with information about what materials have been used in their production and how these materials can be recovered (Bringezu 2009). This would greatly enhance efforts toward urban mining, which is key to the transition toward a steady-stocks society²⁷ and could

²⁵ COM(2011) 571

²⁶ COM(2009) 512

²⁷ The steady-stocks society is characterised by a dynamic, steady-state flow equilibrium between inputs and outputs. It means that the physical stock in buildings and infrastructures has reached a maturity stage, where the net addition to stocks approaches values of around zero, and the industrial metabolism is no longer characterised by the linear flow of resource extraction to disposal, but rather on greater cycling within the economy.

result in a wide range of positive economic impacts, especially on a regional scale. Sourcing secondary resources, rather than extracting or importing primary resources, opens regional opportunities for development. Companies in the waste business, for instance, may use their strengths to create new business models, developing new logistical know-how and a wide range of experience in metal scrap trading (EIO 2011b). Expanding the skills set to incorporate more IT in construction and construction minerals recycling could re-vamp the more traditionally-structured construction sector to drastically lower primary resource requirements while creating new business opportunities and maintaining competitiveness (EIO 2011b).

Box 7: Resource-efficient construction

The construction sector has the highest TMR and DMI share in the EU-27 (Figure 12). Construction and demolition activities account for around 33% of waste generated annually (EEA 2010). Reducing resource use and re-using waste more effectively would significantly reduce the total material requirement of European societies. Examples of good practices and leading edge technologies are rampant. A snapshot includes activities to

- **Reduce the resource intensity of construction design.** Resource-light construction is an approach that takes an integrated approach to building functionality, finding the best material for each application. Ultra-high performance concrete may help to reduce the overall footprints of infrastructures and buildings. Thinking outside the box may also enable functionality to be achieved in a more resource-efficient way. For example, wireless building technology linking switches and sensors reduces the need for copper cables.
- **Use and re-use resources more effectively.** In the building phase, higher levels of industrialisation may significantly reduce on-site construction waste, e.g. prefabricated modular components are built in a factory with a high level of precision and better opportunity to minimise and re-use waste. Around two-thirds of the material used during the construction and use phases can be saved by converting an existing building (Lemken 2008). Urban mining offers an untapped source of resources. Positive experiences with urban mining in the city of Zurich, Switzerland, reveal potential.
- **Build smarter to save energy.** Use of modern technologies like resource-efficient cladding can cut the final energy consumption of buildings by 80% (Wuppertal Institute 2009). Also use of historical practices can lower energy consumption—e.g. green roofs provide a thermal gradient between the roof and building interior, reducing the need for heating and air conditioning.

Other transformative ‘solutions’ enabled by ICT include, for instance, smart grids or more broadly smart cities, smart planning (urban and rural), and dematerialising products through digital equivalents or intelligent optimisation of energy (EIO 20120, GeSI 2008).

The potential of ICT as a key enabling technology for improving resource efficiency seems to be considerable. Nevertheless, there are also risks connected to the ever increasing expansion of ICT around the planet. While ICT can make the use of natural resources more efficiently, this can provoke rebound-effects. For example, more ICT can improve the traffic flow, but less congestion will attract more drivers, thus resulting in an absolute increase of traffic and thus use of natural resources.

The use of short-lived electronic appliances which often consist of rare or hazardous materials and which create additional energy requirements can contribute to an absolute increase of the pressure on the planet. The opportunities and risks of ICT for achieving a resource efficient Europe are yet uncharted territory and need to be explored.

Box 8: Need for integrated policy solutions to foster the transition to a resource-efficient Europe

According to Bringezu (2009) a future sustainable metabolism may be characterised by four paradigmatic and complementary perspectives:

1. a resource-efficient and recycling-based industry,
2. the steady stocks society,
3. a solarised technosphere and
4. a balanced bio-economy.

