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ANALYSIS OF THE KEY CONTRIBUTIONS TO RESOURCE EFFICIENCY

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ABSTRACT

This study is a first attempt to assess the extent to which recycling, waste prevention and improvements in product design in the EU contribute to overall material use and material productivity. Based on Material Flow Accounts (MFA) and waste statistics, material savings for non-energy materials: biomass (excl. wood fuel), minerals, metals and plastics, were analysed. Material savings were estimated for four scenarios: (1) current policies and (2) policies with targets reached; (3) feasible potential, and; (4) a theoretical 100% recycling rates. The study assumed identical consumption patterns and population numbers when considering the different scenarios. Besides the theoretical 100% recycling scenario, all the other scenarios were based on material savings that could be achieved with little or no additional costs (in some cases there would be cost benefits). For recycling the effects of various EU policies were investigated based on waste statistics. For waste prevention and product design, EU wide data was not available so estimates were based on evidence from case studies. Here the effects of diverse strategies such as lean production, reuse, sustainable consumption, design for recyclability, product lightweighting and design for longevity were analysed.

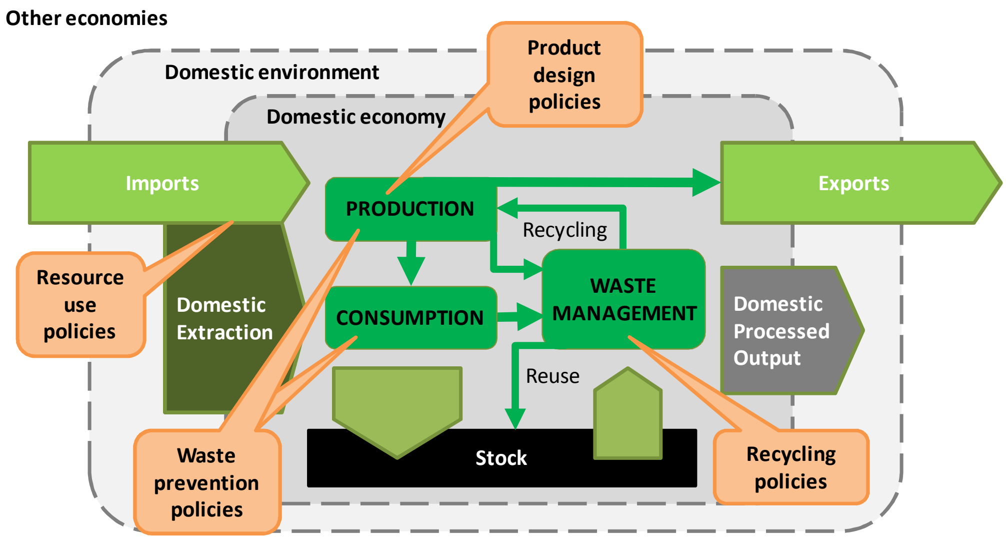
The estimates for material savings range considerably depending on the source of waste statistics and assumptions made. The study estimated that 7 - 18% of all non-energy material consumption is saved or avoided due to current recycling, waste prevention and ecodesign policies and practices. Recycling has by far the largest contribution (accounts for over 75% of total contributions) compared to waste prevention and product design. Waste prevention measures have considerable potential to reduce waste and overall material consumption. In both cases product design is the key to achieve greater amounts of recycling and waste prevention. The future feasible potential for material savings from recycling, waste prevention and ecodesign are estimated to be from 15% to 28% of all non-energy material consumption. As material consumption is measured in weight, construction materials represent the greatest share of materials saved (about two thirds of the total materials saved). The recycling of metals, however, plays an important role in material productivity as this represents both significant environmental impact reductions as well as cost benefits. It was also shown that in general, increasing material productivity can also significantly reduce greenhouse gas emissions (3 - 5% of total annual GHG emissions).

EXECUTIVE SUMMARY

Natural resources are fundamental for the economy and prosperity. They provide raw materials, energy, food, water and land, as well as environmental and social services. However, our current patterns of resource use, production, consumption and waste are unsustainable. The Earth has only finite resources, and the use of these resources places increasing pressure on our natural environment resulting in global warming, pollution and degradation of eco-systems and biodiversity. In order to reduce the environmental impacts related to resource use in the economy, we have to be efficient with the resources that we have.

Tracking the resource efficiency of economies is one way of understanding whether we are progressing towards sustainable development. An indicator often used for resource efficiency is the total amount of materials directly used by an economy (measured as domestic material consumption [DMC]) in relation to economic activity (measured as GDP). It provides an indication to whether decoupling between the use of natural resources and economic growth is taking place.

The objectives of this study is to assess in quantitative terms the extent to which recycling, waste prevention and improvements in product design together with existing policies contribute to overall material use and material productivity.



An overview of where the different resource efficiency policy areas contribute to material flows

Specific objectives of the analysis performed in this study are:

1. to assess the material savings and material productivity of current measures;
2. to assess the potential of achieving existing targets and by the full implementation of policies; and,
3. the potential of other possible methods, approaches and policies.

The study also considers the general environmental, economic and social implications and consequences of possible actions to improve material productivity.

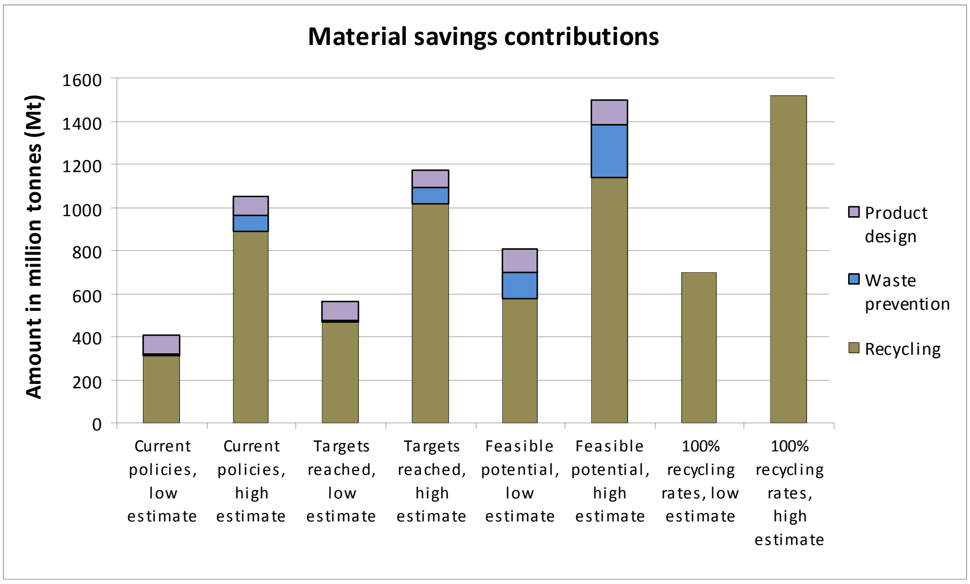
The resources investigated in this study are limited to non-energy materials: biomass (excl. wood fuel), minerals, metals and plastics. Furthermore the study assumes identical consumption patterns and population numbers when considering the different scenarios (current policies and practices; policies with targets reached; feasible potential, and; a theoretical 100% recycling rates) with and without recycling, waste prevention and ecodesign measures.

Data sources and methodology

Waste statistics from Eurostat and the European Topic Centre for Sustainable Consumption and Production formed the main source of data for the amounts of recycling in the EU-27. This data was complemented with data from industry associations and research institutions. There is a high degree of uncertainty in the waste data, particularly for construction and demolition waste, which constitutes the majority of waste in terms of weight. Estimates vary from 510 Mt to 970 Mt. The recycling amounts from production statistics were generally significantly higher than those reported in the national waste statistics, as the waste statistics do not capture all waste streams and might miss out several flows, whilst production statistics include internal material recycling flows. The data for waste prevention and product design is limited. Based on their recent implementation, there is a lack of measurement and no economy wide estimates exist. The estimates for waste prevention and product design are mainly based on case studies of material savings from local initiatives.

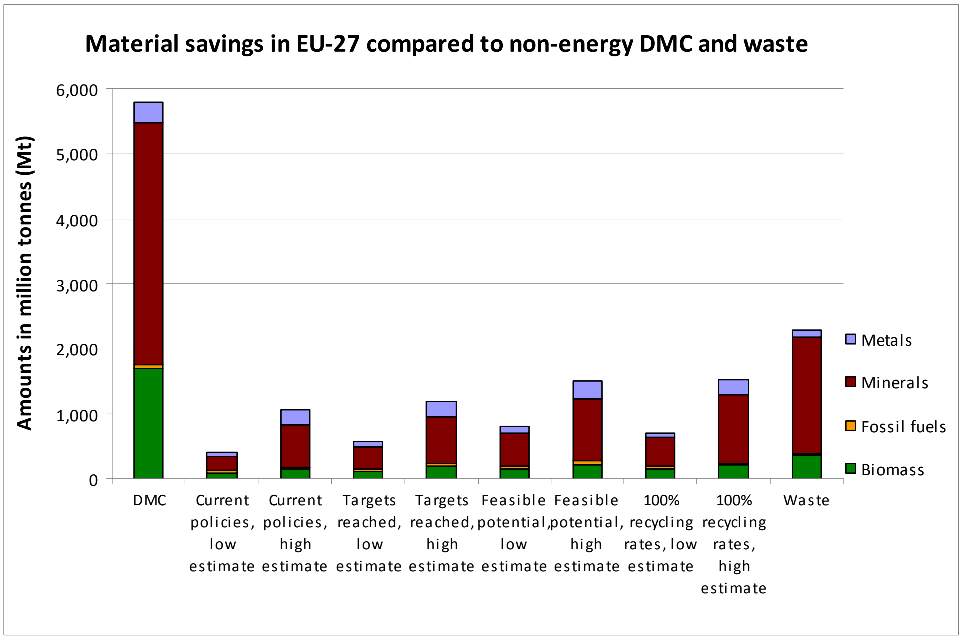
Material savings

In the investigation performed in this study of the contributions to material savings and efficiency, recycling has by far the largest contribution compared to waste prevention and product design. Waste prevention has not demonstrated any significant effects on material savings yet, but it is assessed that through leaner production and construction methods, more reuse and sustainable consumption patterns this could hold significant material savings without a negative effect on GDP. Design-oriented product policies have only showed limited material savings, but there is evidence that both packaging and electrical and electronic equipment has benefited considerably from ecodesign approaches. Ecodesign approaches show promise to further reduce material consumption in the economy through lightweighting, but also by supporting recycling and reuse.



An overview of material savings due to recycling, waste prevention and product design from current practices and policies as well as future potentials

Estimates for material savings range considerably depending on the source of waste statistics and assumptions made for waste prevention, e.g. from 406 Mt to 1048 Mt for material savings due to current policies and practices. This corresponds to 5 - 14% of total material consumption (including energy carriers). If only non-energy material consumption was considered, then these material savings would correspond to 7 – 18%.



Material savings in the EU-27 compared to non-energy related Domestic Material Consumption (DMC) and waste. As less than 2% of fossil fuels are used for plastics, this is almost not visible on the graph.

Future feasible potential for material savings from recycling, waste prevention and ecodesign is estimate to be from 11% to around 21% of total material consumption (including energy carriers). These potential material savings correspond to 15 – 28% if seen in relation to total non-energy related material consumption. These estimates do not take into account any additional savings arising from fossil fuel savings from reduced transport or lighter vehicles.

Construction materials recycling is by far the most important activity relevant for material savings. Metal recycling is important since it substitutes very material intensive up-stream processes related to mining and refining. Wood, paper and cardboard recycling has the largest contributions to biomass (forestry) savings. Reductions from food waste prevention are very small compared to overall consumption.

There is a high degree of uncertainly to the above values as the data they are based on is not very robust and several general assumptions have been made in order to perform the calculations. For some material streams the recycling data varies up to a factor 5. Overall the difference between the conservative estimates and high estimates is up to a factor 2.6. However, if controlled for the uncertainty of construction and demolition waste the difference is about 30%.

- **Environmental impacts**

Three methodologies for calculating environmental impacts were chosen as most suited for the purposes of this study: land use, Ecological Footprint (EF) and Environmentally Weighted Material Consumption (EMC). Although all methods have their shortcomings, they are thought to provide a fair indication of different environmental impacts in relation to the key contributions to material productivity. Land use and EF caters more for biomass production and land use indicators, while EMC has a broad application for all types of material streams and environmental impact categories.

The reduction of land use in the EU due to material savings was only calculated for biomass materials as there is no direct relationship between the other material streams and land use. In any case the area of land taken for mining, production and landfill sites is very small in the EU and changes to this are considered insignificant. Regarding land use reductions for forestry and agriculture, the material savings from wood, paper and food that could be achieved from best practices implemented in all Member States would correspond to about 30 million ha of bioproductive area. Most of this would be forest area.

Material savings go hand in hand with reductions in environmental impacts. The Environmentally weighted Material Consumption (EMC) methodology was used to calculate the achieved and potentials for environmental impact reduction. Here it was calculated that 135 Mt of CO_2 equivalent (based on the conservative estimate) are current saved annually due to the contributions to material productivity from recycling, waste prevention and product design. Plastics, biomass and metals are the material streams with the highest contribution to reductions in this impact category. If all the recycling policy targets identified are reached, 176 Mt of CO_2 equivalent would be saved annually. In the cases of the maximum recycling potential and 100% recycling rates achieved, the annual amount of CO_2 equivalent emissions saved would be 278 Mt and 315 Mt, respectively. Plastics are the material stream with higher environmental impact reductions in the current situation and also with the highest improvement potential in the other three scenarios analysed. The reductions in greenhouse gas emissions do not take into account any additional savings arising from fuel savings from reduced transport or lighter vehicles.

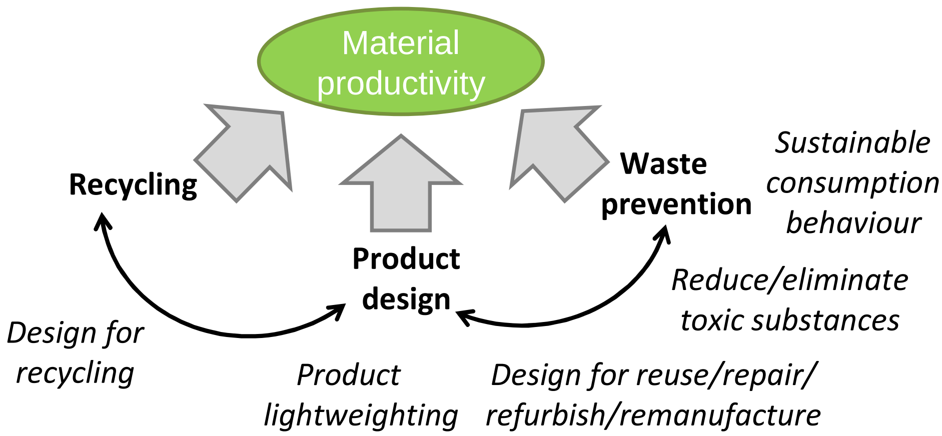
- **Socio-economic impacts**

The impacts of recycling, waste prevention and product design were analysed in relation to employment and competitiveness. A review of the existing knowledge was provided, but no direct relationship with increased material productivity could be determined. In general, direct-employment in all EU-27 eco-industries in 2008 reached approximately 3.4 million whereas it was at 2.8 million in 2004[139]. Waste management and recycled materials have important annual growth rates, 7.1% and 10.6% respectively, and usually in countries where the rate of waste recycled is high (i.e. Germany), the rate of employment in this sector is also high.

However, the net jobs creation due to increasing material productivity should be calculated accounting the number of jobs created and the possible job losses. The assessment of direct job losses, transformation, and substitution is difficult to determine because no data is readily available.

- **General implications and consequences**

In the study it is estimated that recycling has by far the largest contribution to material productivity (currently and also future potential), but it would seem that waste prevention through reuse and consumption behaviour could contribute significantly. In order for material productivity to increase, product design is the key to achieve greater amounts of recycling and waste prevention.



How product design is key to achieving greater material productivity through recycling and waste prevention

To increase resource efficiency through recycling, waste prevention and product design policies, one must consider the various material streams and their application:

- Construction materials constitute the largest material flow, but most go into stock (buildings and infrastructure) for the benefit of future generations
- Waste prevention is most suitable for addressing food, whilst recycling and product design can address the supporting systems surrounding the food cycle (e.g. packaging)
- Rare metals play a critical role in high-tech products (incl. environmental technologies), efforts should be made to ensure that these materials are never wasted

Resource efficiency is an indicator that measures the input and output of natural resources in the economy in relation to GDP. The EU's Resource Strategy has the dual objective of decoupling resource use from economic growth and decoupling environmental impacts from resource use. This study has investigated the contributions of recycling, waste prevention and eco-design polices and measures that contribute to the overall resource efficiency and reduction in environmental impacts. When considering whether targets for resource efficiency should be put forth, as they have been done for energy efficiency, it should be noted that as resource efficiency is based on the relationship of the input and output of resources, the focus so far has been more on the economic aspects rather than the actual reduction of overall resource use.

If the real goal of sustainability is to ensure that the non-renewable resources are not wasted and the renewable resources are only exploited in a way that allows the resource stock to regenerate itself and continue to fulfil the needs of future generations, then the focus should be on the actual amounts of resources that enter and leave the economy. Likewise resource efficiency cannot be used as a proper proxy for reducing environmental impacts on for example biodiversity, as these often depend on actual amounts of emissions locally. The amount of natural resources we have and the endpoints of environmental impacts are absolute, whilst resource efficiency is relative.

1. INTRODUCTION

1.1. BACKGROUND

Natural resources are fundamental for any society and its prosperity. They provide raw materials, energy, food, water and land, as well as ecological and social services. Materials are needed in all human activities and form the basis of our economy. Raw materials are extracted from nature to produce products and services that create economic value. These are then consumed and finally returned to nature in the form of waste and emissions.

Our current rate of extraction and depletion of natural resources is however jeopardising the chances of future generations to meet their own needs. Some renewable resources are already harvested beyond the planet's reproductive capacity and many non-renewable resources are becoming scarce. This depletion of natural resources affects countries' national incomes, international security, employment, human health, and other quality of life issues. Furthermore the associated environmental burden of resource extraction and use (e.g. pollution, waste, soil degradation, habitat disruption), has its effects on the environment (e.g. air, water, soil, biodiversity, landscape) and on the related life sustaining eco-system services.[1]

The current EU strategy focuses on decoupling the benefits of resource use, such as economic growth from the collateral damages, such as resource depletion and environmental degradation. Increasing resource efficiency can contribute to the goal of creating more value by using fewer resources.

1.1.1. THE CONCEPT OF RESOURCE EFFICIENCY

Resources can be defined as natural assets deliberately extracted and modified by human activity for their utility to create economic value.[2] As such, they can be measured both in physical units (such as tonnes, joules or hectares), and in monetary terms expressing their economic value. Resources can include the following:

- **Raw materials** such as materials, minerals, fossil fuels, etc.

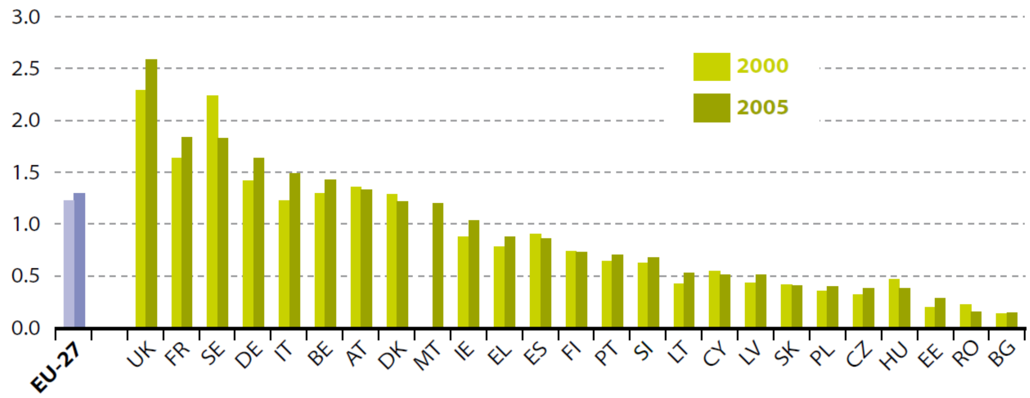
[1] OECD (2008) Measuring material flows and resource productivity – Volume I. The OECD Guide, Chapter 1, OECD, Paris.

[2] Mudgal S., Fischer-Kowalski M., Krausmann F., Chenot B., Lockwood S., Mitsios A., Schaffartzik A., Eisenmenger N., Cachia F., Steinberger J., Weisz U., Kotsalainen K., Reisinger H., and Labouze E. (2010) Preparatory study for the review of the thematic strategy on the sustainable use of natural resources. Contract 07.0307/2009/545482/ETU/G2, Final report for the European Commission (DG Environment). http://ec.europa.eu/environment/natres/pdf/BIO_TSR_FinalReport.pdf

- **Flow resources** such as wind and tidal energy sources, as well as other renewable energy resources such as geothermal and solar energy;
- **Land or space**, with increasingly limited access and competitive uses, are closely linked both to the demand of goods and commodities; and
- **Environmental media** such as air, soil, and water which are the basic resources that support our ecosystems and their diversity.