The dynamics and features of visionary elements which Bringezu (2009) has described may provide orientation for technology and policy development. This will include not only a fundamental redefinition of progress and economic development beyond the simplistic GDP-based growth paradigm, but also practical questions for the implementation of the flagship initiative for a resource efficient Europe. One central question is, for example, how modes of EU governance and social innovations can be combined in order to achieve the necessary transition effects. There are basically three modes of governance which can promote transition: markets, hierarchy and networks (Knill & Lenschow 2003). The market coordinates with “invisible hand” stakeholders which try to maximise their private benefit. Hierarchies in governments and industry are organised centrally on the basis of command-and-control. They can set standards for technologies and products (e.g. on material and energy efficiency) in order to drive innovations towards sustainability, and adjust the incentive framework depending on the overall resource consumption of countries. In networks governance is based on negotiations. While failures of networks, the state and markets are broadly acknowledged, integrated solutions for pragmatic resource-efficiency policies are insufficiently explored (Meyer-Stamer 2009) and need to be made subject to policy-oriented research and development.

Further relevant key enabling technologies exist in the areas of biotechnology, advanced materials, nanotechnology, photonics and micro and nano-electronics. Carbon capture and storage systems as well as systems of carbon capture and re-use have also been highlighted as key activities (EC 2009²⁸, Bringezu 2009). While such technologies may help to modernise and boost competitiveness in other sectors, the arena of enabling technologies in Europe faces increasing competition from the US, Japan, Korea, China, Russia, India and Brazil (Larson et al. 2011). The key challenge for Europe seems to be overcoming barriers to commercial deployment, especially linking value-chains to support tech transfer mechanisms and creating markets for innovative, but expensive, products to capitalise on the first mover advantage. According to stakeholders, policy coordination is especially called for to maximise prioritisation and synergies between programmes, instruments, and levels (Larson et al. 2011).

While enabling technologies will contribute to sectoral development in the EU, achieving a resource-efficient Europe as described in the vision of the Roadmap will require more than just high-tech solutions. More creative ways of approaching functionality, changed consumption behaviours and social innovation are essential to any systemic change (see also the vision described in Bringezu 2009 and EIO 2011).

²⁸ COM(2009) 512

6. RECOMMENDATIONS

KEY FINDINGS

- Defining the indicator base of targets and timetables is a pressing issue. Total resource productivity can provide orientation for industry as a whole and for production sectors, while total material consumption can be recorded in absolute units per capita. Resource efficiency of the primary sector (used/unused), and the relation of domestic and foreign resource use can also be accounted for. Monitoring of the physical trade balance can be based on total resource requirements (including indirect flows).
- Resource efficiency should be firmly integrated into EU policies, financial instruments and programmes. A basis could be “a greening of the EU budget”. To this end, EU cohesion funding could be linked to national green stimulus programmes and monitored with EU Sustainable Development Indicators.
- The first paradigm of a resource-efficient and recycling-based industry can be realised with current political instruments and policy action.
- Getting the prices right is key to mobilising economic allocation mechanisms for a long-term transition of the European economy.

6.1. Using the right indicators

The first recommendation relates to the definition of indicators, which seems to be the most pressing issue. Further delay in defining overall targets for medium to long-term orientation may simply result in disorientation and the design of counteractive policies. The Roadmap RE proposed a “headline indicator” material productivity (GDP/DMC) in order to monitor the decoupling of resource use from economic growth. As this indicator seems to provide the bottom line of information, it may also be addressed as a “base indicator”, which ought to be improved. The steps for such an improvement have been described in the available guidelines of Eurostat and the OECD. A further step is developing a “dashboard” of indicators, which should include GHG emissions, water and land use (specifying direct and indirect use).

Sustainable consumption and production patterns based on a global supply chain or international perspective require different measurements:

1. The *production* of a country or the EU as a whole, which implies the accounting of all life-cycle-wide resource requirements (or emissions) for the production including exports.
2. The (domestic final) *consumption* of a country or the EU as a whole, which implies the accounting of all life-cycle-wide resource requirements (or GHG emissions) within those countries or the EU, excluding exports.

With regard to the materials domain, GDP/TMR is the most comprehensive indicator to monitor the total resource productivity of a country, as total material requirement (TMR) comprises all domestic and foreign resource extractions for domestic production and consumption activities (which can be differentiated into used and unused extraction), and thus also indicate the resource efficiency of the primary sector.

When monitoring consumption oriented indicators these should preferably be expressed on a per capita basis in order to allow cross-country comparisons. In this case, the resource

requirements for exports should be subtracted. Thus, total material consumption (TMC) is the most comprehensive indicator for the material domain.

Such an indicator base would form the foundation for monitoring the *physical trade balance*, including the indirect flows of imports and exports. In other words, it would take account of whether countries shift environmental pressures to other regions due to their production and/or consumption activities. Similar calculations can and should be performed and indicators derived for the other resource domains (land, water) and GHG emissions.

6.2. Policy integration

The ultimate goal of the flagship initiative for a resource efficient Europe should be to integrate resource efficiency firmly as an essential part of EU policies, financial instruments and programs (Schepelmann et al. 2009). This could strengthen resource efficiency as a major source of employment and innovation and improve the industrial base of Europe by promoting entrepreneurship and the development of new skills along the value chain of manufacturing industries. In the framework of the flagship initiative the Eco-Innovation Action Plan (Eco-AP) could become a platform for transition laboratories, setting examples and mobilising EU Member States and stakeholders for integrated policies and actions. Progress could be monitored by the already existing Eco-Innovation Observatory (Box 9).

Box 9: Need for integrated policy solutions to foster the transition to a resource-efficient Europe

The EU already has a number of programmes dedicated to key elements of the transition to a resource-efficient Europe. The central role of these programmes, combined with other instruments, has been described by Bleischwitz et al. (2009b).

The **Competitiveness and Innovation Framework Programme (CIP)** boosts the competitiveness and productivity of European industries and promotes innovation activities by financing and delivering business support services. The programme period runs from 2007-2013 with a budget of €3.6 bn.

The **Seventh Framework Programme for research and technological development (FP7)** is the largest research programme in the world. Collaborative research constitutes the core of EU research funding. Within the ten distinct themes of the FP7 “cooperation” component, several are closely related to central aspects of a resource-efficient Europe, including environment, social science and humanities, nano-production, energy, food, agriculture, fisheries and biotechnology.

For a European transition **the Eco-Innovation Action Plan (Eco-AP) and the Eco-Innovation Observatory** are of special importance because they are specifically meant to stimulate resource efficiency on a broad scale. From yet another innovation and technology platform Eco-AP could evolve into a platform from which the transition towards a resource efficient Europe could be launched.

Different EU programs could converge and be strengthened with Cohesion Funds. A concrete proposal for improving this kind of policy integration has been formulated by the Scientific and Technical Research Committee of the European Union (CREST). The Commission has published a report based on the CREST guidelines on using synergies between Structural Funds, the Research Framework Program and the Competitiveness and Innovation Program (CIP). Further integration with the Eco-Innovation Action Plan could be sought. Such an advanced scheme for using of the EU budget could be the material foundation for developing a “triple-helix” consisting of stakeholders from enterprises, the public sector, research and teaching who could drive resource efficiency.

The material basis for policy integration could be a “greening of the EU budget” with a new emphasis on resource efficiency, not by simply exchanging headlines - as not all “green” approaches are resource efficient - but by the provision of a more concrete goal with measurable progress. EU Member States and regions could be motivated to adapt national stimulus programmes to meet the objectives of improving national resource efficiency, which is already monitored via the Sustainable Development Indicators. Linking EU cohesion funding with national green stimulus programmes, which have emerged after the 2008 financial crisis, and monitoring with EU Sustainable Development Indicators would address two persistent problems of EU Regional Policy: a lack of co-funding and accountability. Using the established Cohesion Funds and reporting mechanisms for monitoring regional policies for improving resource efficiency could allow the Community to implement a transition towards a resource efficient Europe immediately.

The existing EU-wide expertise for improving resource efficiency should be gathered, assessed and further developed. This could be achieved by establishing a European Resource Efficiency Agency (EREA). Box 10 describes the potential role and value of a EREA. In combination to the EREA, national Resource Efficiency Funds (REF) could be established. These funds would finance resource efficiency especially in SMEs, which often lack sufficient capital and expertise for resource efficiency measures. The national REFs could co-finance EU Regional Policy.

The combination of the EREA, the availability of funds (national REF + EU Cohesion Funds) and improved public procurement could initiate a short-term impact on economic development and job creation. In combination with a harmonised, target-oriented policy mix it could eventually lead to a self-sustaining demand for resource efficient products and services, thus having a lasting and long-term effect with structural improvements on consumption and production patterns (transition).