The terms 'resource efficiency' and 'resource productivity' are often used to specifically describe the amount of resources (energy and materials) used to produce one unit of economic activity (generally Gross Domestic Product (GDP)[3].

Overall the resource productivity (including fossil fuels) in the EU increased at an average of 1.1% per year between 2000 and 2005 (see Figure 1-1).



NB: IT 2004 value used for 2005. EU-27, BE, BG, EE, EL, ES, CY, LV, LT, PL, SI, SK, SE, UK data are estimates, no data for LU and NL.

Figure 1-1: Resource productivity in the EU (EUR/kg)[4]

The extent to which this happens varied a great deal among Member States: some countries managed to achieve absolute decoupling of economic growth from material consumption (total material consumption decreased while the economy grew), while others only managed a relative decoupling (material consumption grew slower than the economy) or no decoupling (material consumption grew faster than the economy).

In the context of the present study, as only the resource efficiency of (non-energy carrying) materials are considered, the term 'material productivity' will be used forthwith.

[3] This refers to the physical dimension of the economy where *"it is conceptualised as an activity, as a process of extracting materials from nature, transforming them, keeping them as society's stock for a certain amount of time and, at the end of the production-consumption chain, disposing of them again in nature"*.

[4] Eurostat (2009) Sustainable development in the European Union. 2009 monitoring report of the EU sustainable development strategy. Eurostat Statistical Books.

1.1.2. DEFINITION OF MATERIAL PRODUCTIVITY

Material productivity is a measure of the total amounts of materials directly used by an economy in relation to its economic activity. In order to provide a quantitative assessment of material productivity, economic growth and the consumption of materials need to be quantified. Gross Domestic Product (GDP) is a widely accepted indicator to measure the economic activity in an economy. Regarding material consumption, there is still no consensus on the best indicator to describe this.

Over the past decade, Material Flow Analysis (MFA) has established a framework for documenting and analysing an economy's material resource use. One of the main strengths of MFA is its systemic approach: it seeks to cover all raw materials extracted from nature, and follows them through their life cycle until they are finally returned back to the environment.

MFA keeps track of all materials that enter and leave the economy within one year applying the mass balance principle. MFA therefore provides a biophysical account of the level of material flow in national economies analogue to the concept of GDP in national economic accounting. These flows incorporate extracted or imported materials to be used within the national economy, and all material released to the environment as wastes, emissions or exports to other economies or added to societal stocks. In MFA, the economy is usually treated as a black box where only input and outputs are considered, as presented in Figure 1-2. However, net additions to societal stocks are accounted for to redeem the mass balance equation and recycling and reuse activities are highlighted here since they are relevant for this study.

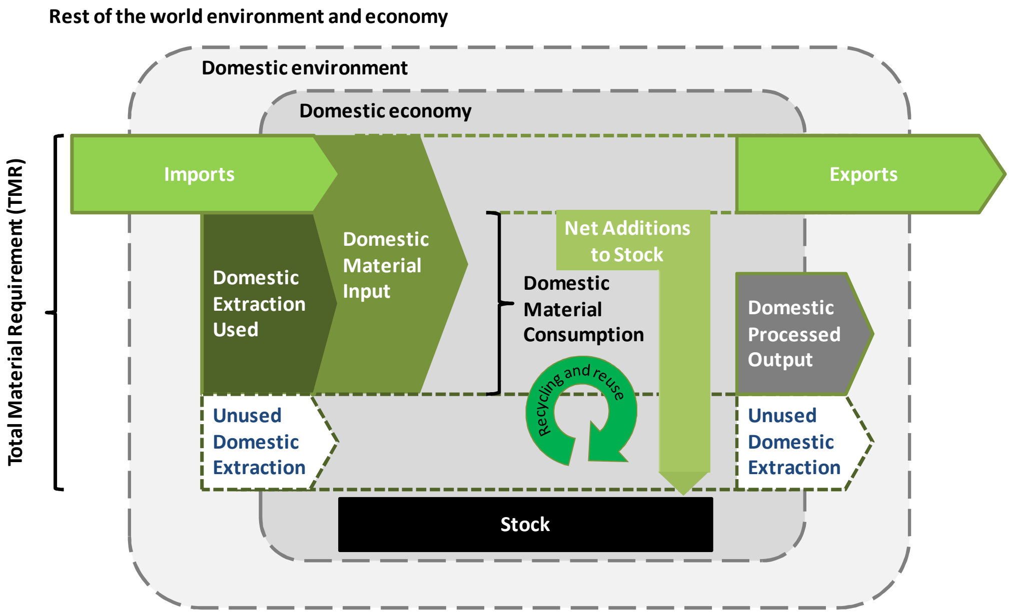


Figure 1-2: Material balance and flow schemes used in MFA[5]

[5] Bringezu, S. & Bleischwitz, R. (editors) (2009) Sustainable Resource Management. Global trends, visions and policies. Greenleaf Publishing.

The boundary of the physical economy[6] is defined in a way that is compatible with the system of national accounts (SNA) as far as possible to facilitate integrated monetary and biophysical analysis[7]. A number of flow aggregates can be derived from the MFA framework for a national economy and for a certain time period (usually one year), expressed in metric tonnes[8]. In order to measure the resource use of the EU at an aggregated level, an economy-wide material flow analysis can be used to account for the material flows in the whole region. A set of indicators that are already measured and reported in various sources will be used throughout this report and their definitions are provided in Annex A.

Domestic Material Input (DMI) and Domestic Material Consumption (DMC) are commonly analysed in the literature reviewed but they are restricted to consumption of economically valued primary materials, without taking into account unused domestic extraction[9] or indirect flows associated with imports and exports. Taking only these indicators as a measure of resource use can be misleading, as a part of the resource use and environmental pressures in other parts of the world might not be accounted for, shifting the consequences of domestic consumption to other regions. Whenever it is possible, the use of Total Material Requirement (TMR) or Total Material Consumption (TMC) is preferred as both indicators consider all the materials extracted from the environment, even if those materials do not physically enter into the economy. However, in a 2007 report from Eurostat[10], GDP over DMC is used as the main indicator for resource productivity, as there is not sufficient data for TMC in all Member States and until such data becomes available DMC can be used as a *"proxy for the more relevant indicator TMC"*. Eurostat has datasets of DMC for EU-15 for 1990 – 2000 and for EU – 27 for 2000 – 2007.

Due to data availability and coherence with the Commission, in this study material productivity is defined as the ratio between the economic activity and the annual amount of raw materials extracted from the domestic territory, plus all physical imports and minus all physical exports; or in other terms:

$$\textbf{Material productivity} = \frac{\textbf{Gross Domestic Product (GDP)}}{\textbf{Domestic Material Consumption (DMC)}}$$

[6] This refers to the physical dimension of the economy where "it is conceptualised as an activity, as a process of extracting materials from nature, transforming them, keeping them as society's stock for a certain amount of time and, at the end of the production-consumption chain, disposing of them again in nature".

[7] Eurostat (2001) Material use indicators for the European Union, 1980-1997. Economy-wide material flow accounts and balances and derived indicators of resource use. Luxembourg, Eurostat. Prepared by Bringezu, S. and Schütz, H.

[8] Schandl, H., Grünbühel, C.M., Haberl, H. & Weisz., H. (2002). Handbook of Physical Accounting: Measuring Bio-physical Dimensions of Socio-economic Activities (MFA-EFA-HNPP). Social Ecology Working Papers. Vienna, IFF Social Ecology.

[9] Unused domestic extraction is the part of the materials extracted that does not enter into the economy.

[10] Eurostat (2007) Measuring progress towards a more sustainable Europe. 2007 monitoring report of the EU sustainable development strategy. European Commission.

In general, resource consumption changes very little over time[11]. The moderate changes that have occurred tend to be closely related to economic downturns. When comparing countries (see Figure 1-1), it becomes apparent that it is possible to improve material productivity considerably[12].

1.2. OBJECTIVES

The goal of this study is to assess in quantitative terms the extent to which **waste prevention**, **recycling** and improvements in **product design** together with existing policies contribute to overall **material use** and **material productivity.** Specific objectives of the analysis carried out in this study are:

1. to assess the material savings and material efficiency of current measures
2. to assess the potential of achieving existing targets and by the full implementation of policies and,
3. the potential of other possible methods, approaches and policies

The study also considers the general environmental, economic and social implications and consequences of possible actions to improve material productivity.

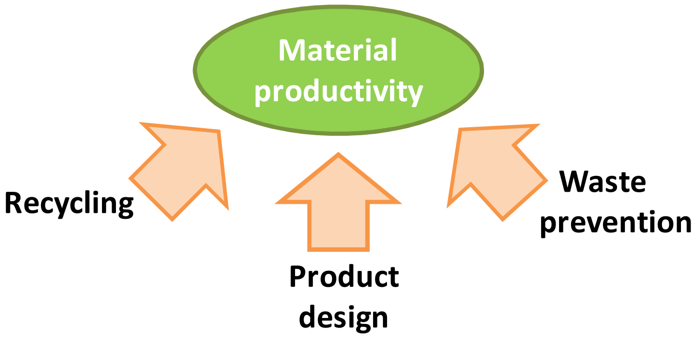


Figure 1-3: Key contributions to material productivity

There are a number of EU policies that aim to improve resource efficiency by implementing strategies for reducing, reusing or recycling or setting targets to increase these practices. In particular, three main policy blocks are considered to contribute to resource efficiency: recycling, waste prevention and product design. However, further analysis needs to be done to establish which areas are already contributing to resource efficiency and to what extent, and to investigate which of these contributions hold the greatest future potential.

[11] Stephan Moll, Stefan Bringezu, Helmut Schütz (2005) Resource Use in European Countries. An estimate of materials and waste streams in the Community, including imports and exports using the instrument of material flow analysis. Wuppertal Institute for European Topic Centre on Waste and Material Flows.

[12] Stefan Bringezu & Raimund Bleischwitz (editors) (2009) Sustainable Resource Management. Global trends, visions and policies. Greenleaf Publishing.

1.3. SCOPE OF THIS STUDY

The three key contributions to material productivity investigated in this study (waste prevention, recycling and improvements in product design) are visualised in the following material flow diagram (Figure 1-4). The study only considers non-energy materials (e.g. biomass (excl. fuel), metals, minerals and plastics (made from fossil fuels)). Furthermore the study assumes identical consumption patterns and population numbers when considering the different scenarios with and without recycling, waste prevention and ecodesign measures.

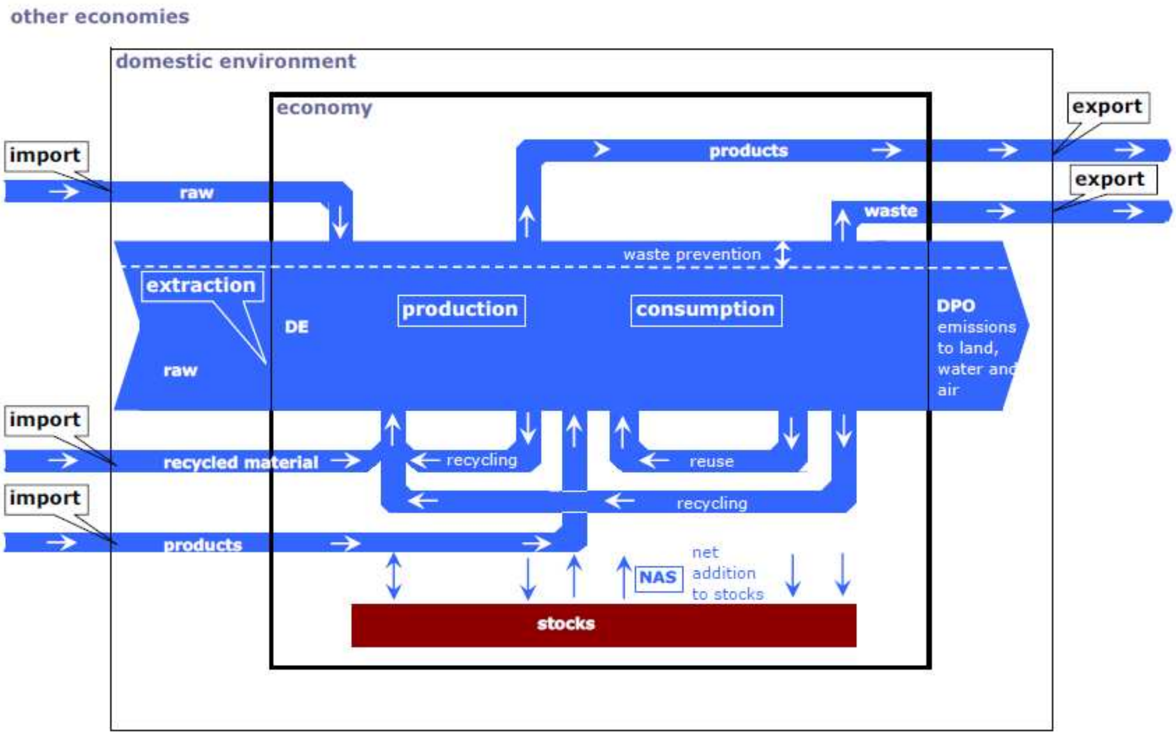


Figure 1-4: Contribution of waste prevention, recycling and improvements to product design to material use

- **Waste prevention**

Waste prevention encompasses a broad range of measures that aim to reduce the quantity and hazardousness of waste by controlling the waste generation throughout the life cycle of products[13]. In this way, waste prevention reduces materials in the economy that could end up as waste. Waste prevention can cover diverse strategies such as increasing the efficiency of the use of products; restricting unnecessary consumption; extending product life (e.g. re-use, repair, refurbishment, etc.). Hence waste prevention can affect the entire flow of materials by restricting unnecessary materials from entering the economy or restricting materials from leaving the economy as waste.

[13] BIO Intelligence Service (2009) Guidelines on Waste Prevention Programmes, European Commission.

- **Recycling**

After waste prevention and re-use, recycling is the next waste management option in the EU waste hierarchy[14]. Recycling occurs when products and materials that have been defined as waste are collected, sorted and processed into raw materials and re-enter the material flow. Recycling takes place after consumption (post-consume) or it can also occur during production (pre-consume), when leftover material from industrial processes is recycled back into the production. Post-production material is not always registered as waste, as it is either used within the same company's production processes or sold to other companies. This form of business resource efficiency can contribute significantly to material savings in the economy, but is not always accounted for in official statistics[15]. Recycled material from the waste streams of other economies may also enter the domestic economy in the form of imports; in the same way, recycled materials can leave the domestic economy as exports. Both flows need to be accounted for in order to measure their contributions to material use in the economy.

- **Product design**

Although material productivity improvements in product design can be seen as a waste prevention strategy, in this study they are considered independently as a policy measure that could be applied under the Ecodesign Directive[16]. Product design has the potential to:

- reduce or avoid the use of materials (i.e. avoiding certain materials from entering the economy);
- increase the durability and reliability of products, as well as encourage the re-use, repair and recyclability of products (i.e. avoiding materials from leaving the economy).

In relation to the material flows, products are created from raw materials entering the domestic economy during production, but they may also be produced in other parts of the world and be imported and thus entering the economy during the consumption phase. Alternatively, products created in the domestic economy can also leave the material flow as exports to other countries.

1.3.1. MATERIAL USE AND ENVIRONMENTAL IMPACTS

The quantities of material used are a major concern in relation to sustainable management of resources. In addition to that, the impacts of the extraction and use of each material on the environment need to be considered. Whilst it is generally beneficial for the environment to reduce the consumption of resources, there is a

[14] Waste Framework Directive (2006/98/EC)

[15] Oakdene Hollins and Grant Thornton (2007) Quantification of the business benefits of resource efficiency. A research report completed for the Department for Environment, Food and Rural Affairs.

[16] Directive for establishing a framework for the setting of ecodesign requirements for energy-related products (2009/125/EC)

large difference in environmental impacts caused by different materials[17]. For example, the environmental impacts of one kg of sand are much smaller than one kg of animal fat (see Figure 1-5). When attempting to reduce resource use, it is therefore more important to aim for the reduction of specific resources than resource efficiency in general.

Another important element of sustainable management of resources is the Earth's carrying capacity: the ability of the planet to absorb the environmental impacts and maintain its ecosystem services[18], such as nutrient cycling, clean water, etc. Whilst it is possible to relate the flow of materials through the economy with the associated environmental impacts using life cycle inventory data, this only gives an indication of the impact, not the actual damage caused, e.g. ecotoxicity is an environmental impact indicator, but does not inform on the specific loss of biodiversity. Although there is a relation between different impact indicators and the state of the environment, these relations are not well understood.

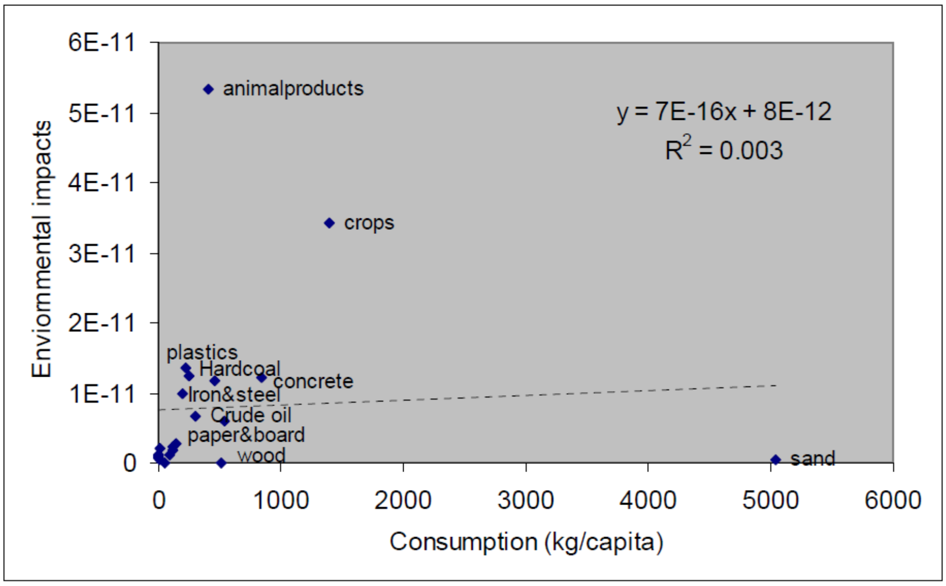


Figure 1-5: The relation between consumption and environmental life cycle impacts for various materials in the EU in 2000[19]

In order to calculate the reduction of environmental impacts due to improved material productivity, a link between material flows and the environmental impacts have to be determined. As such, land use is not an environmental impact category on its own, but it is an important indicator related to natural resources as it provides

[17] CE Delft & CML, Delft (2004) Economy-wide material flows and environmental policy: an analysis of indicators and policy uses for economy-wide material flow policy.

[18] Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Synthesis. World Resources Institute. Island Press, Washington, DC.

[19] van der Voet, E., van Oers, L., Moll, S., Schütz, H., Bringezu, S., de Bruyn, S., Sevenster, M., Warringa, G. (2005) Policy Review on Decoupling: Development of indicators to assess decoupling of economic development and environmental pressure in the EU-25 and AC-3 countries. Institute of Environmental Sciences (CML), Leiden University; Wuppertal Institute for Climate, Environment and Energy; CE Solutions for Environment, Economy and Technology.

an idea of the pressure put on land, but also on eco-system services and eco-system functioning (e.g. biodiversity) by agriculture, forestry, mineral extraction, construction, and infrastructure. Human land use is often in competition with ecosystems and natural habitats. Likewise, it is not entirely correct to talk about depletion of non-renewable resources, as many metals and minerals are not actually depleted (i.e. they are not transformed into other materials), but merely dispersed in products and constructions around the world. It is however an interesting factor to consider in relation to resources as it provides an indicator for material security and equity.

- **Biodiversity**

The establishment of mines and quarries has direct effects on biodiversity through habitat destruction. Sites can however be selected and managed in a manner that is less harmful on the environment, but this depends on the country and the regulation and enforcement in place. Likewise when new roads and infrastructure are built, e.g. for example to access remote areas of agriculture and mining, this furthermore results in loss of biodiversity as species are hindered in roaming. Emissions to air and water of hazardous substances from the production of metals and fossil fuels can also have severe ecotoxic impacts, which directly affect living creatures and their ability to reproduce.

Currently there is no consensus on how to quantify the impacts of materials and products on biodiversity, which is an area of protection. Many midpoint impact categories that are used in LCA are indirect indicators of the impact on the loss of species: acidification, euthrophication, ecotoxicity, land use, etc. The damage an impact can cause depends on where it occurs. Some natural habitats and species are more fragile than others and others are more abundant than others.