6.3. Elements for a resource efficient industry policy

With a pragmatic approach Kristof & Hennicke (2009) propose five core elements to realise the first paradigm of a resource-efficient and recycling-based industry outlined by Bringezu (2009):

1. Sustainable markets, which provide a direction for innovation
2. Strong institutions which act as a key to a successful diffusion
3. Resource efficient products and services
4. Public procurement using the market power and exemplary function of government as a consumer
5. Awareness raising

Sustainable markets of the future – providing a direction for innovation

Markets should promote innovations with a focus on improved resource efficiency. Political arrangement of the market framework conditions should create incentives for the development of resource efficient innovations and reduce counter-productive incentives (e.g. by setting the right price signals). As a result research and development would be oriented towards the development of resource efficient products and services. The central problem is not the lack of resource-efficient inventions, but innovations which are successfully introduced and established on the market. In addition to research and development, diffusion in the EU and export to international markets needs to be supported by instruments such as trade fairs, market information, technology platforms and innovation partnerships. The upcoming framework program (Horizon 2020) and technology

and innovation platforms need adjustment to better support resource efficient solutions and their diffusion.

Box 10: A European Resource Efficiency Agency (EREA) for policy diffusion

The primary objective of a European Resource Efficiency Agency (EREA) would be the development and coordination of Resource Efficiency Agencies, similar agents and diffusion of best practices in EU Member States. The aim would be an EU-wide network of research and technological development for improved resource efficiency. The EREA would initiate international cooperation and communication to raise awareness in Member States and industry sectors in order to stimulate demand for consultancy services. Awareness of cost-reduction potentials among decision-makers in industry would lead to an increased demand for specific resource efficiency technologies, products and services. The desired long-term effect would be a self-sustaining competition for meeting cost-advantages of resource efficiency in the EU's manufacturing industry. This would result in an increased demand for scientific and engineering skills, which cannot be met by the existing market. Therefore, these measures would have to be accompanied by creating the necessary infrastructure for research, training and education. In the short term, diffusion of existing best practices in the EU would be sufficient to harvest the "low hanging fruits" by reducing the most obvious resource inefficiencies. For harvesting these "low hanging fruits" the EU regions can build on more than 10 years of experience of existing resource efficiency agencies and networks (see Box 3).

Based on experiences with the German Material Efficiency Agency (demea, see Box 3 and Box 6), the total costs of such an endeavor are estimated to be lower than the savings. Table 9 depicts the savings and costs if 100 companies in Germany and 100 companies in all EU-27 countries (e.g. 2,700 companies) were to participate in a material efficiency consulting with results matching those achieved by companies participating in the demeas programme. 100 companies is an assumption made for indicative purposes to get a rough idea about the costs and benefits of a material efficiency agency. We strongly recommend further investigations in the potential costs and benefits taking into account specific conditions in Member States. In the actual consultancies funded by the German demeas between 2006 and 2010 average savings per company amounted to €196,000 annually (EIO 2012). Applying this to a theoretical 100 companies reveals a total savings potential of €19.6 million in Germany and €529 million across the EU in the first year.

As regards costs, companies generally have to make some investments to improve material efficiency, for instance in new machines, software and personnel training. These are "one-off" investments for the company and averaged €129,000 per company in the demeas experiences (EIO 2012). Some companies may also need to make further yearly investments to maintain efficiency gains (e.g. for maintenance), and these costs averaged €2,400 per company (although these costs were only needed by 16% of the cases studied and thus probably represent an overestimation of costs in Table 9) (EIO 2012). In the demeas programme, consulting costs are split between companies and the demeas. For instance, when costs are below €15,000, demeas covers 67% of costs (BMW 2011, demeas 2011). To run the demeas programme itself, annual costs of around €1.2 million are estimated (Kristof et al. 2008). This includes, for instance, costs to manage and advertise the programme. However, the €1.2 million also includes costs for a few of the other services that demeas offers (e.g. a 9-month intensive consultancy and a networking support for exchanging information and experiences related to material efficiency). Because potential savings from these activities are not accounted for on the savings side of Table 9, the cost-saving benefit overall may be somewhat different.

Table 9: Indicative extrapolation of savings and costs for resource efficiency agencies

	Germany(100 companies)			EU-27 (100 companies per country)		
	Companies (100)	DEMEA	Total	Companies (2,700)	EREA	Total
Savings (yearly)	€19.6m		€19.6m	€529m		€529m
Total savings	€19.6m		€19.6m	€529m		€529m
Investments costs (one-off)	€12.9m		€12.9m	€348m		€348m
Investments costs (yearly)	€0.2m		€0.2m	€6.5m		€6.5m
Consulting costs (one-off)	€0.9m	€1.4m	€2.3m	€24m	€37m	€61m
Annual programme costs		€1.2m	€1.2m		€32m	€32m
Annual material efficiency award		€0.2m	€0.2m		€5.5m	€5.5m
Total costs	€14m	€2.8m	€16.8m	€378m	€74m	€453m

Source: Demea savings data based on EIO 2012. Demea costs based on Kristof et al. 2008.

Note: One-off investment costs include e.g. new machines, software, new personnel; Yearly investment costs refer to e.g. maintenance; Programme costs refer to e.g. qualification, public relations and agenda setting. Numbers have been rounded to 1 decimal point for sums under € 20m.

Under these assumptions, savings in Germany would amount to €19.6 million in the first year. Costs in Germany would be €16.8 million, of which €14 million are estimated for companies and around €2.8 million for demea. Aggregating this potential to the European level reveals €529 million worth of savings and €453 million in total costs, with €74 million being provided by Resource Efficiency Agencies across the EU or docked in an overarching European Resource Efficiency Agency.

In a short amount of time, the savings generated by such a programme would be considerable. Table 10 extrapolates the savings and costs for the 100 cases presented in Table 9 over 10 years. It reveals that savings around 10 times the total investments are possible within a decade. It should again be emphasised that these calculations are for indicative purposes only. The potential to grasp material efficiency opportunities, as well as the scale and scope of those opportunities, are probably quite different across the EU. Nevertheless, there does seem to be a clear potential for material efficiency, and a European Resource Efficiency Agency could be one strategy to exploit and build on this potential in a more integrated way across the EU.

Table 10: Indicative extrapolation of potential savings and costs for resource efficiency agencies after 10 years

	Germany(100 companies)			EU-27 (100 companies per country)		
	Companies (100)	DEMEA	Total	Companies (2,700)	EREA	Total
Total savings in 10 years	€196m		€196m	€5,290m		€5,290m
Total costs in 10 years	€16.2m	€2.8m	€19m	€437m	€74m	€511m

Source: Based on Table 9. Demea savings data based on EIO 2012. Demea costs based on Kristof et al. 2008.

Note: For costs on the company side, the one-off investments from Table 9 have been accounted for once and the yearly investments 10 times. On the agency side, the costs for the year in which the companies participated in the programme are accounted for (i.e. once).

Facilitating institutions – key to a successful diffusion

Companies rarely have enough expertise, resources and time to implement resource efficiency measures alone. Especially SMEs struggle with in-house capacity and often lack the time to launch resource efficiency measures. In order to realise efficiency potentials, individual and specialised consultancy services are required. These can adapt to the actual situation of a company and follow-up the whole process of the required restructuring. This kind of service requires a large pool of consultants. Experiences from Germany have shown that an intermediate agent can successfully support the cooperation of companies and adequate consultants (see Box 3). Resource efficiency advisory services and networks should be evaluated and best practice supported and diffused throughout the European Union. A European Resource Efficiency Agency (see Box 10) could be a means to this end.

Resource efficient products and services

There are three options for political action to support resource efficient products and services on the market:

- First, cutting-edge products need to be supported especially in the phases of design and market introduction.
- Second, standards need to direct average mass market products towards improved resource efficiency. Existing standards like the eco-design directive (2005/32/EC) should be upgraded by including resource efficiency requirements.
- Third, new resource efficiency standards should also contain minimum requirements for products on the market. As a result, products with old, resource consuming designs will be banned from the market.

The Government as a consumer – setting an example and market power

Strategic consumption can force markets towards more resource efficient products and services. Governments have market power since public procurement accounts for a large share of the total market consumption. Resource efficiency can be established as an important decision factor through specific public purchasing directives. This would also be an incentive for the design of resource efficient products, since commercial risk is limited by a stable demand from public institutions. Moreover, governments can have a pioneering function. If resource efficiency is established and consistently applied, long term cost advantages can be realised. The state can also set an example for socially responsible behaviour.