In a report on the environmental impact of natural resources trade flows to the EU[20], biodiversity was considered for a large range of commodities. In general, biodiversity competes with land use for food, feed and fuel. As there is more biodiversity in tropical and subtropical regions land use changes in these areas have a greater impact on biodiversity loss (particularly when previously uncultivated land is used to expand land for crops or when agricultural practices become more intensive). The amount of biomass removed from the land (HANPP – Human Appropriation of Net Primary Production)[21] is a useful pressure indicator for biodiversity loss, but unfortunately the availability of this type of data is limited. Monoculture of crops, use of herbicides and pesticides reduce biodiversity in cultivated areas. The

[20] Bates, J. and Dale, N. (2008) Environmental Impacts of Significant Natural Resource Trade Flows into the EU. AEA Energy & Environment and Metroeconomica for the European Commission, DG Environment.

[21] Haberl, H., Gaube, V. Díaz-Delgado, R., Krauze, K., Neuner, A., Peterseil, J., Plutzar, C., Singh, S.J. and Vadineanu, A. (2009) Towards an integrated model of socioeconomic biodiversity drivers, pressures and impacts. A feasibility study based on three European long-term socio-ecological research platforms. Ecological Economics 68.

processing of natural resources (e.g. palm oil, rubber) that occur close to where they are grown can also have adverse effects on biodiversity due to untreated effluent.

Changes in land use can provide information on the effects of resource use in biodiversity according to the concepts presented previously. For this reason, a methodology to measure the extent of land use changes that can be attributed to resource efficiency policies is defined in the following section.

1.4. REPORT STRUCTURE

This report is structured in five sections to present the main findings according to the objectives of the study. The first section will introduce the sources and methods defined to conduct the analysis, followed by a section where the main policy blocks under study are analysed: recycling, waste prevention and product design. The last section presents the overall results and general implications after carrying out the study. A short description of the main sections is presented in the following:

Sources and methods:	Presents a state-of-the-art **overview of existing studies, reports and relevant literature.** The methodologies to estimate the contributions to material savings and the economic, social and environmental impacts of the three main building blocks under study are defined.
Recycling:	Presents the estimate of the total potential **contribution of recycling rates** to material savings and efficiency under current and possible policy measures.
Waste prevention:	Presents the estimate of the total potential **contribution of waste reduction** to material savings and efficiency under current and possible policy measures.
Product design:	Presents the estimate of the total potential **contribution of product design** to material savings and efficiency under current and possible product policy measures.
Overall implications:	**Provides an overall map of potential material savings and material productivity** gains for recycling, waste reduction and product design under current and possible policy measures. Assess the **general implications and consequences (including economic, social and environmental impacts) of possible actions** to improve material productivity.

2. SOURCES AND METHODS

This section identifies information and data sources that provide an overview of the status and potential contributions of waste prevention, re-use and recycling and product design policies to material productivity. Existing relevant publications are used as a basis for material productivity trends and estimates. Information gaps are complemented by contacting relevant experts. The methods used for estimating the environmental, economic and social impacts are also derived from the evidence presented in this section.

2.1. DATA SOURCES

Material Flow Analysis (MFA) takes into account all materials flows in the economy (see Figure 2-1). Economy-wide material flow accounts are consistent compilations of the overall material inputs into a national economy or a union of national economies from the environment (domestic extraction) and from the rest of the world economy (imports), the changes of material stock within the economy (net addition to stocks) and the material outputs from the economy to the environment (domestic processed outputs) and the rest of the world economy (exports). Economy-wide MFAs cover all solid, gaseous, and liquid materials, except for bulk water and air; the unit of measurement is tonnes per year.

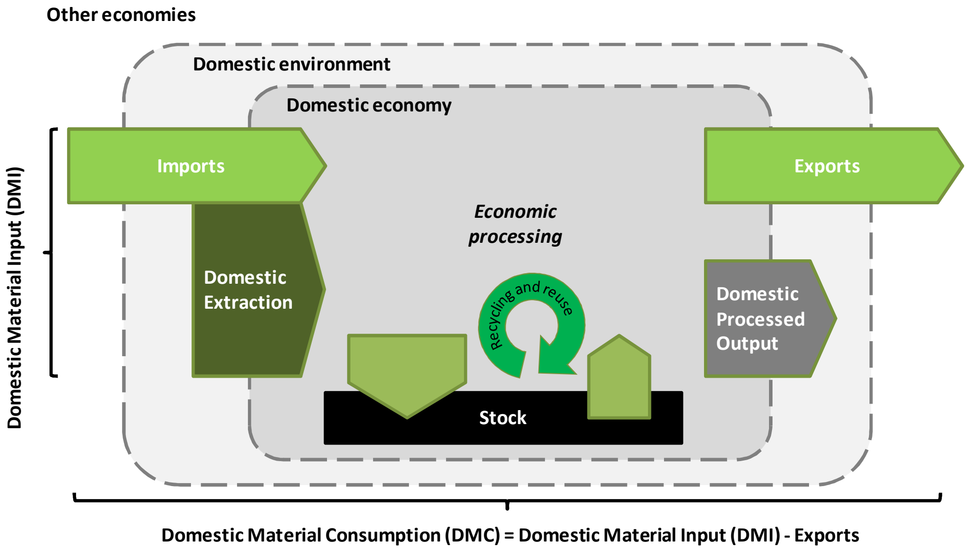


Figure 2-1: Economy-wide material flow accounts and indicators[22]

[22] Modified from: Matthews, E., Amann, C., Fischer-Kowalski, M., Bringezu, S., Hüttler, W., Kleijn, R., Moriguchi, Y., Ottke, C., Rodenburg, E., Rogich, D., Schandl, H., Schütz, H., van der Voet, E., Weisz, H., (2000) The Weight of Nations: Material Outflows from Industrial Economies. World Resources

Similar to the system of national accounts, material flow accounts serve two major purposes. The detailed accounts provide a rich empirical database for numerous analytical studies. They are also used to compile different extensive and intensive material flow indicators for national economies at various levels of aggregation.

The current available material flow accounts for the EU by Eurostat[23] tracks material flow data (by weight) on:

- Fossil fuels (hard coal, lignite, crude oil, natural gas, peat, etc.)
- Minerals
  - Metal ores
  - Industrial minerals
  - Construction minerals
- Biomass
  - Biomass from agriculture
  - Biomass from forestry
  - Biomass from hunting
  - Biomass from fishing
  - Biomass from other activities (honey, gathering of mushrooms, berries, herbs etc.)

As requested by the Commission, only non-energy carrying materials are considered in this study. However, plastics (made from fossil fuels) and wood (biomass) are considered. When data is available, a further breakdown of materials is provided, e.g. ferrous and non-ferrous metals, concrete, sand, glass, stone, paper, food.

Eurostat has datasets of DMC for EU-15 for 1990 – 2000 and for EU-27 for 2000 – 2007. In Annex A the main material flows in the EU are presented.

In 2004, the EU-27 economies extracted 6,477 Mt of materials (most of it was construction materials). A further 3,038 Mt of materials (half of this fossil fuels) was imported, whilst 1,801 Mt was exported. This resulted in a domestic material consumption (DMC) of 7,714 Mt of materials (half of this was construction materials, a quarter fossil fuels and a bit less than a quarter metals). The total amount of waste generated in the economy was 2,920 Mt (the majority mineral wastes).

Institute, Washington, D.C.

[23] Eurostat (2001) Economy-wide material flow accounts and derived indicators — A methodological guide, 2000 edition, Eurostat theme 2, economy and finance.

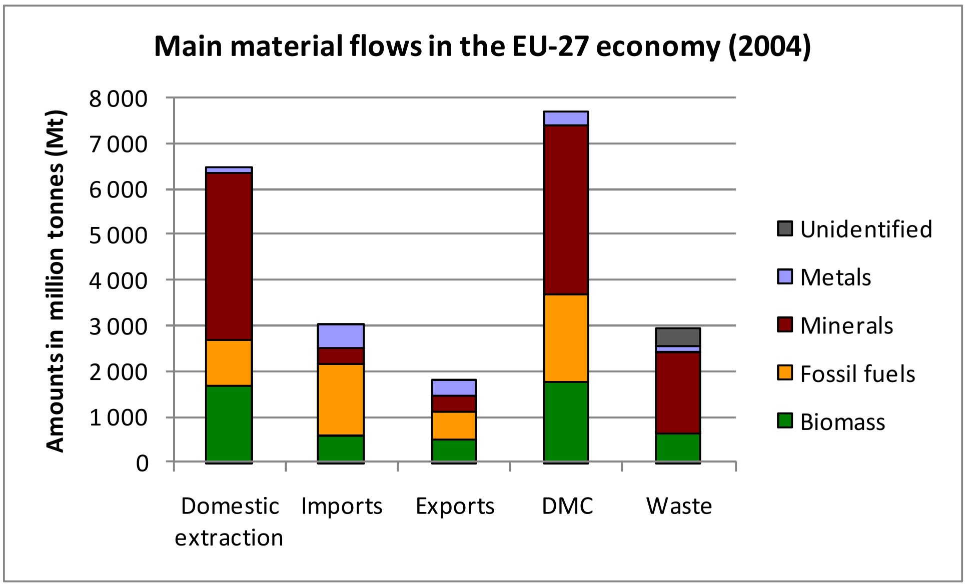


Figure 2-2: Quantitative description of input and output of material flows in the EU-27 economy (Eurostat)

Material productivity would benefit from any reductions that could be made in any of the material streams as long as these do not affect the economy negatively. An alternative approach could be to analyse the impact of material productivity in economic terms, accounting the price of the raw materials and the costs of recycling, prevention and alternative design practices. However, even if this could allow an interesting discussion, this would be beyond the scope of this study. Nevertheless, this issue will be raised within the economic impacts assessment section.

Eurostat also provides data on waste flows, emissions and land use, which are used in this study. This is complemented with other sources, such as the European Environment Agency (EEA) / European Topic Centre on Sustainable Consumption and Production and the Commission's Joint Research Centre (JRC), in the case of waste management data, or specific industrial associations, in the case of recycling rates and improvements in design.

The majority data used in this study is taken from recent related studies commissioned by DG Environment, such as:

- Arcadis, Eunomia (2009) Assessment of the options to improve the management of biowaste in the European Union
- Arcardis, VITO, Umweltsbundesamt, BIO Intelligence Service (2010) Analysis of the evolution of waste reduction and the scope of waste prevention.
- BIO Intelligence Service (2010) Study on management of construction and demolition waste in the EU.
- BIO Intelligence Service, AEA, Umweltsbundesamt (2010) Preparatory study on food waste across EU-27.

- BIO Intelligence Service, AEA Technology, and IEEP (2010) Plastic waste in the environment.

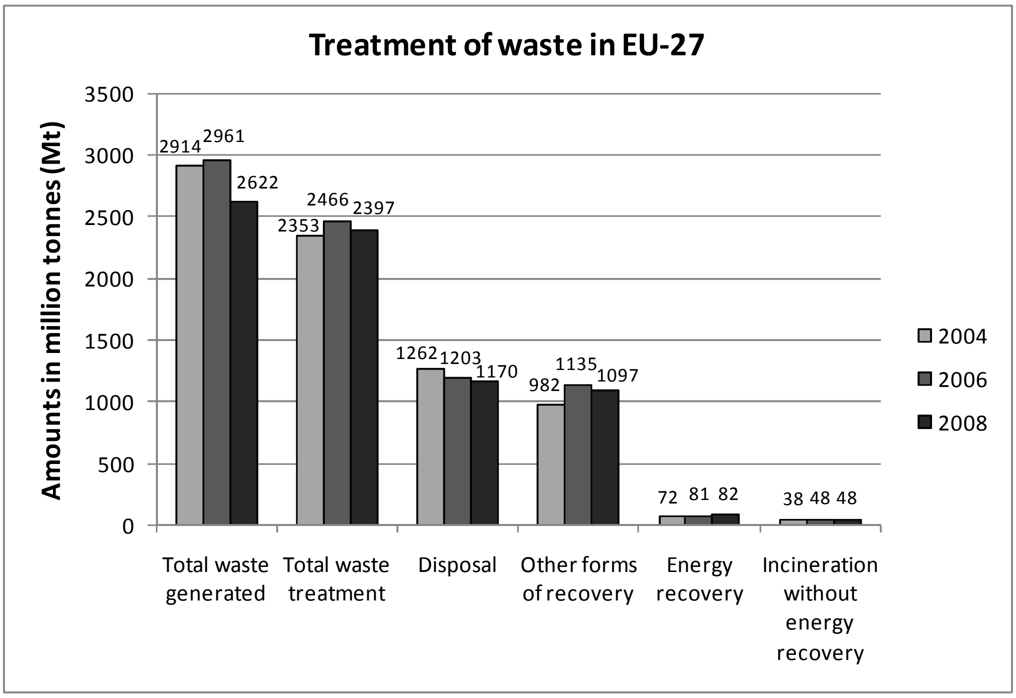


Figure 2-3: Total waste treatment in EU-27 in 2004, 2006 and 2008 (Eurostat)

The total amount of waste generated in EU-27 in 2004 was 2,914 Mt (hazardous and non-hazardous) of which 2,353 Mt was treated. This corresponds to over a third of the materials consumed. Only a third of all waste (982 Mt in 2004) is recovered and used in the economy again.

In addition to this data from alternative sources (e.g. publications from research institutions, governmental organisations, trade associations, etc. internationally and in different countries) were found as contrast in order to find and explain possible inconsistencies. This is the case of waste collection and management data, where amounts are different depending on the source and methodology of gathering the information. For example, Member States differ in their reporting of municipal solid waste (MSW); some include all packaging waste (generated by both households and industries) in MSW, while others do not..[24]

The material shares in waste management data are based on assumptions of the composition of the different kinds of waste treated, while the share of recycled materials entering into the economy are based on data provided by industry associations.

In Annex A, a summary of data sources is presented, with detailed sources used per section of this study. Although there is more recent datasets for some materials and

[24] EEA - ETC/SCP (2009) Europe as a Recycling Society- Present recycling levels of Municipal Waste and Construction &Demolition Waste in the EU. Prepared by Christian Fischer and Mads Werge, ETC/SCP working paper 2/2009.

sectors, the data and calculations used within this study have as reference the year 2004, as this is the most recent MFA complete data available when this study was performed. When data for 2004 were not available, data from 2005 or 2006 were used. In some cases a comparison with more recent data will be presented, in order to discuss the trends in the EU-27. For example, the most recent waste datasets available in Eurostat at the time of writing was for 2008, and the total waste amounts arising in that year were around 2,600 Mt, 11% lower than in 2004.

2.1.1. MATERIAL FLOWS AND SECTORS

Building upon the gathered data and information listed in Annex A, the composition of materials consumption (by weight) in each of the sectors (and subsectors, e.g. automotive, packaging, paper, etc.) can be observed. The following illustrations are trying to throw light on the main sectors examined in this study (construction, agriculture, and industry).

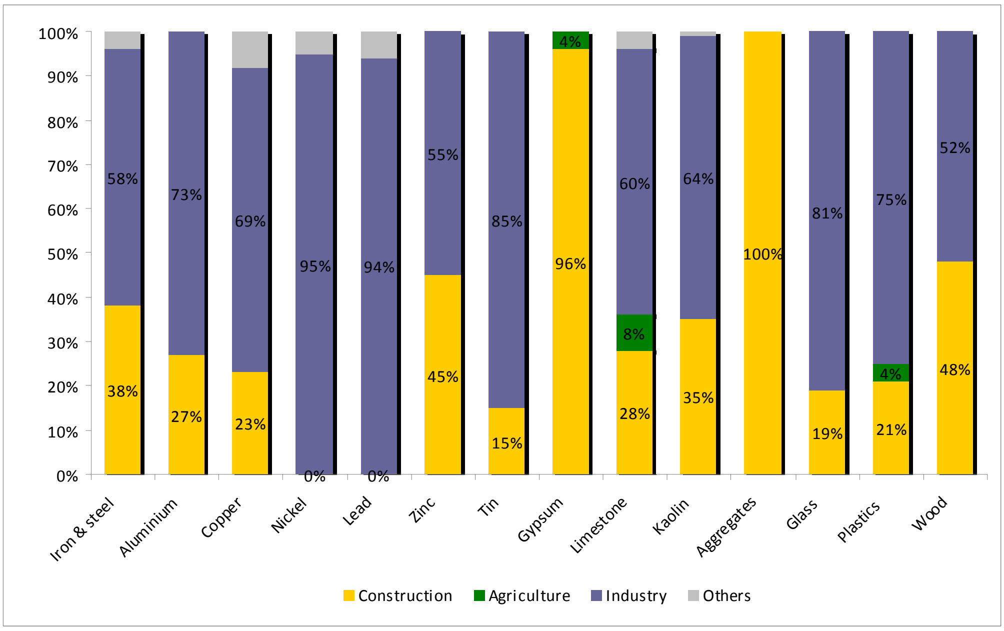


Figure 2-4: The distribution of materials according to the three main material consuming sectors by weight[25]

The construction sector consumes the minerals as a major resource, in terms of weight (see Figure 2-4). Metal and woods are of equal importance to the construction sector. Plastics and glass, by contrast, play a less important role in comparison with non-metallic minerals. Similarly, non-metallic minerals are the principal resources contributing to the agriculture sector. The scope of this study does not allow a systematic identification of wood, metal and glass contributing to

[25] Source: Eurofer (2009), European Steel in Figures 2005 - 2009; World Steel Association, Steel Statistical Yearbook 2009; Mineralinfo (www.mineralinfo.org); British Geological Survey (2009), European Mineral Statistics 2004-2009 and 2000-2004; Eurostat (for_remov and for_basic); Plastics Europe, Compelling Facts About Plastics 2009; Plastics Europe, Plastics: the Fact 2010; CPIV (Standing Committee of the European Glass Industry), Statistics, available at: www.cpivglass.be/main.html

the agriculture sector, regardless of possible intermediate consumption. When it comes to the industry, a more diversified composition of material consumption can be discovered. Again, the non-metallic minerals account for nearly a half of materials consumed in the industry, the lion's share. Metal and wood represent roughly one fifth each. Glass and plastics share the rest 13% material consumption in the industry.

Whereas the above sectoral comparison shows the structure of material consumption in each of the sectors, the following is trying to find out how each material is consumed by different sectors and sub-sectors. This comparison comes up with a general observation that metals are mainly consumed by the industry (60%), followed by the construction sector (36%) (See Figure 2-5).

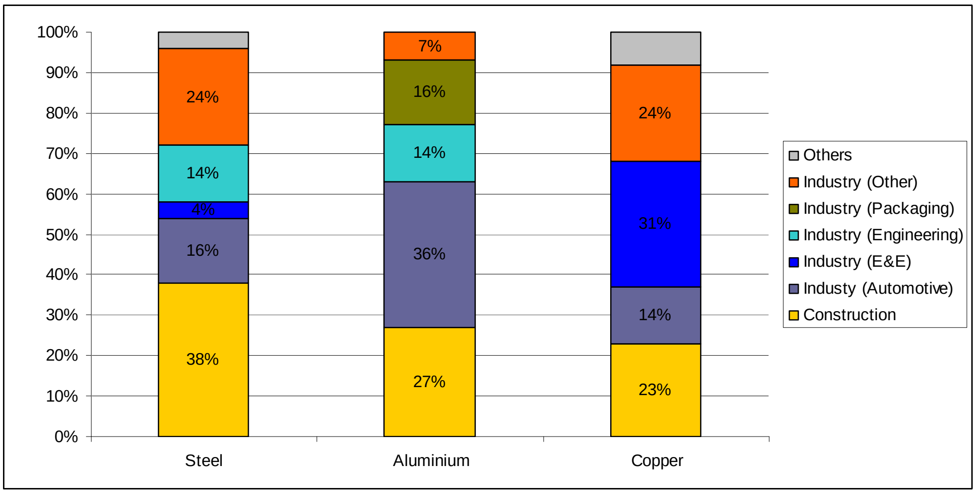


Figure 2-5: Distribution of industries that use metals (Fe, Al & Cu)[26]

A further breakdown of end-use market segmentation of major metals shows the automotive, engineering and E&E (electrical and electronics) are the main sub-sectors that use various metals. By contrast, packaging industry is one of the major consumers of plastics, glass and woods (See Figure 2-6). Non-metallic minerals are principally used by the construction sector. This is resulted from the use of aggregates in the construction sector, which accounts for an overwhelmingly large portion of minerals in terms of weight. Gypsum is a typical case in this regard as well, 96% of which ends up in the construction sector. For limestone and kaolin, about one fifth of each is used in the paper industry. Limestone has a multiple end-use in the engineering industry and agriculture sector as well.

[26] Source: DG ENTR (2009), Annex V to the Report of the Ad-hoc Working Group on Defining Critical Raw Materials (DG ENTR); Eurofer (2009), European Steel in Figures 2005 - 2009

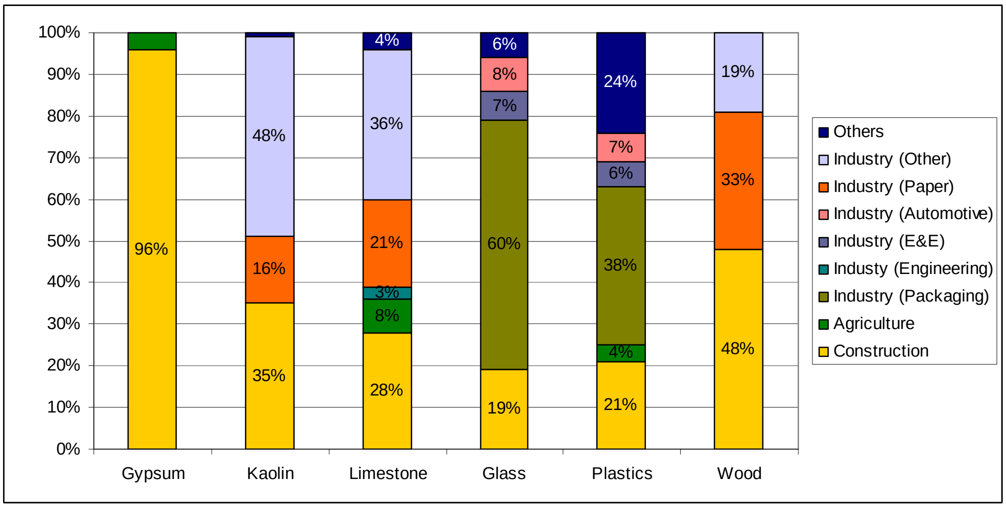


Figure 2-6: Distribution of industries that use gypsum, kaolin, limestone, plastics, glass and wood [27,28]

2.2. METHOD FOR CALCULATING MATERIAL SAVINGS

Recycling, waste prevention and product design are all meant to enable production and consumption with fewer materials than without employing such measures and thereby increasing the material productivity. This section describes the methodology developed for calculating material savings and material productivity improvements due to recycling. The methodologies estimating material savings from waste prevention and product design will be slightly different; however, they follow the same principles. The methodology uses the framework of Material Flow Accounts (MFA) described in the previous section.

Recycling induced material savings refer to a reduction in the economy wide material flow accounts (MFA). More specifically material savings are the amount by which Direct Material Input (DMI) of an economy is reduced by a specific measure. DMI is the sum of all extracted raw materials (the Domestic Extraction, or DE) – and all imports. Consequently, material savings finally are expressed in a reduction of imports and/or domestic extraction.

At a conceptual level recycling does not alter exports since recycling can be seen as an internal improvement of material management in an economy. Domestic

[27] Source: UNECE, FAO, University Hamburg (2008), Wood Resources Availability and Demands (Part I): National and Regional Wood Resource Balances 2005 (EU/EFTA Countries); Eurostat (2009), Forestry Statistics; Plastics Europe (2009), Compelling Facts About Plastics; Plastics Europe (2010) Plastics: the Fact; CPIV (Standing Committee of the European Glass Industry), 3 Points about the Glass Industry, available at: www.cpivglass.be/main.html

[28] Various sources: World Mineral Production (British Geological Survey); business.highbeam.com/industry-reports/mining/kaolin-ball-clay; European Commission (2010) Annex V to the Report of the Ad-hoc Working Group on Defining Critical Raw Materials. DG Enterprise.

Processed Output (DPO) is not part of calculating DMC and material productivity, therefore it is not considered here.

The first step in the calculation of material savings due to recycling is to link recycled materials with imports and domestic extraction. The main assumption of this methodology is that one unit of recycled material saves the amount of raw materials necessary to produce one unit of material, i.e. 1 kg of recycled glass saves the amount of raw material necessary to produce 1 kg of glass.

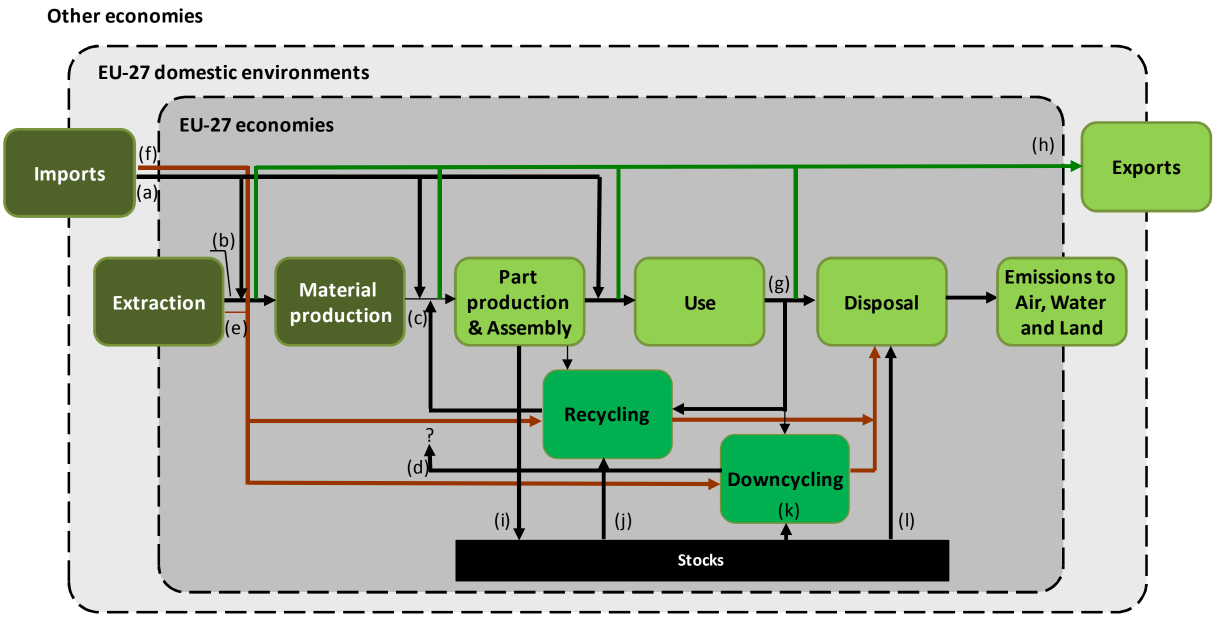


Figure 2-7: Recycling streams in the context of economy-wide material flow accounts[29, 30]

A precondition to calculate material savings is data on the recycled material that finally can replace materials used in the production of a similar product **(c)**. The calculation needs to follow the material flow up-stream to the point of imports **(a)** and/or extraction **(b)** and to deduct the additional material extraction **(e)** and imports **(f)** necessary for recycling.

To calculate the material savings the imports **(a)** and the extraction **(b)** have to be considered in the case of recycling and no recycling. **(a_0)** respectively **(b_0)** is devoted to the case without recycling and **(a_R)** and **(b_R)** in the case of recycling. The material savings is then given by **(a_0)** – **(a_R)** plus **(b_0)** – **(b_R)**.

"Downcycling" can be considered a special case. This refers to recycled material that is lost from material-specific recycling through its mixing with other materials during collection, insufficient liberation during separation, or incomplete sorting; it becomes an impurity or "tramp element" in the dominant material with which it is

[29] Graedel, T.E., Allwood, J., Birat, J.-P., Bucher, M., Hagelüken, C., Meskers, C.E.M., Reck, B., Sibley, S.F., Sonnemann, G., (2009) The Recycling of Metals: A Status Report.

[30] JRC - Institute for Environment and Sustainability (2010) ILCD handbook. International Reference Life Cycle Data System. General guide for Life Cycle Assessment - Detailed guidance. European Commission.

recovered (in analogy to Graedel et al. (2009)[31]). For the calculation of "downcycling" it is a precondition to know which up-stream material flow it substitutes (see question mark in Figure 2-7). If this information is available, material savings can be calculated with the same methodology as for recycling.

A further issue that needs to be considered is that after manufacture, produce can become stocks, like infrastructure, or it can become a consumer product, like food. According to MFA conventions, all produce that is used up within a year is calculated as a flow (use) and everything that lasts longer is calculated as an addition to stocks (stocks). When the life time of stocks is over, it can be disposed, recycled or downcycled. Stocks gain relevance the longer they last and the faster they grow, e.g. the stocks on new buildings grow fast while per annum only a small number is demolished. So the actual DMI is very high and the relevant waste flow of demolished buildings relevant for recycling is relatively low.

At EU-27 level, the material savings can be counted at the point of "domestic" material extraction **(b)** and at the point when imports cross the EU-27 border **(a)**. Material savings are a mix of saved raw materials (extraction within EU-27) and materials imported from other economies. For the calculation of material savings it is assumed in the first proxy that recycled material will replace imports and extraction proportionally to the status quo in the respective year. Furthermore imports can be raw materials, semi-processed materials or finished products. Again it is assumed that the mix of imported raw materials and products will stay the same and the reduction will be proportionally for each group. The employment of proportional reduction is a simplified assumption.

More sophisticated methods could be developed. One example could be to find out price structures and extraction capacities and to reduce the most expansive sources with same qualities first (and up to its limits). However, such a method development is time consuming. In this study we restrict ourselves to a sensitivity analysis to find out how relevant these assumptions are for the overall material savings.

In summary this means that due to recycling **(c)** the material savings are imports **(a_0)** – **(a_R) – (f)** plus domestic extraction **(b_0) – (b_R) – (e)**.

In order to deal with the lack of data on recycling rates, a first rough estimation was made in order to set priorities on which material streams should receive most attention. As first step, for each material category a factor was estimated to link pure material (recycled material) with the respective direct material inputs into EU-27. These factors have to reflect the following issues:

- relation between domestic extraction, import of raw materials and import of semi-finished/finished products since this is quite significant in the estimation of material savings

[31] Graedel, T.E., Allwood, J., Birat, J.-P., Bucher, M., Hagelüken, C., Meskers, C.E.M., Reck, B., Sibley, S.F., Sonnemann, G., (2009) The Recycling of Metals: A Status Report.

- relation between pure material (recycled material) and raw material (e.g. with metals the ore grade gives a first hint on the relation)
- relation between pure material (recycled material) and products in various finishing stages

To illustrate this: If recycling material in the context of MFA just replaces imported products made of metal the factor is 0.7 - 1, if it replaces domestic extraction the factor for metal is between 2 and 50.

The factors were estimated with expert judgment and by looking at various data sets (MFA, trade statistics) and studies[32,33,34]. Multiplying these factors with the available recycling amounts[35] gives a first priority list of material streams where further attention must be given (see Annex B).

Based on these results the calculations were made for iron and copper. Since all metals follow the same scheme, it was calculated for the other metals as well. As aggregates from C&D waste have the highest recycling amounts this was given more attention. For paper, the LCA based calculation was used. For glass, plastic and wood a very simplified approach was used since they represent very small amounts compared to the overall material savings.

In principle, the approach was to model the material streams for each material category within the MFA framework as in the case of amount of extracted raw material to recycled material. By modelling the material streams “backwards” it was possible to calculate the additional amount of materials required, if no recycled material was available. These additional material requirements for production without recycling equal the material savings that can be contributed to recycling. The approach used for estimating material savings in each type of material stream is presented in Annex B.

Material savings and material productivity

Using the definition provided in section 1.1.2. , material productivity is GDP/DMC (Domestic Material Consumption). Recycling induced material savings reduce the necessary imports and domestic extraction while the exports will stay the same. Therefore, DMC decreases due to recycling leading to higher material productivity. The calculation used for the improvement of material efficiency therefore is:

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[32] Eurostat (2009) Economy-wide Material Flow Accounts. Compilation Guidelines for reporting to the 2009 Eurostat questionnaire (Version 01 - June 2009). European Statistical Office, Luxembourg

[33] Graedel, T.E., Allwood, J., Birat, J.-P., Bucher, M., Hagelüken, C., Meskers, C.E.M., Reck, B., Sibley, S.F., Sonnemann, G. (2009) The Recycling of Metals: A Status Report.

[34] Allwood, J.M., Cullen, J.M., Milford,. R.L. (2010) Options for Achieving a 50% Cut in Industrial Carbon Emissions by 2050.

[35] Prognos (2008) European Altas of Secondary Raw Materials. 2004 Status Quo and Potentials.

Material productivity$_C$ (€/tonnes) = GDP/DMC$_C$ …. Current situation including recycling
Material productivity$_0$ (€/tonnes) = GDP/DMC$_0$ …. Scenario without recycling

↓

Productivity increase (%) = Material productivity$_C$ / Material productivity$_0$ – 100%

In an analogue manner the productivity increases for the four scenarios were calculated by relating them to the material efficiency$_0$ of the scenario without recycling:

- **Current situation** in the year 2004 with the recycling situation as it was at that time (material productivity$_c$)
- **Targets fully reached** means that all present recycling targets are achieved already in 2004 (material productivity$_t$)
- **Potential** stands for maximum recycling rates according to expert judgement are achieved in 2004 (material productivity$_p$)
- **100% recycling** is a hypothetical scenario and represents 100% recycling of the respective waste stream in 2004 (material productivity$_{100\%}$)

2.3. METHOD FOR CALCULATING IMPACTS

The following three methodologies for calculating environmental impacts were chosen as most suited for the purposes of this study: land use, Ecological Footprint (EF) and Environmentally Weighted Material Consumption (EMC). Although all methods have their shortcomings, they provide a fair indication of different environmental impacts in relation to the key contributions to material productivity[36]. Land use and EF caters more for biomass production and land use indicators, while EMC has a broad application for all types of material streams and environmental impact categories.

2.3.1. LAND USE

Land is a key resource and the use of land is closely interrelated with socio-economic material flows. The availability of biologically productive land is the basis for the production of biomass and the provision of food for humans, feed for domesticated livestock, raw materials for manufacturing and industry and, increasingly, also for renewable energy carriers. The EU-27 covers a territory of 4.3 million km². Of this, roughly 45% is for agricultural use, and over 42% of the land is covered with forests (about 30% is forests available for wood supply)[37]. Figure 2-8 shows the area and

[36] Best, A., Giljum, S., Simmons, C., Blobel, D., Lewis, K., Hammer, M., Cavalieri, S., Lutter, S. and Maguire, C. (2008) Potential of the Ecological Footprint for monitoring environmental impacts from natural resource use. Analysis of the potential of the Ecological Footprint and related assessment tools for use in the EU's Thematic Strategy on the Sustainable Use of Natural Resources. Ecologic, SERI, Best Foot Forward and EnviroCentre. Report to the European Commission, DG Environment.

[37] Eurostat (2009) Forestry statistics

distribution of different types of land in the EU. Land use for mining and quarrying is estimated to amount to less than 0.5% of the total area in Europe[38].

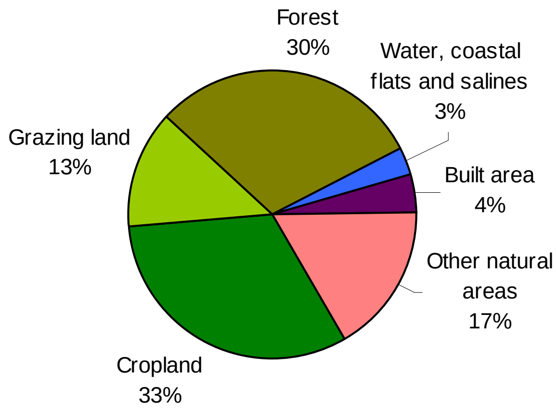

Figure 2-8: Land use coverage in EU-27 (2004)[39]

As in many other industrialised regions, the EU has experienced a long term trend of declining agricultural areas.[40] During the last ten years, an annual average of 10,700 km² was taken out of production and either reforested or taken by urban or infrastructure land. As a consequence of declining agricultural areas, forests grew by roughly 7,100 km² per year. Figure 2-9 illustrates this shift from intensively used agricultural land towards extensively used woodlands in the EU.

Estimating the impact of material flows on land use is a complex issue[41]. As a key resource, land has importance not only on the extraction of other resources (forests, agriculture, and mining) but also as support of natural ecosystems and biodiversity. However, it is not always considered as an impact category within the existing methodologies, and it is not always clear what should be taken into account when assessing the environmental impacts on land use. Nevertheless every human activity produces environmental impacts on land, degrading or changing its possibilities to be used. Whilst there is no consensus on the methodology to assess the impact of resource consumption on land use, this study will attempt to estimate the reductions land use due to material productivity in three different ways:

- Relating CORINE land use data with domestic material consumption of biomass resources to estimate domestic land use reductions

[38] Bleischwitz, R., Bahn-Walkowiak, B. (2006) Sustainable Development in the European aggregates industry: a case for sectoral strategies. Wuppertal Institute for Climate, Environment and Energy & College of Europe.

[39] EEA, CORINE (Coordination of Information on the Environment) Land Cover database

[40] Mudgal S., Fischer-Kowalski M., Krausmann F., Chenot B., Lockwood S., Mitsios A., Schaffartzik A., Eisenmenger N., Cachia F., Steinberger J., Weisz U., Kotsalainen K., Reisinger H., and Labouze E. (2010) Preparatory study for the review of the thematic strategy on the sustainable use of natural resources. Contract 07.0307/2009/545482/ETU/G2, Final report for the European Commission (DG Environment). http://ec.europa.eu/environment/natres/pdf/BIO_TSR_FinalReport.pdf

[41] W.M.J. Achten et al. (2008) Proposing a life cycle land use impact calculation methodology

- Recalculating the EU's Ecological Footprint with the reduced demand for biomass resources to estimate global land use reductions
- Using the Environmentally Weighted Material Consumption (EMC) methodology (which is based on Ecoinvent data) to estimate land use

For biomass resources the reduction of land use due to material savings is assumed to be proportional.

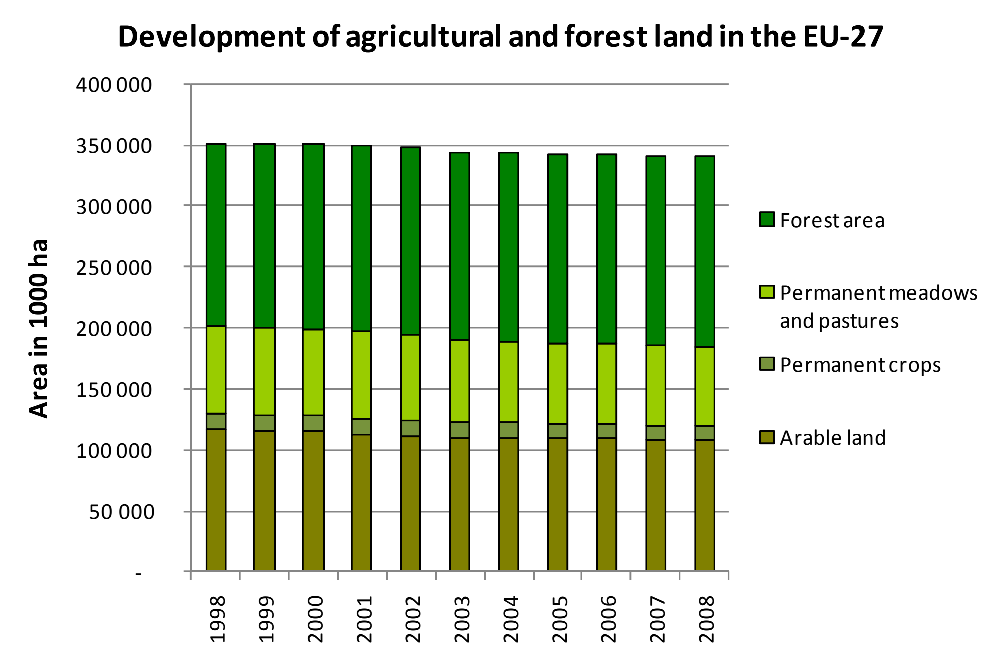

Figure 2-9: Development of agricultural and forest land in the EU-27 from 1998 to 2008[42]

2.3.2. ECOLOGICAL FOOTPRINT

The Ecological Footprint (EF) measures how much biologically productive land and water area is required to provide the resources consumed and absorb the wastes generated by a human population, taking into account prevailing technology. In other words, it evaluates resource use in terms of demand of regenerative capacity, calculating a virtual land area in order to translate carbon dioxide emissions. This is measured by calculating the environmental impacts on land use and climate change, excluding other impacts related to pollution e.g. stratospheric ozone depletion, human health, eco-toxicity, photo-oxidant formation, acidification, eutrophication or ionizing radiation. The unit of measurement is global hectares, a standardised unit of measurement equal to 1 hectare of land with global average bioproductivity. EF tracks the use of six categories of productive areas: cropland, grazing land, fishing grounds, forest area, built-up land, and carbon demand on land. The data

[42] FAOSTAT (2010) FAO Statistical Database. Food and Agriculture Organization (FAO)

requirements for the indicator are material flows, land use and CO2 emissions which are widely used and reported in several databases in the EU (see Figure 2-10)

The Global Footprint Network estimates that the EU's Ecological Footprint per capita in 2005 was 4.7 global hectares (see Table 2-1), which is much higher than the global average of 2.7 global hectares[43]. This is over double its own domestic supply of biocapacity, if calculated in global hectares (in real terms however, the EU is more self-sufficient than this due to its highly productive and intensive agricultural production[44]).