Awareness raising and education

The four elements listed above can only be realised when people in institutions, companies and society understand the importance and opportunities of improved resource efficiency. In order to raise awareness for resource efficiency all communication and education channels have to be used. Students need to learn about resource efficient consumer behaviour in school. Later on in their education and studies they should have awareness for resource efficient technologies and services and be able to get the necessary professional training. Furthermore, awareness-raising campaigns should be launched. Visualisation of the requirements and benefits of resource efficiency with best practice examples is essential to initiate learning processes. The resource-related communication and education process must become part of everyday life.

In summary, concrete actions exist which can be implemented now. Nevertheless, the transition to a resource efficient economy also requires new actions to address systemic failures. Research and development need to broaden their scope by finding relevant

answers to a number of systemic challenges, which should be embedded in a comprehensive vision of a sustainable metabolism of industrial societies.

6.4. The transition to a resource efficient Europe

The transition to a resource efficient Europe is a step up from mere support for “green tech” towards a systemic transition of the EU economies. The focus of transition to a resource efficient economy requires revised and reinforced actions reflecting changed priorities as well as drivers and barriers. The Eco-AP actions could be stepped up, reinforced and additional financial resources would have to be mobilised including the large financial flows of the CAP and Cohesion Policy.

Moving towards cleaner and more energy and resource-efficient products and processes will result in a competitive advantage for manufacturing industries irrespective of the sector. This requires a broad policy-mix. For example, by “getting the prices right” economic allocation mechanisms can be mobilised for a long-term transition of the European economy. Over the short and medium term, public authorities must strengthen underlying incentives if capital is to be deployed to cover the time gap and have the desired impacts. The transition to a resource efficient Europe must therefore give the right price-signals for resource-efficiency.

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ANNEX: AVAILABILITY OF TMR DATA

COUNTRY	REPORTING PERIOD	ORGANISATION	REPORT	LINK	REMARKS
USA	1975 to 2000	World Resources Institute - WRI	Adriaanse et al. 1997; WRI	Link²⁹	Two WRI reports followed the Adriaanse et al. 1997 report; data is freely available for download as given under link
Japan	1975 to 1994	National Institute for Environmental Studies - NIES	Adriaanse et al. 1997	Link³⁰	Data is available in print form as given under link
China	1995 to 2008	Northeastern University, China	n.a.	n.a.	Data is currently being processed in a joint study on China, Japan, the EU-27 and Germany - by Northeastern University, University of Tokyo and Wuppertal Institute
Brazil	1975 to 1995	Federal University of Para, Belém, and University of Amazonas, Manaus - Brazil	n.a.	n.a.	Data provided by personal communication of José Alberto da Costa Machado - University of Amazonas
EU27	2000 to 2009	Wuppertal Institute - WI	n.a.	n.a.	Data build on direct material flows data of Eurostat, estimates for hidden flows by WI
Austria	1995 to 2008	Wuppertal Institute - WI	n.a.	n.a.	Data build on direct material flows data of Eurostat and IFF/Statistics Austria, estimates for hidden flows by WI
Czech Republic	1990 to 2006	Charles University Environment Centre - CUEC	Kovanda et al. 2010	Link³¹	Publication is not freely available

²⁹ <http://www.wri.org/publication/material-flow-accounts#database>

³⁰ http://pdf.wri.org/resourceflows_bw.pdf

³¹ <http://onlinelibrary.wiley.com/doi/10.1111/j.1530-9290.2010.00253.x/abstract>