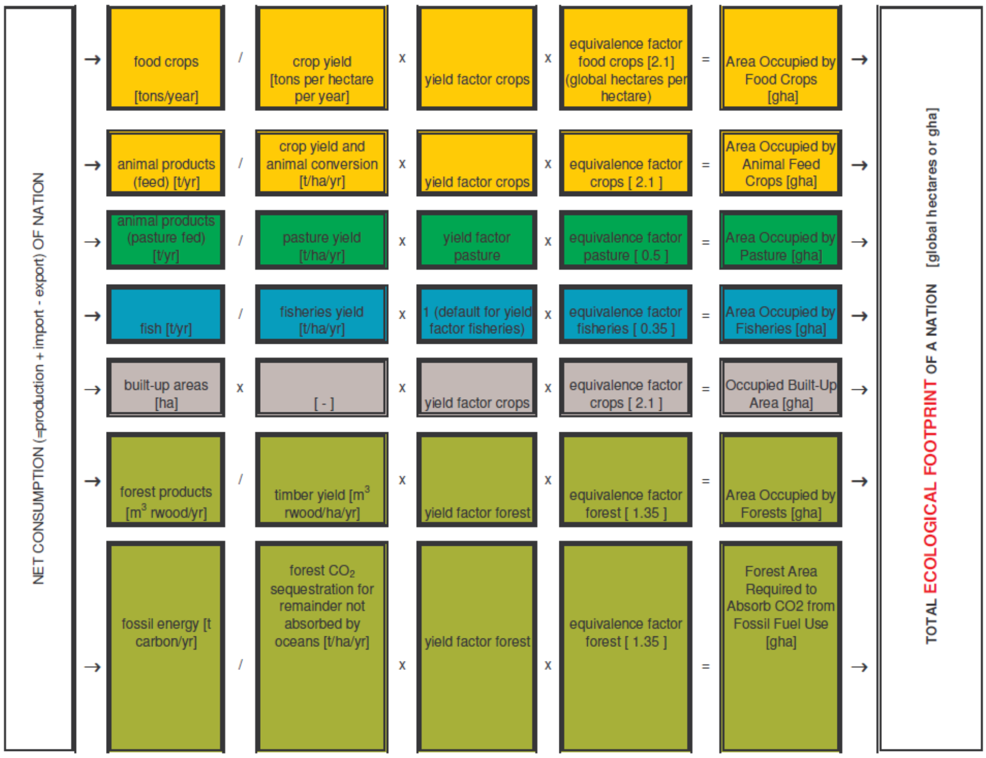

Figure 2-10: Structure of the national Ecological Footprint calculation methodology based on Global Footprint Network[45]

The Ecological Footprint provides an indication that EU's consumption is not sustainable. It is particularly the amount of cropland and land for carbon sequestration where the EU has a much larger footprint than its own global biocapacity. The EU also has the highest shares of built-up area per person in the world.

[43] WWF, Global Footprint Network & ZSL (2008) Living Planet Report 2008.
[44] Eurostat (2008) Food: from farm to fork statistics, 2008 edition
[45] Von Stokar, T., Steinemann, M., Rüegge, B., Schmill, J. (2006) Switzerland's ecological footprint. A contribution to the sustainability debate. Swiss Statistics Series. Federal Statistical Insitute of Switzerland et al., Neuchâtel, Switzerland.

Table 2-1: The Ecological Footprint of EU-27 in global hectares (a hectare of land with world average ability to produce resources and absorb wastes)[46]

EU-27 (2005)	Ecological Footprint		Biocapacity			Difference	
Land type	Global ha per person	Global ha (million)	Global ha per person	Global ha (million)	%	Global ha per person	Global ha (million)
Cropland	1.17	570.1	1.0	487.3	43.3%	-0.17	-82.8
Grazing land	0.19	92.5	0.21	102.3	9.1%	0.02	9. 7
Forest	0.48	233.9	0.64	311.9	27.7%	0.16	78.0
Fishing ground	0.1	48.7	0.29	141.3	12.6%	0.19	92.6
Built-up land	0.17	82.8	0.17	82.8	7.4%		
Carbon	2.58	1 257.2				-2.58	-1 257.2
Total	**4.7**	**2 285.4**	**2.3**	**1 125.7**	**100.0%**	**-2.4**	**-1 159.8**

From the table it could be observed that according to the Ecological Footprint the EU in 2005 had sufficient biocapacity in global terms of grazing land, forest and fishing grounds to fulfil its own consumption of natural resources from these types of areas. This is however contradictory to the fact that the EU is a net importer of fish, wood and beef. It must be remembered that the Ecological Footprint is based on a global average and does not take into consideration the specificities of local extraction and consumption of resources.

The ability of land to uptake carbon is a major component of the Ecological Footprint calculations. Whilst this study does not consider fossil fuels, the materials savings due to recycling, waste prevention and product design also represent avoided CO_2 emissions from the decrease in need for energy to extract, produce and transport these materials. In this study, the contribution of the various components of resource efficiency in terms of Ecological Footprint is calculated in the same manner as the reductions in land use: the reduction of natural resource consumption is considered proportional to the land needed to supply these resources. The yields, yield factors between land types and the equivalence factors between national and global land types remain constant in the estimation.

2.3.3. Environmentally Weighted Material Consumption (EMC)

The concept of Environmentally Weighted Material Consumption (EMC) was developed in 2005 by van der Voet *et al.*[47] to estimate the contribution of different materials to environmental impacts. The apparent consumption of selected base materials is combined with quantifiable impact categories by means of a multiplying

[46] WWF, Global Footprint Network & ZSL (2008) Living Planet Report 2008.

[47] van der Voet, E., van Oers, L., Moll, S., Schütz, H., Bringezu, S., de Bruyn, S., Sevenster, M., Warringa, G. (2005) Policy Review on Decoupling: Development of indicators to assess decoupling of economic development and environmental pressure in the EU-25 and AC-3 countries. Institute of Environmental Sciences (CML), Leiden University; Wuppertal Institute for Climate, Environment and Energy; CE Solutions for Environment, Economy and Technology.

factor which is derived by using life cycle inventory data sets, i.e. it is a weighted indicator of the environmental impacts of material consumption. It is then capable of illustrating how data on material flows, such as Domestic Material Consumption (DMC), is linked with data derived from Life Cycle Assessments (LCA), considering the cradle-to-material and recycling-to-disposal pathways of materials. The potential environmental impacts of different materials should be considered in relation to the weight or volume of their use. In the end, it is the environmental pressures and impacts which should be decoupled from economic growth, not their use per se.

EMC is defined as:

$$EMC = \sum_{k} \sum_{i} M_i * E_{i,k}$$

where M_i is material consumption of material **i**, E_i the cradle-to-grave environmental impact of that material and **k** the number of impact categories included in the analysis.

The impact categories covered by the EMC include land use, climate change, stratospheric ozone depletion, human health impacts, eco-toxicity, photo-oxidant formation, acidification, eutrophication, ionising radiation and the impact on ecosystems and biodiversity. This broad coverage of environmental impacts make it the most appropriate tool to integrate in a comprehensive manner most of the environmental impacts assessed independently by other tools. The data requirements for the indicator are material flows and production and trade statistics. It also needs data on life-cycle emission inventories and environmental impacts of different materials. In this study, the main environmental impact categories (e.g. global warming, acidification, ecotoxicity) are calculated and presented separately for each material stream.

3. RECYCLING

The main objective of this chapter is to investigate to what degree current recycling practices contribute to overall material productivity and what increases in recycling rates could be foreseen in the future. First the current recycling targets in the EU were analysed. The relationship between the current recycling rates and the material flows into the EU-27 economy was established for the main materials covered by current legislation: ferrous and non-ferrous metals, minerals (including aggregates, concrete and glass), plastics, biomass and paper. Subsequently, for each of these materials, the total contribution of recycling target rates to material savings and material productivity was estimated. These estimates were based on current material flows and recycling rates as well as on the assumption that all current recycling targets are fully met. The last section addresses the potential for improvement in the recycling targets and identifies the barriers that could impede possible increases of recycling rates.

Recycling means different things for the various material streams. The following options are currently the most common recycling options[48]:

- **Metals**: Most metals can be recycled any number of times without loss of quality.
- **Minerals**: Construction materials such as aggregates, concrete and asphalt can be recycled either on site (in situ) or in a central plant (ex situ).
- **Glass**: Glass can be remelted to become new glass products without loss of physical property or quality. The coloured glass cannot be turned into clear glass products, but can be recycled into other coloured glass products. Otherwise alternative uses of recycled glass are water filtration; fluxing agents in bricks and clay pipes; shot blasting; and, aggregates.
- **Plastics**: Besides PET bottles, which can be recycled into their previous form (closed-loop recycling), the recycling options for plastic usually involve down-cycling, where polymers are turned into lower quality products.[49] The main end-applications of recycled plastics are films and bags for the distribution sector, fibres to manufacture household goods, and building and construction materials. LDPE and HDPE can be recycled from packaging applications. PVC is relatively difficult to recycle, and there are currently no large-scale recycling schemes operating for post-consumer PVC.

[48] WRAP, www.wrap.org.uk/recycling_industry/information_by_material/index.html & www.recyclenow.com

[49] Arcadis & Eunomia (2009) Assessment of the options to improve the management of biowaste in the European Union. Study for the European Commission, DG Environment.

- **Wood**: The recycling options of post-consumer wood depend to a large extent on the quality of the wood (e.g. decay, impurities, contamination, etc.)[50]. Recovered wood suitable for recycling is cleaned and processed to remove contaminants and then shredded into wood chips that can be used different uses such as particle boards, landscaping or animal bedding products[51].
- **Paper**: Used paper and cardboard is repulped, which breaks it down into fibres and then screened, cleaned and deinked. Depending on the quality of the recycled fibres, the pulp can be used to make new paper and cardboard products, or mixed with virgin fibres to produce better grades. Recycled fibres do deteriorate over time and therefore cannot be recycled indefinitely, but have to be mixed with virgin fibres.
- **Biowaste**: Biowaste (i.e. food and garden waste) is recycled by composting or anaerobic digestion (which uses micro-organisms to produce biogas and biofertilisers).

3.1. RECYCLING POLICIES AND TARGETS SET AT EU LEVEL

EU recycling targets are set in the Waste Framework Directive (2006/12/EC). Annex D presents an overview of the waste and recycling legislation that make use of recycling targets, the collection targets, reuse/recycling/recovery-targets and deadlines. The following key definitions are included in the Waste Framework Directive:

- **Preparing for reuse**: checking, cleaning or repairing recovery operations, by which waste products or components of products are prepared for reuse without any other pre-processing.
- **Recovery**: any operation the principal result of which is waste serving a useful purpose by replacing other materials in order to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.
- **Recycling**: any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

Further details are provided below about the requirements of the individual Directives, including definitions of waste streams, deadlines for implementation, exceptions, derogations and reporting mechanisms.

[50] Merl, A.D. et al. (2007) Amounts of recovered wood in COST E31 countries and Europe. 3rd European COST E31 Conference: Management of recovered wood.

[51] www.wrap.org.uk/recycling_industry/information_by_material/wood/uses_for.html

Table 3-1 : Overview of rates related to reuse, recycling or material recovery

Material/waste	collection target	deadline	reuse	recycling	material recovery	energy recovery	recovery*	target**	deadline
Waste Framework Directive	separate collection	2015							
• paper Municipal Solid Waste (MSW)			x	x				≥ 50 w%	2020
• metal MSW			x	x				≥ 50 w%	2020
• plastic MSW			x	x				≥ 50 w%	2020
• glass MSW			x	x				≥ 50 w%	2020
• Construction and Demolition (C&D) waste			x	x	x			≥ 70 w%	2020
End-of-life vehicles (ELV) Directive	100 w%		x				x	≥85 w%	2006
			x				x	≥95 w%	2015
			x	x				≥80 w%	2006
			x	x				≥85 w%	2015
Waste Electric and Electronic Equipment (WEEE) Directive	4 kg/person	2006							
	65 w% of EEE put on market in two preceding years has to be separately collected and fully sent to treatment	2016***							
• large domestic appliances and automatic dispensers							x	≥80 w%	2006
							x	≥85 w%	2011***
• small domestic appliances, lighting equipment, electrical and electronic tools, toys, leisure and sports equipment and monitoring and control instruments + **medical devices**							x	≥70 w%	2006
							x	≥75 w%	2011***
• IT and telecommunications equipment and consumer equipment							x	≥75 w%	2006
							x	≥80 w%	2011***
• discharge lamps			x	x				≥80 w%	2006
			x	x				≥85 w%	2011***
• large domestic appliances and automatic dispensers			x	x				≥75 w%	2006
			x	x				≥80 w%	2011***

Material/waste	collection target	deadline	reuse	recycling	material recovery	energy recovery	recovery*	target**	deadline
• small domestic appliances, lighting equipment, electrical and electronic tools, toys, leisure and sports equipment and monitoring and control instruments			x	x				≥50 w%	2006
+ **medical devices**			x	x				≥55 w%	2011***
• IT and telecommunications equipment and consumer equipment			x	x				≥65 w%	2006
			x	x				≥70 w%	2011***
Batteries Directive									
• Portable batteries and accumulators	25 w% 45 w%	2012 2016							
• Industrial and automotive batteries and accumulators	100 w%	2009							
• lead acid				x				> 65 w%	2010
• Ni-Cd				x				> 75 w%	2010
• other (button cells excluded)				x				> 50 w%	2010
Packaging and Packaging Waste Directive									
• packaging waste						x		50 - 65w%	2001
• packaging materials				x				25 - 45 w% , min 15 w% per type	2001
• packaging waste						x		> 60 w%	2008
• packaging waste				x				55 - 80 w%	2008
• glass				x				60 w%	2008
• paper & cardboard				x				60 w%	2008
• metals				x				50 w%	2008
• plastics				x				22,5 w%	2008
• wood				x				15 w%	2008

As defined in Directive 75/442/EEC

** Recovery/recycling targets for WEEE and waste batteries are expressed as a percentage of the total weight of WEEE/batteries that has to be separately collected and fully sent for treatment and recycling.

*** As proposed in COM(2008)810 final[52]. Reuse in this case also includes the reuse of whole appliances. The 2006 target only covers component, material and substance reuse.

[52] European Commission (2008) Proposal for a Directive of the European Parliament and of the Council on waste electrical and electronic equipment (WEEE) (Recast).

In Annex C, the current EU recycling targets are analysed in detail, taking into account definitions of the waste streams, deadlines for implementation, exceptions, derogations and links to the reporting requirements. Furthermore, the reporting mechanisms and data sources are listed. However, it is necessary to bear in mind that new Member States have transitional periods often negotiated in their accession treaties.

3.2. ESTIMATION OF CURRENT CONTRIBUTIONS TO MATERIAL SAVINGS FROM RECYCLING

The following recycling related waste streams covered by EU legislation were analysed:

- Municipal Solid Waste (MSW)
- Construction and Demolition (C&D) waste
- End-of-Life Vehicles (ELV)
- Waste from Electric and Electronic Equipments (WEEE)
- Waste batteries
- Packaging waste

Figure 3-1 shows the relative weight of the different waste streams analysed. Each year just under 3 billion tonnes of waste are generated in the EU-27[53].

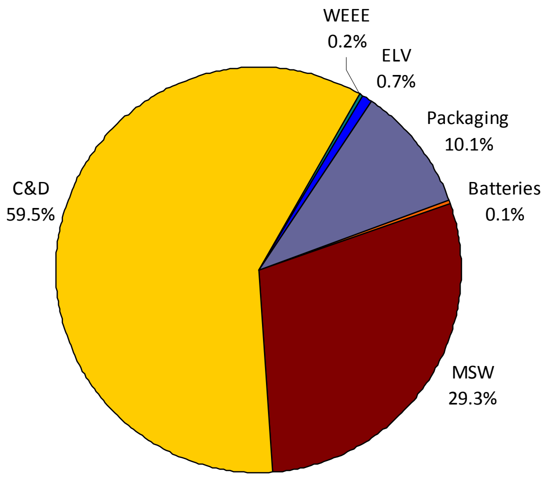

Figure 3-1: Relative weight of waste streams under study

The waste streams analysed in this study account for 800 – 1,300 Mt (depending on data source). The rest of the waste sectors (i.e. agricultural, industrial, mining waste) are not accounted, not being directly affected by EU regulations related to the

[53] Arcardis, VITO, Umweltsbundesamt, BIO Intelligence Service (2010) Analysis of the evolution of waste reduction and the scope of waste prevention.

objectives of this study. Further information about assumptions and calculations made in estimation of material savings can be found in Annex C.

Table 3-2 presents the estimates of the recycling amounts of the most important material fractions based on waste statistics resulting from the various policies currently in place. The C&D amounts per material fraction result from averaging the ranges provided in Annex C and recalculating these values in order to obtain the total C&D recycling amount reported.

Recycled C&D waste represents by far the largest amount in weight, particularly of aggregates, but also important amounts of steel, plastic and wood are recycled. Recycled municipal solid waste and packaging waste are the next largest contributors to total recycling. Here paper and cardboard and bio waste (MSW) constitute the majority of material, but also large amounts of metals, glass, plastic and wood are recycled. ELV and WEEE contribute to quite important amounts of metals. For battery waste the recycled amounts at the level of the main material flows discussed in this study appear relatively small, but the contribution of recycling to very specific flows as e.g. lead or cadmium may not be underestimated.

However, all amounts must be interpreted with caution: most of them are rough estimates, based on the assumptions of the preceding paragraphs. Uncertainty also remains regarding the amounts of packaging waste included in the MSW figures. Therefore, the calculated row totals are expected to comprise some double counting.

Table 3-2: Overview of estimates of current recycling amounts in the EU according to material fraction

<table>
<tr><th></th><th colspan="7">Material recycled under current situation for 2004 (ktonnes) - Data from EU based waste statistics and other sources</th></tr>
<tr><th>Material</th><th>MSW</th><th>C&D</th><th>ELV</th><th>Packaging</th><th>Battery</th><th>WEEE</th><th>Total</th></tr>
<tr><td>Metals</td><td>2 570</td><td>5 094</td><td>4 006</td><td>3 227</td><td>179</td><td>975</td><td>16 051</td></tr>
<tr><td>Glass</td><td>9 193</td><td></td><td>82</td><td>10 003</td><td></td><td></td><td>19 278</td></tr>
<tr><td>Concrete and masonry</td><td></td><td>138 278</td><td></td><td></td><td></td><td></td><td>138 278</td></tr>
<tr><td>Asphalt</td><td></td><td>36 389</td><td></td><td></td><td></td><td></td><td>36 389</td></tr>
<tr><td>Gypsum</td><td></td><td>728</td><td></td><td></td><td></td><td></td><td>728</td></tr>
<tr><td>Other mineral waste</td><td></td><td>13 343</td><td></td><td></td><td></td><td></td><td>13 343</td></tr>
<tr><td>Plastics</td><td>4 843</td><td>2 547</td><td>66</td><td>3 894</td><td>24</td><td>443</td><td>11 818</td></tr>
<tr><td>Paper & cardboard</td><td>17 545</td><td></td><td></td><td>23 793</td><td></td><td></td><td>41 338</td></tr>
<tr><td>Wood</td><td>2 965</td><td>7 278</td><td></td><td>4 883</td><td></td><td></td><td>15 126</td></tr>
<tr><td>Bio waste</td><td>22 290</td><td></td><td></td><td></td><td></td><td></td><td>22 290</td></tr>
<tr><td>Other</td><td>27 430</td><td>46 093</td><td>307</td><td>15</td><td></td><td>355</td><td>74 198</td></tr>
<tr><td>Total</td><td>86 836</td><td>249 749</td><td>4 461</td><td>45 814</td><td>203</td><td>1 773</td><td>388 836</td></tr>
</table>

Figure 3-2 shows the contribution of each waste policy area in relation to the total amount of current recycled materials. C&D waste represents by far the largest amount of recycled material. MSW and packaging are the two other main waste streams that contribute with recycled materials are recycled.

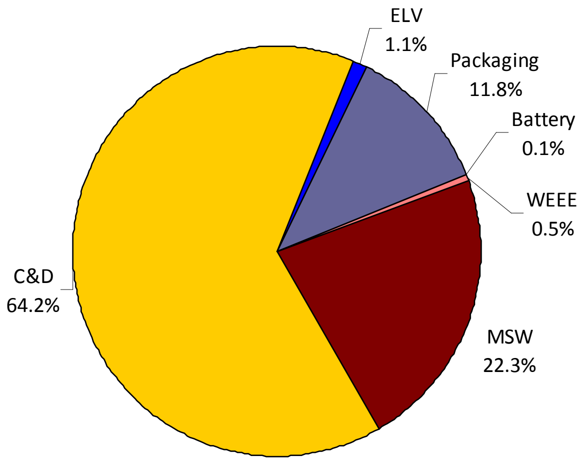

Figure 3-2: The contribution of each waste policy area to current recycling

The above estimates were then compared to a similar study done by Prognos on resource savings[54] (see Table 3-3). Here the recycling amounts and rates of 18 waste streams were considered for EU-27. The study estimated that 1,051 Mt of material was recycled in 2004 (out of a total of 2,417 Mt treated waste). This is much greater amount than what was found in this study. Compared to the Prognos, the estimates for amounts of recycled metals and minerals are severely underestimated. The estimates for paper, wood and biowaste are more comparable, whilst glass and plastic are estimated to be lower in the Prognos study. This might indicate that packaging waste has been accounted for twice in MSW and packaging waste (due to different reporting methods).

Data from production statistics and industrial associations is also presented in order to provide a comparison of the recycling amounts calculated using the waste statistics. The production figures have been taken from Eurostat database. The total amount of recycled material is comparable to what was estimated in this study. However the same trend of metals being underestimated, and glass and plastic seems to be overestimated.

The deviations between these data sets are due to the different nature of the sources and the uncertainties encountered during the process:

- Waste data is based on waste collection and treatment, while production data is based on data reported by the industry.
- In production statistics, there is a risk of counting material amounts that never become waste and are recycled by internal processes.
- Waste data are based on estimations of material composition of waste products.

[54] Prognos (2008) Resource savings and CO2 reduction potential in waste management in Europe and the possible contribution to the CO2 reduction target in 2020.

- Waste data for the EU-27 is calculated by extrapolation from MS figures based on population.
- Production statistics are based on Eurostat data, and where data is not available the recycling rate have been extrapolated from similar material streams.
- Waste from agriculture, mining and manufacturing are not included in the present study, since no policy targets were identified.

Table 3-3: Recycling amounts from waste statistics compared to MFA/production data and their deviation, current scenario for 2004, amounts in million metric tonnes (Mt), deviation in % (100% signifies that the same production data is used)

	Data based on waste statistics a)		Prognos study b)			Data based on MFA statistics			Data based on production statistics c)		
Material categories	Recycling rates	Recycling amounts	Recycling rates	Recycling amounts	Deviation to waste statistics	Recycling rates	Recycling amounts	Deviation to waste statistics	Recycling rates	Recycling amounts	Deviation to waste statistics
Iron & steel	55%	13.9	76%	77.7	560%	55%	33.0	238%	47%	75.2	541%
Aluminium	52.1%	1.7	67%	3.1	185%	52%	2.4	140%	46%	4.7	276%
Copper d)	47.5%	0.3	64%	0.9	269%	48%	0.9	256%	41%	2.4	800%
Nickel e)	-	-	-	-		14%	0.01		40%	0.28	
Lead e)	14%	0.2	60%	0.6	392%	14%	0.04	29%	60%	0.98	490%
Zinc e)	-	-	58%	0.7		14%	0.1		35%		
Glass	43.2%	19.3	50%	10.7	56%	43%	6.7	35%	65%	11.1	58%
Aggregates	47%	187.5	43%	610.6[55]	410%	47%	187.5	100%	50%	184	98%
Plastic f)	32.6%	11.8	17%	4.5	38%	21%	5.2	44%	21%	5.3	45%
Paper	48.7%	41.3	56%	44.2	107%	49%	42.2	102%	48%	58.3	141%
Wood	40.5%	15.1	31%	21.7	143%	14%	9.34	62%	39%	11.4	76%
Biowaste	33%	22.3	33%	28.8	129%	33%	22.3	100%	25%	20.8	93%
Other		74.2		91.1	123%						
Total	**-**	**388.8**	**44%**	**894.6**	**230%**	**-**	**309.7**	**80%**		**374.4**	**96%**

[55] Two figures are given for recycling and recovery of mineral demolition waste for the year 2004 in the Prognos study: 769.2 Mt (p. 20) and 610.6 Mt (p. 127)

a) Sources:
- Eurostat
- European Topic Center on Resource and Waste Management (2009): EU as a Recycling Society - Present Recycling Levels of Municipal Waste and C&D Waste in the EU
- BIO Intelligence Service (2010) Study on management of construction and demolition waste in the EU. Study commission by the European Commission, DG Environment
- Umweltbundesamt (2008) Aggregates Case Study - Final Report
- European Commission (2010) Preparatory study for the review of the Thematic Strategy on the Prevention and Recycling of Waste.
- GHK and BIO IS (2006) A study to examine the benefits of the End of Life Vehicles Directive and the costs and benefits of a revision of the 2015 targets for recycling, reuse and recovery under the ELV Directive ANNEX 2 : arisings and treatment of End of Life Vehicles
- EEA – European Environment Agency (2009): Statistics for member states for SOER part C waste. Copenhagen. Submitted on 10.02.2010

b) Prognos (2008) Resource savings and CO2 reduction potential in waste management in Europe and the possible contribution to the CO2 reduction target in 2020.

c) Sources:
- Eurostat
- EUROFER- European Confederation of Iron and Steel Industries
- Organisation of European Aluminium Refiners and Remelters
- EAA - European Aluminium Association
- EUROcopper- European Copper Institute
- Nickel Institute
- World Bureau of Metal Statistics
- European Commission (2010) Annex V to the Report of the Ad-hoc Working Group on Defining Critical Raw Materials. DG Enterprise.
- EPRO (2008) Plastic Waste Management in Europe

d) European Aluminium Association (2007) Aluminium Recycling in Europe: *Production of recycled aluminium in 2004 (EU-25) 4.5 Mt. Recycling rates range from 90% for transport and construction applications and about 60% for beverage cans.*

e) Eurometaux (European Association of Metals): recycling efficiency of available non-ferrous metals is 60-90%
- 60% of lead used in Western Europe from recycled or reused material
- European Commission (2010) Annex V to the Report of the Ad-hoc Working Group on Defining Critical Raw Materials. DG Enterprise.

f) PlasticsEurope: *Plastic waste generated EU-27 + CH & NO in 2008: 24.9 Mt; Post consumer plastic recycled: 5.3 Mt (recycling rate 21.3%)*

3.3. ESTIMATION OF CONTRIBUTIONS TO MATERIAL SAVINGS FROM RECYCLING WITH ALL CURRENT RECYCLING TARGETS FULLY REACHED

Based on the same data sources as before, the calculations are reiterated, assuming that all current recycling targets are fully met by each individual Member State. For Member States that already meet or exceed the recycling targets, the current recycling rate of the respective Member State is kept constant. Further information about assumptions and calculations made in the below sections can be found in Annex C.

Table 3-4 presents the estimates of the recycling amounts of the most important waste fractions discussed in this study, under the assumption that all existing targets are fully achieved. As before C&D waste and municipal solid waste are the areas were the recycling amounts are the highest, followed by packaging waste. The other waste streams contribute mostly to the metals fraction. The currently recycled amounts of materials represent approximately 67% of the total amounts which could be recycled if all targets set in EU legislation were fully reached. Hence, one third of the recycling potential under current legislation still has to be realized. An important contribution is to be expected from the recycling of C&D and municipal solid waste.

Again, it must be noted that all amounts are to be interpreted with caution since most of them are rough estimates, based on the assumptions of the preceding paragraphs. Some double counting is expected to be present in the row totals, as uncertainty remains regarding the amounts of packaging waste included in the MSW.

Table 3-4: Overview of estimates of the recycling amounts in the EU under the assumption that all current recycling targets are fully reached.

	Material recycled with current recycling targets fulfilled (ktonnes) - Data from EU based waste statistics and other sources						
Material	**MSW**	**C&D**	**ELV**	**Packaging**	**Battery**	**WEEE**	***Total***
Metals	3,856	7,998	4,352	3,275	787	1,151	*21,420*
Glass	13,793	n/a	89	11,059			*24,942*
Concrete and masonry		217,101					*217,101*
Asphalt		57,132					*57,132*
Gypsum		1,143					*1,143*
Other mineral waste		20,948					*20,948*
Plastics	7,267	3,999	71	4,091	106	523	*16,058*
Paper and cardboard	26,326			23,975			*50,301*

	Material recycled with current recycling targets fulfilled (ktonnes) - Data from EU based waste statistics and other sources						
Material	**MSW**	**C&D**	**ELV**	**Packaging**	**Battery**	**WEEE**	***Total***
Wood	4,449	11,426		4,936			*20,812*
Bio waste	33,445						*33,445*
Other	41,157	72,367	333	15	173	419	*114,463*
Total	**130,293**	**392,114**	**4,846**	**47,351**	**1,066**	**2,093**	***577,763***

The total recycling amounts are still much less than what was estimated in the Prognos study. The differences in amounts of the individual material streams are the same as before: recycled metals, minerals and wood are estimated by Prognos to be much higher; biowaste and paper are about the same; and, glass and paper are estimated to be less than what this study indicates (possibly due to double counting for MSW and packaging waste).

Table 3-5: Recycling amounts with targets achieved based on waste statistics compared to Prognos study and their deviation, amounts in Mt, deviation in %

	Waste statistics		Prognos study		
Material categories	**Recycling rates**	**Recycling amounts**	**Recycling rates**	**Recycling amounts**	**Deviation to waste statistics**
Iron & steel	71%	18.25	79%	81.5	447%
Aluminium	64%	3.17	79%	3.7	117%
Copper	67%	0.36	79%	1.1	306%
Lead	65%	0.71	79%	0.9	127%
Glass	56%	24.94	66%	14.3	57%
Aggregates	74%	294.42	78%	670.2	228%
Plastic	44%	15.06	30%	8.0	53%
Paper	59%	50.30	76%	60.2	120%
Wood	56%	20.80	80%	56.2	270%
Biowaste	50%	33.44	38%	33.7	101%
Other		116.31		261.8	225%
Total		**577.76**		**1192.2**	**206%**

3.4. POTENTIAL FOR IMPROVEMENT OF THE RECYCLING TARGETS

This chapter provides a brief overview of the available literature concerning the improvement of recycling targets set in EU legislation. It summarises the results of the current study and previous reports in light of the improvement potential for each of these recycling targets. A more in depth analysis of the economic, environmental, social and legislative factors influencing the desirability of such improved targets is not intended, as this would be the subject of a detailed impact assessment study.

Table 3-6 shows the potentially reused and recycled amounts for the most important waste fractions discussed in this report if all recycling targets of section 3.4. were fully reached by each Member State. The most important contributions to the recycling potential on a weight basis can again be found in the C&D waste, the municipal solid waste and the packaging waste categories. Also for WEEE, significant contributions are to be expected, especially for the metals fraction. Of course, it must clearly be stated that these conclusions are derived from weight-based recycling amounts. However, the importance of the contributions of other waste streams to the recycling of more environmentally hazardous fractions or scarce resources as e.g. rare metals cannot be neglected. Additionally it must be noted that all amounts are to be interpreted with caution since most of them are rough estimates, based on the assumptions of the preceding paragraphs. Some double counting is expected to be present in the row totals, as uncertainty remains regarding the amounts of packaging waste included in the MSW.

Table 3-6: Overview of estimates of the recycling amounts in the EU according to material fraction, under the assumption that all potential recycling targets are fully reached.

	Future potential for amount of material recycled based on best practice (ktonnes) - Data from EU based waste statistics and other sources						
Material	**MSW**	**C&D**	**ELV**	**Packaging**	**Battery**	**WEEE**	***Total***
Metals	5,013	9,800	4,597	3,382	843	2,819	*26,454*
Glass	17,931	n/a	94	15,532			*33,557*
Concrete and masonry		265,994					*265,994*
Asphalt		69,998					*69,998*
Gypsum		1,400					*1,400*
Other mineral waste		25,666					*25,666*
Plastics	9,448	4,900	75	6,501	113	1,281	*22,319*
Paper and cardboard	34,223			24,346			*58,570*
Wood	5,784	14,000		9,335			*29,119*
Bio waste	43,478						*43,478*
Other	53,504	88,665	352	15	187	1,025	*143,747*
Total	**169,381**	**480,422**	**5,119**	**59,112**	**1,143**	**5,125**	***720,302***

This study estimates the future potential for recycling amounts in EU-27 with current best practices implemented to be about 720 Mt. In their study Prognos[56] estimated the future potential to be much higher: 1,300 Mt (see Table 3-7).

Table 3-7: Future potential recycling amounts based on waste statistics compared to Prognos study and their deviation, amounts in Mt, deviation in %

[56] Prognos (2008) Resource savings and CO2 reduction potential in waste management in Europe and the possible contribution to the CO2 reduction target in 2020.

	Waste statistics		Prognos study		
Material categories	Recycling rates	Recycling amounts	Recycling rates	Recycling amounts	Deviation to waste statistics
Iron & steel	82%	22.45	94%	96.2	429%
Aluminium	76%	2.52	87%	4.0	159%
Copper	100%	0.41	87%	1.2	294%
Lead	64%	0.71	87%	0.9	128%
Glass	76%	33.56	85%	18.4	55%
Aggregates	90%	360.72	85%	728.5	202%
Plastic	60%	22.32	42%	11.1	50%
Paper	69%	58.57	85%	67.9	116%
Wood	78%	29.12	90%	63.1	217%
Biowaste	65%	43.48	42%	37.3	86%
Other		146.46		271.5	185%
Total		**720.30**		**1300.1**	**180%**

Compared to the Prognos study, the amounts of recycled metals, minerals and wood are severely underestimated in this study, whilst glass and plastic are overestimated (possibly due to double counting for MSW and packaging waste).

4. WASTE PREVENTION

The main objectives of this section are to provide an overview of waste prevention measures and policies and to estimate the total potential contributions of waste prevention to material savings and productivity. Most of the data that this is based on are derived from recent studies performed for the Commission on waste prevention[57,58].

The EU policy framework that first included waste prevention as a means to avoid waste generation was the *"Thematic strategy on the prevention and recycling of waste"* adopted by the European Commission in 2005. Following this, the Waste Framework Directive[59] (adopted in 2008) introduced a new vision on waste management, encouraging the prevention of waste and the setting of recycling targets. It also required Member States (MS) to develop national waste prevention programmes by December 2013. Other EU policies that address waste prevention such as the Packaging and Packaging Waste Directive, the End-of-Life Vehicles (ELV) Directive, WEEE (Waste from Electric and Electronic Equipment) Directive, RoHS (Restriction of the use of certain Hazardous Substances) Directive, Environmental Technologies Action Plan (ETAP) and EMAS (Eco-Management and Audit Scheme) are also assessed in order to estimate their current impacts on material use, and their contributions to material savings.

4.1. DEFINITION OF WASTE PREVENTION

The definition of waste prevention for this study is consistent with the Waste Framework Directive[59], where *prevention* means:

> *Measures taken before a substance, material or product has become waste, that reduce:*
>
> *(a) the quantity of waste, including through the re-use of products or the extension of the life span of products;*
>
> *(b) the adverse impacts of the generated waste on the environment and human health; or*
>
> *(c) the content of harmful substances in materials and products.*

[57] IEEP, Ecologic, Bio Intelligence Service, Umweltsbundesamt, Arcardis, and VITO (2010) Preparatory study for the review of the Thematic Strategy on the Prevention and Recycling of Waste. Study commissioned by the European Commission, DG Environment.
[58] Arcardis, VITO, Umweltsbundesamt, and BIO Intelligence Service (2010) Analysis of the evolution of waste reduction and the scope of waste prevention. Study commissioned by the European Commission, DG Environment.
[59] Waste Framework Directive (2008/98/EC)

From a quantitative point of view, waste prevention means preventing or limiting waste generation. This can be achieved through a greater duration of the use of products, substances or materials (notably through re-use and the production of products with extended life spans that replace the need for new products) or merely through less use of materials (reducing material intensity). From a qualitative point of view, waste prevention means preventing or limiting environmentally harmful waste, in particular hazardous and/or toxic substances.

In the context of this study, a distinction is made between waste prevention and product design measures that lead to material productivity[60]. Typically ecodesign is seen as a possible waste prevention measure, but in order not to double-count the contributions to material productivity, a clear distinction is made. In many cases ecodesign supports certain waste prevention measures, e.g. by improving product durability to prolong product life, etc. The effects on material savings of such actions should only be accounted for once (similarly products, which are designed to be recycled or have recycled material content, are already accounted for under the contribution of recycling). In this chapter, only the amounts of material saved from avoided waste are considered, or in other words, measures that lead to:

- more efficient use of materials/ minimising waste during production/ construction (reduction at source);
- increased reuse/refurbishment/repair/remanufacturing of products and buildings, which prolongs product life – this includes measures that increase the sharing of products, e.g. by offering services instead of products; and,
- reduced use of substances, consumption of products and waste production, e.g. avoiding food waste, junk mail, etc. (strict avoidance[61])

The different forms of waste prevention explained above will be considered in the following sections.

4.2. WASTE PREVENTION RELATED POLICIES

The following EU policies that provide criteria for waste prevention and/or require the establishment of regulations for waste prevention (as defined in section 4.1. were examined to determine their impacts on material use:

- **End-of-Life Vehicles (ELV) Directive**
- **Waste from Electric and Electronic Equipments (WEEE) Directive**
- **Packaging and Packaging Waste Directive**
- **Restriction of Hazardous Substances (RoHS) Directive**

[60] Often improvements in product design are also considered as waste prevention

[61] OECD (2000) OECD Reference manual on strategic waste prevention, ENV/EPOC/PPC(2000)5/FINAL, Paris.

- **Eco-management and Audit Scheme (EMAS)**
- **Environmental Technologies Action Plan (ETAP)**

Further information about evidence and estimates for waste prevention can be found in Annex D.

Although waste prevention is a priority in EU waste management policy, not many specific policies dedicated to waste prevention have been identified compared with recycling. Even though many of the recycling targets include reuse (a waste prevention strategy), the evidence from WEEE and ELV suggest that recycling is by far the preferred waste treatment option. A reason for this could be that waste prevention, compared to recycling, is more difficult to account (i.e., measurability of waste not generated).

At present the impact of prevention initiatives is considered to be limited. The Waste Framework Directive, which was adopted in 2008, has not resulted in many strong waste prevention policies. MS are only required to have national waste prevention programmes by December 2013. The waste prevention measures that do exist are still in an early stage of development, even though there are a number of waste prevention initiatives at Member State level (see section Annex D). Furthermore there is a lack of studies and measurement of the effects of waste prevention. The data gathered in this study are mostly based on case studies at a local level.

The amounts of hazardous substances annually avoided each year due to RoHS is taken from the Commission's impact assessment, whilst the amount of manufacturing waste is derived from a recent report on the potential of waste prevention in the EU[62].

Table 4-2 presents the estimated material savings based on the above contributions of waste prevention instruments. It should be noted that it is not clear whether the reduction in using the banned substances in RoHS actually result in a net reduction of resources. It is not known what amounts of other materials that are needed to substitute the hazardous substances. As mentioned since the current waste data often does not distinguish between recycling and reuse, reuse could actually be a bit higher that what the table below suggests. For example, if assuming the experience from France that 1.5% of WEEE generated is reused, at an EU-27 scale this would correspond to 46,230 tonnes of material (of which 31,890 tonnes is metal and 7,965

[62] Arcardis, VITO, Umweltsbundesamt, BIO Intelligence Service (2010) Analysis of the evolution of waste reduction and the scope of waste prevention. Study commissioned by the European Commission, DG Environment.

tonnes is plastic). These are minor amounts compared to recycling, and in any case already accounted for in the previous chapter.

4.3. THE POTENTIAL OF WASTE PREVENTION APPROACHES

The above section has presented the various EU and MS policies related to waste prevention. Except in the case of RoHS and EMAS (which is nonetheless anecdotal) there is little evidence of actual waste prevention that can be attributed to implemented policy. In order to estimate the total potential contribution of waste prevention policies, the following provides a broad overview of different feasible waste prevention approaches with estimates of what could be achieved. The main waste prevention strategies considered are:

- **Lean production** (more efficient use of materials/ minimising waste during production/ construction);
- **Reuse** (including refurbishment/repair/remanufacturing of products and buildings);
- **Sustainable consumption behaviour** (reduced consumption of products/waste production, e.g. avoiding food waste, junk mail, etc.

Each approach is briefly described and the potential for contributing to material productivity is estimated. Further information about evidence and estimates for waste prevention can be found in Annex D.

4.3.1. LEAN PRODUCTION

The main idea of Lean Production (or Lean Manufacturing)[63] is the systematic elimination of waste by focusing on production costs, product quality, delivery, and employee involvement. Initially developed by Toyota for the car assembly lines[64], the principles in lean production have been widely adopted in the manufacturing sector and has even proved to be applicable to other different sectors (such as the food and construction industries[65] as well as public service offices[66]). In the context of this study, lean production is used as a term to cover all types of strategies that can be used in organisations to increase material efficiency in work processes (including manufacturing plants, offices, construction sites, etc.).

Although lean production can involve the feeding back of waste materials into the manufacturing process and reducing the amount of materials used in the final

[63] US EPA (2000) Pursuing Perfection: Case Studies Examining Lean Manufacturing Strategies, Pollution Prevention, and Environmental Regulatory Management Implications.
[64] Womack, James P. and Jones, Daniel T. (1991) The Machine that Changed the World. New York: Harper-Collins.
[65] Lean Construction Institute, www.leanconstruction.org
[66] www.leanamerica.org

product, these aspects are covered in the other chapters on recycling and product design, respectively. Here, only the contribution of material savings achieved by reducing material consumption and waste in production is considered. Lean production is guided by some key principles on eliminating waste and minimising inventory in a culture of continuous improvement. This is achieved by mapping the value chain and eliminating any steps that do not create any value (as perceived by the customer). The process flows are then rearranged to respond to customer demands. The main reasons that companies adopt lean production techniques is that it often results in better quality, together with a reduction of production costs and lead times. Although not environmentally motivated, lean production can be compatible with environmental management systems such as EMAS or ISO 14001.