COUNTRY	REPORTING PERIOD	ORGANISATION	REPORT	LINK	REMARKS
Denmark	1981; 1990; 1995; 1997; 2000; 2005-2007	Statistics Denmark (1981, 1990, 1997); other years: Wuppertal Institute - WI	Gravgaard Pedersen, O. (2002). DMI and TMR Indicators for Denmark 1981, 1990 and 1997 – An Assessment of the Material Requirements of the Danish Economy. Report for Eurostat, Statistics Denmark	n.a.	Data by WI builds on direct material flows data of Eurostat and Statistics Denmark, estimates for hidden flows by WI
Finland	1945 to 2008	Statistics Finland	Hoffren 2010	Link³²	Data is available in print form as given under link
France	1990 to 2008	Institut Français de l'Environnement - IFEN (1990 to 2006); 2007-2008 by Wuppertal Institute - WI	Jamet 2009	Link³³	Data from IFEN is freely available for download as given under link; Data by WI build on direct material flows data of Eurostat and IFEN, estimates for hidden flows by WI
Germany	1991 to 2009	Statistics Germany - Destatis; Wuppertal Institute - WI	Destatis: UGR Presseberichte jährlich	Link³⁴	Data by WI builds on direct material flows data of Eurostat and Statistics Germany (partly also for unused domestic extraction), estimates for (remaining) hidden flows by WI; Data for former West-Germany are available for 1975 to 1990 in Adriaanse et al. 1997 (see under USA), from 1960 in the database of WI

³² http://www.stat.fi/tup/julkaisut/tiedostot/isbn_978-952-244-233-8.pdf

³³ <http://www.statistiques.developpement-durable.gouv.fr/>

³⁴ http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/DE/Navigation/Publikationen/Fachveroeffentlichungen/UGR.templateId=renderPrint.psml_nnn=true

COUNTRY	REPORTING PERIOD	ORGANISATION	REPORT	LINK	REMARKS
Hungary	1993 to 1997	International Institute for Applied Systems Analysis - IIASA	Hammer, M. and Hubacek, K. 2003: Material Flows and Economic Development - Material Flow Analysis of the Hungarian Economy. Interim Report IR-02-057.	Link³⁵	Data available in print format under given link
Netherlands	1975, 1980, 1985, 1990 - 1993; 1995, 2000, 2005-2007	Data until 1993: Center of Environmental Studies at Leiden University - CML; data for other years: Wuppertal Institute - WI	CML personal communication	n.a.	Data by WI builds on direct material flows data of Eurostat and Statistics Netherlands, estimates for hidden flows by WI
Italy	1980 to 2007 - annually	Statistics Italy - ISTAT	Barbiero et al. 2003; Femia (ed.) 2004	Link³⁶	Basic publication was Barbiero et al.; the data is freely available for download as given under link
Poland	1992, 1995, 1997	Institute for Sustainable Development, Warsaw (Poland) and Wuppertal Institute for Climate, Environment and Energy (WI), Wuppertal (Germany)	Mündl, A. et al. (1999). Sustainable development by dematerialisation in production and consumption — strategy for the new environmental policy in Poland. Report 3, 1999. Institute for Sustainable Development, Warsaw.	n.a.	Data is available at WI

³⁵ <http://www.iiasa.ac.at/Admin/PUB/Documents/IR-02-057.pdf>

³⁶ http://en.istat.it/dati/dataset/20100517_00/

COUNTRY	REPORTING PERIOD	ORGANISATION	REPORT	LINK	REMARKS
Portugal	1995, 2000, 2005-2007	Wuppertal Institute - WI	n.a.	n.a.	Data builds on direct material flows data of Eurostat and Statistics Portugal, estimates for hidden flows by WI
Spain	1996 to 2000	Statistics Spain - INE	Statistics Spain 2003	n.a.	INE currently reports direct material flows only
Sweden	1995, 2000, 2005-2007	Wuppertal Institute - WI	n.a.	n.a.	Data builds on direct material flows data of Eurostat and Statistics Sweden, estimates for hidden flows by WI
Switzerland	1990 to 2007	Statistics Switzerland - BFS	Statistik Schweiz	Link³⁷	Data is freely available for download as given under link
UK	1970 to 2009 - annualy	Statistics UK - ONS	Statistics UK (ONS)	Link³⁸	Data is freely available for download as given under link
Venezuela	1988 to 1997	Oficina de Estudios Hercilio Castellano, Venezuela	n.a.	n.a.	Data provided by personal communication of Hercilio Castellano

Source: H. Schütz, Wuppertal Institute, personal communication

³⁷ <http://www.bfs.admin.ch/bfs/portal/de/index/themen/02/05/blank/dos/03.html>

³⁸ <http://www.ons.gov.uk/ons/search/index.html?newquery=material>

NOTES

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