As lean production is already best practice in many manufacturing companies, it is assumed that it already contributes to approximately 2% waste reduction[67].

4.3.2. REUSE

Reuse and the related strategies are often mentioned as waste prevention approaches. These are different from recycling because they involve preserving the whole or parts of products. In contrast, recycling activities require the destruction of the product to its component materials so they can be reprocessed into new forms. Reuse strategies can be classified as[68]:

- **Direct reuse**: the product is passed on to someone else by reselling or donation.
- **Refurbishment**: cleaning, lubricating or other improvement.
- **Repair**: rectifying a fault.
- **Redeployment & cannibalisation**: using working parts elsewhere.
- **Remanufacturing**: the only option that requires a full treatment process – like new manufacture – to guarantee the performance of the finished object.

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[67] Own estimate based on various sources:

- COWI (2010) Economic Analysis of Resource Efficiency Policies. Study commissioned by the European Commission, DG Environment.
- Mollenkopf, D., Stolze, H., Tate, W.L. & Ueltschy, M. (2010) Green, lean, and global supply chains, International Journal of Physical Distribution & Logistics Management, Vol. 40 No. 1/2.
- University of Cambridge (2008) Towards a sustainable industrial systems
- US EPA (2000) Pursuing Perfection: Case Studies Examining Lean Manufacturing Strategies, Pollution Prevention, and Environmental Regulatory Management Implications.
- US EPA (2009) "Green Servicizing" for a More Sustainable US Economy: Key concepts, tools and analyses to inform policy engagement.
- WRAP (2009) Meeting the UK climate change challenge: The contribution of resource efficiency. WRAP Project EVA128. Report prepared by Stockholm Environment Institute and University of Durham Business School.

[68] Arcardis, VITO, Umweltsbundesamt, BIO Intelligence Service (2010) Analysis of the evolution of waste reduction and the scope of waste prevention. Study commissioned by the European Commission, DG Environment.

Reuse strategies contribute to material savings by providing an alternative to purchasing new items. This leads to the reduction in the amount of new materials and resources used to manufacture new products. However, this is only true if the reused item is not replaced by a new item.

Approaches that seek to prolong and/or optimise product life by increasing the sharing/ renting/ leasing/ pooling of products, e.g. by offering services instead of products, are considered to have the potential to further encourage the above mentioned reuse strategies. Communal use refers to the sharing of products among a number of individuals, either simultaneously (such as carpooling) or in succession (such as renting items). Communal use of products or equipment can lead directly to waste prevention by providing individuals with the option of sharing a product instead of buying one of their own. This contributes to less consumption of certain product types, and ultimately less raw material extraction and manufacturing. An indirect result of communal use is also a decreased need for related infrastructure (for example, less car parks needed for vehicles).

Direct reuse refers to the reuse without the need for repair, refurbishment or remanufacturing of a product. This often occurs through passing on of items from one individual to another, such as through second hand purchase (e.g. eBay's Rethink Initiative[69]), or by donation (e.g. Freecycle[70]). Remanufacturing and repair involves the reprocessing and repair of waste products to be reused for their originally intended use. As with direct reuse, remanufacturing can result in deferring the purchase of a new item, in favour of an older item which has been restored to good working condition, or even upgrading parts to increase an older product's efficiency (particularly the case with modular products). This again results in less need for the manufacturing of new products. However, unlike direct reuse, this process can involve steps similar to manufacturing, in that new components or repairs may be needed to restore an item. Although less material intensive than when producing new items, the amount of resources needed for remanufacturing can depend heavily on the extent of damage or wear a product may have suffered. In some cases, this may be less cost effective than producing a new product to replace an old one. Although hard to quantify, a conservative estimate could be that already 2% of the waste from manufacturing is currently avoided due reuse in some or another form and reduces the need for new materials.[71]

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[69] Enabling consumers to find others that can put old products to new use. www.pages.ebay.com/rethink/

[70] A non-profit movement that helps people give (and get) used products for free. According to Freecycle, their 7 million members help keep 500 tonnes a day out of landfills. www.freecycle.org/

[71] Own estimate based on various sources:

- US EPA (2009) "Green Servicizing" for a More Sustainable US Economy: Key concepts, tools and analyses to inform policy engagement.
- Steelcase - Office furniture through leasing and management services: www.steelcase.co.uk/en/services/pages/ecoservices.aspx
- Caterpillar – equipment rental and remanufactured products www.cat.com/cda/layout?m=94942&x=7

Reuse of WEEE equipment is specifically seen as a form of waste prevention. In France, recent figures indicate that of the 364,613 t of WEEE generated, 5,776 t have been reused. This amounts to a 1.5% reduction in the amount of WEEE appliances recycled or disposed of[72]. Assuming the same reduction figure throughout the rest of Europe (based on the total amount of WEEE collected[73]), a total amount of 22,290 t of WEEE is reused.[74] An older study in Scotland (2001/2002) indicates a higher potential for WEEE reuse[75]. The study identified that of the 7,149 t of WEEE being managed by recovery companies, 2,492 t were reused; approximately 35%. Again it is unclear what waste streams are affected by this practice. At a more local scale, the Network Worcestershire Appliance Re-use Centre has estimated that of the total amount of WEEE goods collected, 30% can potentially be re-used[76]. This figure is closer to that determined in Scotland; however, this figured looks only at the potential for re-use, and not the amount currently reused. Applying this figure as a potential maximum throughout the EU would amount to savings of 637,500 t (or just under 7% of all EEE put on the market).

For cars, it is assumed that 1 out of 10 cars could be avoided with a combination of increased car sharing, preventive maintenance, taxes and better public transport options[77]. This corresponds to 10% of vehicles annually registered or 1.5 Mt of materials. In the construction sector, the reuse of materials is also thought to be able to reduce C&D waste with 10%[78]. The savings is assumed to follow the same distribution of the current material composition of waste. Finally, Chemical Management Services[79] seems to be able to reduce 30% of the wastes of spent

- Rolls-Royce – complete engine management: www.rolls-royce.com/civil/services/corporatecare/index.jsp
- Tukker, A. & Tischner, U. (eds) (2006) New Business for Old Europe. Product-Service Development, Competitiveness and Sustainability. Greenleaf Publishing.

[72] ADEME (2009) French WEEE Register

[73] Available at: epp.eurostat.ec.europa.eu/portal/page/portal/waste/data/wastestreams/weee

[74] Based on breakdown figures in EC (2008), Proposal for a Directive of the European Parliament and of the Council on waste electrical and electronic equipment (WEEE) (Recast).

[75] SEPA (2003) Priority Waste Stream Project: Waste Electrical and Electronic Equipment

[76] Parliamentary Office of Science and Technology (2007) Postnote - Electronic Waste. No. 291.

[77] Own estimate based on various sources:

- Streetcar – a self-service pay-as-you-go car in the UK: www.streetcar.co.uk/
- US EPA (2009) "Green Servicizing" for a More Sustainable US Economy: Key concepts, tools and analyses to inform policy engagement.

[78] Own estimate based on various sources:

- US EPA (2009) "Green Servicizing" for a More Sustainable US Economy: Key concepts, tools and analyses to inform policy engagement.
- Bioregional (2008) Pushing Reuse : Towards a low-carbon construction industry
- www.communitywoodrecycling.org.uk/woodwaste.htm

[79] Own estimate based on various sources:

- CMS Forum website, www.cmsforum.org
- COWI (2008) Promoting Innovative Business Models with Environmental Benefits. Study commissioned by the European Commission, DG Environment.

solvents, acid, alkaline or saline wastes, used oils, spent chemical catalysts, chemical preparation and chemical deposits and residues. Current material savings from the reuse of car parts and WEEE are already accounted for in the previous chapter on recycling as the registered data does not distinguish between the two types of waste treatment.

4.3.3. SUSTAINABLE CONSUMPTION BEHAVIOUR

Sustainable behaviour orients individual consumption not just towards more environmentally efficient solutions, but also towards sufficiency. In many cases, consumers are tempted to buy more than they need (e.g. *"buy one – get one free!"* offers) and/or have the choice between options ranging from low to high environmental impacts (e.g. ecolabels). As a strategy, sustainable behaviour and consumption patterns requires increasing consumer awareness about environmental topics and individual responsibility.

Modifying behaviours towards sustainable consumption will lead to waste prevention. There are two general types of incentive and dissuasive instruments to encourage sustainable behaviour: economic instruments (e.g. deposits, subsidies, levies, taxes, etc.); and, communication instruments (e.g. environmental labelling, information campaigns) to raise awareness and educate consumers. Financial stimuli are mainly a response action influencing the pressure executed on the environment. This preventive effect can be seen both in qualitative and quantitative terms. Taxes and subsidies can be applied to the amounts of raw materials extracted / imported or waste generated (e.g. landfill tax) in order to increase material productivity. Levies can be put on hazardous substances (e.g. tax on PVC foils for packaging[80]) in order to shift consumption to products with lower environmental impact. In both cases financial stimuli is used to change producer / consumer behaviour.

Another important instrument for encouraging more sustainable behaviour is environmental labels. Often products that have the same functionality can have very different environmental impacts. The European Ecolabel and specific Member State labels such as Nordic Swan and Blue Angel, are all examples of environmental labels that seek to guide consumers to purchasing more environmentally friendly products and services. Material reduction and avoidance of certain substances are typical criteria for environmental labels and do contribute to waste prevention. The contribution of the European Ecolabel in this study is examined more closely in the next chapter as a product design approach to achieving material productivity.

An area for significant material savings is 'Green Public Procurement (GPP)'. It is estimated that public authorities have a budget of 17% of GDP[81], which represents a corresponding large amount of products and materials consumed. If guided by

- US EPA (2009) "Green Servicizing" for a More Sustainable US Economy: Key concepts, tools and analyses to inform policy engagement.

[80] Introduced in Denmark in 1999 for food packaging.

[81] Green Public Procurement: www.ec.europa.eu/environment/gpp/what_en.htm

environmental labelling GPP does have the potential to reduce the waste generated and increase material productivity. However, in some instances, there may not be a practical choice between equivalent products. For example, consumers can choose between different kinds of meats: even though red meat (e.g. beef) is more resource and land-use demanding that white meat (e.g. chicken meat), they are not always substitutes as each has its own tastes and traditions. Nonetheless following the guidelines of a healthy diet would reduce the portion of meat and increase the consumption of vegetables[82]. This would lead to a reduction of biomass demand as meat is a more resource demanding way of providing food when compared with vegetables. No estimates for the reduction of meat have been provided.

The recent *"Preparatory study on food waste across EU-27"*[83] provided a first estimate for the reduction of food waste in the EU due to waste prevention initiatives. Based on WRAP's *"Love food, Hate waste"* campaign's results so far, it was assumed that food waste could be reduced with 1.8% of total food waste or 3% of avoidable household food waste. It should however be noted that the preparatory study specifically states *"there is simply not enough data available to extrapolate the scale of potential food waste prevention to the EU-27"*, so this first estimate is not considered very reliable.

4.4. ESTIMATION OF CURRENT CONTRIBUTIONS TO MATERIAL SAVINGS FROM WASTE PREVENTION

To estimate the current contribution of waste prevention measures to material savings, the following data and assumptions were used.

Table 4-1: Overview of the data and assumptions used to estimate the current contribution of waste prevention policies and related approaches

Instrument	Assumed impact on material savings
RoHS[84]	89 800 t of lead, 4 300 t of cadmium, 537 t of hexavalent chromium, 22 t of mercury, and 12 600 t of octa-BDE
Lean production (including EMAS)	2% of current manufacturing waste
Reuse strategies	2% of current manufacturing waste

[82] McMichael, A.J., Powles, J.W., Butler, C.D., Uauy, R. (2007) Food, livestock production, energy and health. Series Energy and Health 5. The Lancet, pp. 55-65.

[83] BIO Intelligence Service, AEA, Umweltsbundesamt, (2010) Preparatory study on food waste across EU-27. Study commissioned by the European Commission, DG Environment.

[84] European Commission (2008) Impact Assessment – Commission staff working paper accompanying the Proposal for a Directive of the European Parliament and of the Council on waste electrical and electronic equipment (WEEE) (recast). COM(2008) 810.

Table 4-2: Summary of material savings achieved from current waste prevention policies and measures (amounts in ktonnes)

	RoHS	Lean manufacturing		Reuse strategies in manufacturing	*Total*
Material	**Material avoided**	**Manufacturing waste**	**Material savings**	**Material savings**	**Amount**
Metals	94.1	29 160	583.20	583.20	*1 260.50*
Iron and steel		26 244	524.88	174.96	*1 049.76*
Aluminium		2 041.2	40.82	17.50	*81.65*
Copper		583.2	11.664	361.58	*23.33*
Lead	89.8	291.6	5.83	29.16	*101.46*
Cadmium	4.3				*4.30*
Non-metallic minerals		19 230	384.60	384.60	*769.20*
Glass		1 290	25.80	25.80	*51.60*
Hazardous substances	13.2				*13.16*
Plastic		1 680	33.60	33.60	*67.20*
Paper & board		11 680	233.60	233.60	*467.20*
Wood		54 210	1 084.20	1 084.20	*2 168.40*
Food		8 140	162.80	162.80	*325.60*
Other biowaste		29 160	583.20	583.20	*1 166.40*
Other					
Total	**107**	**154 550**	**3 091**	**3 091**	**6 289**

This study estimates only about 6.3 Mt of materials are currently saved due to current waste prevention measures and policies. This is less than 2% of the current amount of recycled material (388.8 Mt) and almost insignificant compared to the total amount of waste generated in 2004 (2,920 Mt).

4.5. ESTIMATION OF POTENTIAL CONTRIBUTIONS TO MATERIAL SAVINGS FROM WASTE PREVENTION

As waste prevention measures have not been fully put in place and the impacts of these measures are not well documented, the estimation of potential material savings that could be achieved from waste prevention was based on evidence from a variety of different sources. The waste prevention strategies considered include lean production (in the manufacturing and construction sector); the full range of reuse strategies (e.g. refurbishment, repair, remanufacturing, servicing, communal use);

and, more sustainable behaviour (e.g. green public procurement, consumption patterns, dietary changes, etc.). The data and the assumptions used in this study to calculate the potential feasible material savings that could be achieved through stronger waste prevention policies, more sustainable consumption and new service-oriented business models are listed in the following table.

Table 4-3: Overview of the assumptions used to estimate the potential contribution of waste prevention policies and related approaches to achieve greater material productivity

Instrument	Assumed impact on material savings
RoHS	89 800 t of lead, 4 300 t of cadmium, 537 t of hexavalent chromium, 22 t of mercury, 12 600 t of octa-BDE, 40 000 t of non-reacted TBBPA, 210 tonnes of HBCDD, 29 000 t of DEHP and 1.5 t of beryllium oxide
Lean production (including EMAS)	10% of manufacturing and construction waste
Reuse, repair, remanufacturing and sharing/servicising	10% of WEEE 10% of registered vehicles 10% of construction waste
Chemical Management Services	30% of chemical wastes
MSW waste prevention through sustainable behaviour	7% of MSW

Assuming that green public procurement and that more intensive waste prevention programmes are launched, it would seem feasible that MSW could be reduced with 7% (same target as France as set). The material savings is assumed to follow the same distribution of the current material composition of MSW waste. These amounts would also include any reductions arising from specific waste streams such as food waste prevention, banning/taxation of plastic bags and limiting junk mail.

Using the above evidence and assumptions the potential for material savings through the variety of different waste prevention strategies were calculated. Table 4-3 lists the material savings according to each strategy and the composition of materials (the material savings are assumed to follow the same percentage fraction as the composition of materials in current waste streams).

Waste prevention measures have yet to realise its potential for material savings. Leaner production and construction methods, reuse and more sustainable behaviour shows great potential for material savings, particularly regarding non-metallic materials, chemicals and metals. The total potential for material savings due to waste prevention based on current best practices is estimated to be about 156 Mt annually. This is over a third of the material saved through current recycling. The main savings come from better use (and reuse) of construction materials, but also from overall changes in consumption behaviour.

Table 4-4: Summary of potential material savings achievable from waste prevention policies and measures (all amounts in ktonnes)

	RoHS	Lean manufacturing		Lean construction		Reuse of EEE		Car sharing		Reuse in construction		CMS		Sustainable behaviour		*Total*
Material	Amount	Manu-facturing waste	Material savings	Construc-tion waste	Material savings	Amount of WEEE collected	Material savings	Amount put on market	Material savings	Construc-tion waste	Material savings	Chemical waste	Material savings	MSW	Material savings	Amount
Metals	*94.1*	*29 160*	*2 916*	*10 839.2*	*1 083.9*	*1 169*	*350.7*	*11 400*	*1 140*	*10 839.2*	*1 083.9*			*7 817.6*	*547.2*	*7 215.9*
Iron and steel		26 244	2 624.4	10 297.3	1 029.7	1 052.1	315.6	10 200	1 020	10 297.3	1 029.7			6 254.1	437.8	*6 457.3*
Aluminium		2 041.2	204.1	433.6	43.4	87.7	26.3	1 020	102	433.6	43.4			1 329.0	93.0	*512.2*
Copper		583.2	58.3	108.4	10.8	29.2	8.8	180	18	108.4	10.8			234.5	16.4	*123.2*
Lead	89.8	291.6	29.2													*119.0*
Cadmium	4.3															*4.3*
Non-metallic minerals		***19 230***	***1 923.0***	***401 567.4***	***40 156.7***					***401 567.4***	***40 156.7***					***82 236.5***
Concrete and masonry				294 207.5	29 420.7					294 207.5	29 420.7					*58 841.5*
Asphalt				77 423.0	7 742.3					77 423.0	7 742.3					*15 484.6*
Gypsum				1 548.5	154.8					1 548.5	154.8					*309.7*
Other mineral waste				28 388.4	2 838.8					28 388.4	2 838.8					*5 677.7*
Glass		1 290	129.0					500	50					15 635.4	1 094.5	*1 273.5*

	RoHS	Lean manufacturing		Lean construction		Reuse of EEE		Car sharing		Reuse in construction		CMS		Sustainable behaviour		*Total*
Material	Amount	Manu-facturing waste	Material savings	Construc-tion waste	Material savings	Amount of WEEE collected	Material savings	Amount put on market	Material savings	Construc-tion waste	Material savings	Chemical waste	Material savings	MSW	Material savings	Amount
Chemicals	13.2											41 100	12 330			*12 343.2*
Hazardous substances	13.2															*13.2*
Plastic		1 680	168	5 419.6	542.0	531.0	159.3	1 500	150	5 419.6	542.0			28 664.4	2 006.5	*3 567.7*
Oil												4 200	1 260			*1 260*
Paper & board		11 680	1 168											91 205.0	6 384.4	*7 552.4*
Wood		54 210	5 421	15 484.6	1 548.5					15 484.6	1 548.5					*8 517.9*
Food		8 140	814											52 117.2	3 648.2	*4 462.2*
Other biowaste		29 160	2 916											13 029.3	912.1	*3 828.1*
Other				98 069.2	9 806.9	425.0	127.5	1 800	180	98 069.2	9 806.9			52 117.2	3 648.2	*23 569.5*
Total	**107.3**	**154 550**	**15 455**	**531 380**	**53 138**	**2 125**	**637.5**	**15 200**	**1 520**	**531 380**	**53 138**	**45 300**	**13 590**	**260 585**	**18 241**	**155 827**

In the recent study: *"Analysis of the evolution of waste reduction and the scope of waste prevention"*[85], the full (theoretical) potential for waste prevention was estimated. Here the study investigated the amount of waste at different stages of the life cycle of materials. Using the assumption that all waste at the production and end-of-life stages is potentially preventable, the study estimated that 155 Mt of production waste could be prevented and correspondingly 141 Mt of end-of-life waste. Even though the study only counted waste that is clearly related to the production process of each industry, e.g. metal waste from the metal producing industries, the potential amounts of material saved are at present only theoretic figures, as industry is still far from a 'zero-waste' situation. In general, the potential for waste prevention in this study is estimated to be around 10% of the current waste streams.

Table 4-5: Waste prevention potentials – a comparison between this study and theoretical amounts with 'zero waste', all amounts in Mt

		Analysis of the evolution of waste reduction and the scope of waste prevention				
Waste type	**Total in this study**	**Extraction waste**	**Production waste**	**End of life waste (incl. household waste)**	**Total**	**Percent of total waste**
Metals	**7.2**	0.0	29.2	34.4	**63.6**	11%
Glass	**1.3**	0.0	1.3	25.0	**26.2**	5%
Paper and cardboard	**7.6**	0.0	11.7	92.2	**103.9**	7%
Plastic	**3.6**	0.0	1.7	26.9	**28.6**	13%
Wood	**8.5**	0.0	54.2	21.3	**75.5**	11%
Food	**4.5**	32.6	37.3	90.1	**160.0**	3%
Mineral	**82.2**	736.7	19.2	886.8	**1642.8**	5%
Total	**155.8**	**769.4**	**154.6**	**1176.7**	**2100.6**	7%

[85] Arcardis, VITO, Umweltsbundesamt, BIO Intelligence Service (2010) Analysis of the evolution of waste reduction and the scope of waste prevention. Study commissioned by the European Commission, DG Environment.

5. PRODUCT DESIGN

Design can play a critical role in material use and material savings since these are to a large extent determined at the design stage of a product's life. For example, the shape and dimensions of the product; the choice of materials used in the manufacturing process or during its life time; the possibility of reusing, recycling or any other end-of-life option after its use, are all defined during product conception. Each one of the aspects listed above directly influence the type and amounts of materials used and their corresponding environmental impacts during the product's life cycle.

This section provides an overview of possible contributions of product design to material savings and productivity. First the relevant existing policies and measures are studied by looking at the methods and approaches that could or have affected material use after their implementation. This part forms the basis for the estimation of the contribution of product design to material savings and to material productivity under the current state of policy implementation as well as an estimation of future potentials.

5.1. DEFINITION OF ECODESIGN

The concept of ecodesign lies in the process of creating a product that delivers a specific functionality whilst taking into consideration the environmental impacts throughout its entire life cycle. The aim of this product life thinking is to reduce the environmental impacts related to each stage from raw material extraction to end-of-life. Since environmental effects are determined during the development of the product, design plays a critical role when the goal is to reduce the negative effects on the environment. According to a guide to improve environmental performance through development, 80% of the products environmental profile is fixed under the concept creation stage[86]. Likewise it is claimed that around 80% of a product's environmental impacts can be eliminated through better design.[87]

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[86] McAloone, T. & Bey, Niki, B. (2008) Environmental improvement through product development – a guide. Danish Environmental Protection Agency. Available at: www.kp.man.dtu.dk/English/Research/areas/Ecodesign/guide.aspx

[87] House of Lords (2008) Waste Reduction. Volume I: Report 6th. Report of Session 2007–08. Science and Technology Committee, UK.

Ecodesign principles

A list of common strategies to develop environmentally sound products, also known as *ecodesign principles* is presented below[88]:

- Reduce the **material intensity**: using less material for the same functionality (product lightweighting)
- Reduce the **energy intensity**: consuming less energy for the same output
- Eliminate or reduce the **dispersion of harmful substances**
- Increase the amount of **recycled and recyclable material**: design for recycling
- Optimise the product's **durability**: increase the product's lifetime by making it durable, repairable and upgradeable (design for longevity)
- Incorporate **environmental features** into the product: e.g. duplex printing, standby functions, eco-programmes
- **Signal the product's environmental features**: make them visible to the user or setting them as a default
- Maximise the use of **sustainable resources and supply chains**: using resources that have small environmental impacts, ethically produced and require minimum transport
- Optimise the product's **performance**: an effective product is the most efficient way to meet user's needs
- **Design the life cycle first** then the product: consider all the environmental impacts throughout the product's life cycle stages and develop the product based on user's activities and needs

The above principles are not independent and sometimes even contradictory, e.g. reducing material intensity and optimising product's durability. Trade-offs often have to be made by designers and manufacturers. They must consider these principles carefully by taking into account the overall environmental impacts for each specific product. Furthermore, not all of these strategies are directly relevant for material productivity. In the context of this study only **reducing material intensity** (**lightweighting**); **design for recycling**; the **elimination/dispersion of harmful substances** (already covered in Chapter 4)**;** and, **design for longevity;** are considered in relation to how they can lead to material savings.

5.2. ECODESIGN RELATED POLICIES

In this section current policies that have lead to material savings and productivity through product design are analysed. Only the policies that have provisions for ecodesign parameters and that have entered into force are included, these are: the

[88] McAloone, T. & Bey, Niki, B. (2008) Environmental improvement through product development – a guide. Danish Environmental Protection Agency.

Ecodesign Directive; EU Ecolabel; WEEE Directive; Packaging and Packaging Waste Directive: and, the End-of-Life Vehicles Directive. Although policies that aim to limit or prevent the use of hazardous substances, e.g. RoHS, can be seen as a design-oriented policy, these have been dealt with in the previous chapter.

Further information about evidence and estimates for ecodesign can be found in Annex E.

From the five types of design related policies, the Ecolabel presents the most important contributions to resource savings at present. The total amount of materials saved was estimated to be 0.53 Mt for an assumed 5% market share of Ecolabelled products (see Table 5-1). If the market penetration increases and/or product categories are included in the forthcoming years, greater savings could be achieved.

Table 5-1: Total estimated materials saved (in ktonnes) due to EU Ecolabel[89]

Material stream	Ecolabelled products market share (5%), in ktonnes
Reduced use of hazardous substances	13.80
Material savings	
Pesticide	1.58
Fertiliser	45.41
Granite	233.81
Peat	113.30
Titanium dioxide	25.11
Others	111.49
Total materials saved	**530.70**

Actual contributions of the Ecodesign Directive to material use and efficiency have not been significant for two main reasons: 1) the first implementing measures with ecodesign requirements were only approved of in 2008, and 2) the methodology for assessing products focuses on energy efficiency (for more details see Annex E). Besides (indirect) material savings due to change in energy efficiency technology for domestic lighting, the contributions of the Ecodesign Directive to material productivity is limited as none of the implementing measures so far address material issues.

For the WEEE, ELV and Packaging Directive the contribution of design to recycling has already been accounted for in Chapter 3. There is evidence that significantly less material per packaging is now being used (see Table 5-2), but it is not clear whether this is a natural development or due to the Packaging Directive. Likewise, technological development and ecodesign has resulted in considerable lightweighting of electrical and electronic equipment (EEE).

[89] AEAT (2004) The direct and indirect benefits of the European Ecolabel. Study for the European Commission, DG Environment.

Table 5-2: Evolution of packaging weight[90]

Type of packaging	1950s	1960s	1970s	1990s	2000	2008	Per cent change[91]
Washing-up liquid bottle (1 litre)	–	–	120g	67g	50g	43g	64%
Soup can (400g)	90g	–	69g	57g	55g	49g	46%
Yoghurt pot (165g)	–	12g	7g	5g	–	4g	67%
Plastics fizzy drinks bottle (2 litre)	–	–	58g	–	43g	40g	31%
Metal drinks can (330ml)	–	60g	–	21g	15g	14g	77%
Glass beer bottle (275g)	–	–	450g	–	325g	176g	61%
Glass milk bottle (1 pint)	538g	–	397g	230g	–	186g	65%

It was seen that in early stages (i.e. in the 1960s) material weight reductions were significant, and changes of more than 50% in the weight of some packaging materials was achieved. It would seem that the technical limits of packaging have been reached as the weight reductions have been less in the later years There is however still a potential for further weight reduction by substituting material, e.g. from glass bottles to plastic or carton.[92] A study conducted by PlasticsEurope claims that the use of plastic for packaging helps in reducing the overall material consumption of alternative packaging material by almost 4 times (by weight)[93]. For example, by changing the material of their beer bottles, Carlsberg reduced the weight of a beer bottle from 260 g (glass bottle) to 38 g (plastic bottle). [94]

It has not been possible to determine the extent that packaging manufacturers use more recycled material in their products, but it has been observed that higher amounts of packaging waste are being recycled[95]. Regardless, the effects of packaging recycling have already been accounted for under recycling in Chapter 3.

5.3. THE POTENTIAL OF ECODESIGN APPROACHES

This section aims to identify methods that could effectively contribute to material savings and efficiency outside policies. It analyses the possible contributions of other relevant methods besides policies, such as private sector initiatives. The aim of looking at possible contributions beyond current policies is to find examples of design approaches that have an impact on material use in a significant manner which can then be used later on to provide grounds for new policy measures.

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[90] EUROPEN; Packaging and Packaging Waste Statistics 1998 – 2006.

[91] The per cent change measures the weight reduction in 2008 compared with the first year of data reporting for the product in the table

[92] www.tetrapak.com/us/Documents/tetrapak_consumerminbrochure.pdf

[93] Denkstatt AG (2010) The impacts of plastics on life-cycle energy consumption and greenhouse gas emissions in Europe.

[94] www.carlsbergdanmark.dk/omol/AtVide/Emballager/Pages/Flasker.aspx

[95] Treatment of packaging waste in the EU-27, Packaging waste 2007, EUROSTAT, Environmental Data Centre on waste.

Changes to a product's design can be made on various levels: technology (e.g. change from incandescent light bulb to LEDs), structure (e.g. use three wheels instead of four), shape (e.g. decrease wall thickness) or material (e.g. substitute plastic made from fossil fuel to plastic made from maize).

The following three design strategies to achieve material savings through design is analysed in the subsequent sections:

- **Design for recyclability** - using recycled materials and designing the product so it is easier to recycle
- **Product lightweighting** - reducing the material intensity of products by using less material or choosing another material for the same functionality
- **Design for longevity** - increasing the product lifetime: by making products more durable, repairable and upgradeable in order to increase product life time and encourage reuse.

The reduction of the use and dispersion of harmful substances is also a design strategy that could contribute to material savings, but as it is strongly linked to waste prevention, this strategy was covered under the previous chapter in relation to RoHS.

Further information about evidence and estimates for ecodesign can be found in Annex D.

5.3.1. Design for recyclability

The methods and approaches found for this option are mainly related to:

- **Using materials that can be recycled**. This can be achieved by using materials with compatible fixings/attachments as it greatly increases the product's recyclability, while incompatible materials, non-dismountable surface attachments and factors reducing recycling performance increase the steps required for recycling, making it both costly and resource-intensive. The chemical structures of the materials need to be similar in order to be broken down into their raw form together. For example, thermoset plastics and composite materials are extremely difficult to recycle.
- **Using recycled materials**. Designing products to be made out of recycled material stimulates the demand for recycled material and leads to higher recycling rates. Avoid using virgin materials such as titanium, magnesium and aluminium.
- **Minimising number of parts** involved in product components. Fewer parts mean that sorting for recycling is made easier.

- **Minimising the number of different types of material**. Switching from using several materials to mono materials for the same purpose.[96] The main advantage of using only one material is that it facilitates recyclability.
- **Marking parts for easier identification**. Plastic components are difficult to sort, if they are not properly marked. For example, marking plastic parts weighing more than 25 grams according to ISO 11469 international standards allows for easier sorting.
- **Eliminating labels or product components that have to be removed before recycling**. Labelling of products is often desirable for consumer information, batch differentiation or be required by legislation. Eliminating incompatible labels or metal inserts on plastic parts will help to improve the overall recyclability of the product. For example, a choice between moulded-in legends and/or compatible ink printing or paper labels with compatible adhesive, can instead be made for polymer casings.
- **Making the product easy to disassemble**. One of the crucial aspects to carry out product recycling is optimum disassembly so that the revenue gained from recycling the parts is greater than the cost of carrying out the operations. Often valuable parts of a product such as transformers, electric motors, etc. are located in parts of the product that are not very accessible. In many cases, once the parts have been removed any recycling value that they may have had is cancelled out by the costly disassembly which is needed to access them. Therefore, placing highly valuable parts in easily accessible places within the product will encourage and facilitate its recyclability. Disassembly can be made easier and faster by reducing the number of fasteners; making them easily assessable; using snap-fits that are designed to be undone or break; avoiding glues and adhesives to join parts made of different materials; etc.

Design for recycling is key to achieving higher recycling rates. As a strategy it allows products to be more easily recycled (creating supply), but also increases the demand for recycled material by using recycled material instead of virgin raw material. However, the real contribution of design for recycling can only be seen in the recycling amounts and the performance of collection and recycling systems. A product that is designed to be 100% recyclable does not result in material savings if it is not collected and recycled at the end of its life. The contribution of design for recycling to material productivity has already been accounted for in the chapter on recycling. Any further effects are not considered here as this would be double-counting.

5.3.2. Product lightweighting

The main idea of lightweighting is to reduce the weight of products during design whilst considering the environmental impacts throughout its entire lifecycle.[97] As it

[96] Several examples are found in the database at: www.conseil-emballage.org/web/c_fiche.asp

involves producing the same product with less material, it contributes directly to material productivity. However, caution must be taken as a *'lightweighted'* product is not necessarily a *'rightweighted'* product. Sometimes a heavier product is a better environmental choice when considering its function or the entire product life cycle, e.g. it is often better to use more material in house walls to achieve better insulation, or using more materials can make a product more durable (doubling the product's life corresponds to halving its material use). Likewise, a reduction in the weight of materials used in a product may not be the best environmental option, particularly where this involves substitution of materials which have far greater environmental impacts during the extractive phase, or cannot be recycled. In practice, product lightweighting is about redesigning the product's shape and structure, material substitution, and changes in production technologies and processes[98].

Although slightly different, two related approaches can also be considered as lightweighting:

- **Dematerialisation**[99] – reducing the amount of material needed to provide the function or benefits of the product or service. This includes both the unused indirect materials disturbed in the extraction of natural materials as well as the direct material input to the product. The indicator *material intensity per service unit (MIPS)*[100] is often used to measure dematerialisation.
- **Miniaturisation** – as the weight of a product's is a function of both the density of materials used and the volume of the product, a reduction in the size or volume of the product will automatically reduce the mass of the whole.

There is a clear overlap between all the concepts, but lightweighting is not just about making things smaller (e.g. miniaturisation) or replacing goods with services (e.g. dematerialisation through servicising). When lightweighting a product during design, the entire system that the product is a part of should be taken into consideration. Lightweighting a single component does not necessarily result in a lightweighted product. In general, when considering the lightweighting of products careful consideration must be made between the trade-off between environmental impacts as well as the trade-offs between safety, cost and quality, e.g. using less durable materials in packaging may result in more damaged/spoilt goods/food.

Often materials that have lower densities and are stronger are used to achieve lightweighting, e.g. plastics, advanced steels and alloys, aluminium, magnesium, titanium, berylium, lithium, composites such as glass fibre and carbon fibre, foams,

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[97] Oakdene Hollins & Cranfield University (2007) Product Lightweighting. A strategy to deliver a sustainable economy? Resource Efficiency Knowlegde Transfer Network, DTI, UK.

[98] Wallentowitz, H., Leyers, J., Parr, T. (2003) Business briefing: Global Automotive Manufacturing & Technology.

[99] CML (2003) Dematerialisation: Not just a matter of weight – Development and application of a methodology to rank materials based on their environmental impacts.

[100] Material Intensity per Service Unit. See www.wupperinst.org/en/projects/topics_online/mips/index.html

biomaterials, etc. With the considerable research in nanotechnology and material science, many new possibilities will be available in the future to improve the properties of existing materials and break the link between strength, stiffness and weight in materials. Within the context of this study, as already mentioned, it is not only the reduction of weight that is the issue, but the environmental impacts of the system over its entire life cycle. Lightweighting must be seen in relation to other material productivity approaches such as recycling (e.g. carbon fibre is difficult to recycle), the use of rare/scarce materials, prolonging product life, etc.

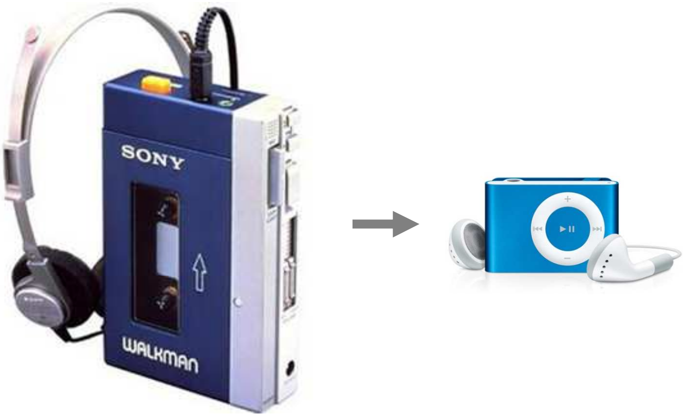

Figure 5-1: An example of a product providing the same function that has undergone drastic lightweighting with digitalisation

A special case of lightweighting by dematerialisation is the provision of products as services through digitalisation. Instead of physical materials (e.g. floppy disks, CDs, books, paper letters, etc.), ICT can provide the same service as an information service (e.g. email, music download, PDF files, etc.). This leads to the replacement of material goods with 'immaterial' information. However, it is worth noting that the embodied materials and energy of the electronic equipment, through which these information services may be accessed, may also be significant. In the case of digital books, certain products have been made (known as e-readers) which serve only to access these products. Furthermore, although offices have become more digitalised, the amount of paper consumed, contrary to what one might think, has also increased[101].

It is estimated that changing car manufacturing production structures may improve material productivity up to 29%, substituting material can save 20% and product design can reduce up to 84% of material usage in car production[102]. However, before these technical potentials can be achieved, further R&D is needed.

[101] Vowler, J. (2002) The end of paper?. Computer Weekly, 43.

[102] Wuppertal Institute for Climate Environment and Energy (2007) The relation between resource productivity and competitiveness.

Table 5-3: Selected potentials to reduce the usage of materials in compact class car (VW Golf)[102]

Option		Theoretical potential for reduction of material usage in car production (in % by weight)
Substitution of materials by	Plastics	Up to 10% compared with conventional steel production
	Aluminium	Up to 20% compared with conventional steel production
Product design	Ex. Loremo	49%
	Ex. PAC-Car II	84%
Changing production structure		23-29%

Ecodesign has become common practice in most leading manufacturing firms. The effects of these can be seen with the material intensity of each new generation of product being improved. Given the evidence, it seems economically feasible that packaging, electronic and electrical equipment (EEE) and vehicles could be redesigned using less materials and/or substituting materials with less environmental impacts. Packaging has already seen large weight reductions per unit of about 50% on average, but it would still seem possible to further reduce the weight of packaging by at least 5%. Likewise for EEE, miniaturisation and digitalisation has resulted in products which on average are estimated to require half the amount of materials compared with earlier generations of the same product. From the achievements of individual firms on material savings through ecodesign, it is assumed that a further 10% of materials could be saved and still provide the same value. Finally, the evidence shows that although lightweighting has occurred in the automotive industry, these savings have been outweighed by the increase in size and features of the average car sold on the market. If consumers accept smaller cars (which seems to be the case with the popularity of cars such as BMW Mini, Fiat 500, Smart fortwo), it would seem plausible that vehicles could be designed with as much as 30% less materials (see Figure 5-2).

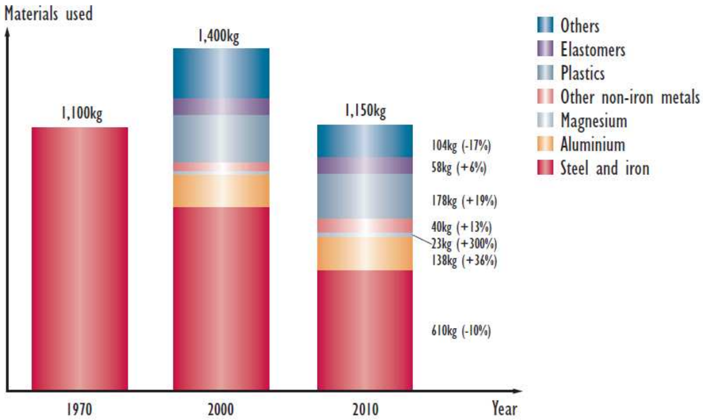

Figure 5-2: Development of materials used in the design of a mid-sized car[103]

[103] Wallentowitz, H., Leyers, J., Parr, T. (2003) Business briefing: Global Automotive Manufacturing & Technology.

It must be pointed that the above mentioned estimates assume that consumers are willing to accept these changes to products and that these material savings do not entail rebound effects in terms of increased consumption.

5.3.3. Design for longevity

The methods and approaches under this option are normally related to increasing the lifetime of products by making them more durable, repairable and upgradable. This supports waste prevention measures for reusing/ refurbishment/ repair/ remanufacturing.

Unless specific targets are set for products to last longer, it is difficult to believe that the industry will voluntarily design products that will last longer or that can be updated easily, as their rationale is to sell as many products as possible. Products that last longer and are easily updated are sold in fewer numbers and thus less attractive from a commercial point of view. If, however, manufacturing companies retained the ownership of their products and instead offered their products as a service (e.g. you paying for using the product, not for owning it)[104], this will enable and motivate companies to reuse, rationalise and enhance their products throughout their life phases in a more resource efficient manner.

Several designers believe that by creating products that induce emotional attachment with their owners, consumption of products would slow down and encourage products acquired to be used for a longer period of time.[105] This is typically observed with antique objects, e.g. clothes, furniture, cutlery, vintage cars, etc., therefore by designing products that appeal more to people's emotions, it would be possible to reduce the need for more products. Design for longevity supports various strategies to prolong product life including waste prevention strategies such as reuse, repair, remanufacture, etc. The effects of these have already been accounted for in the previous chapter on waste prevention.

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[104] As Product/Service-Systems (PSS) or 'servicising'. See COWI (2008) Promoting Innovative Business Models with Environmental Benefits. Study commissioned by the European Commission, DG Environment.

[105] See e.g.:

- Chapman, J. (2005) Emotionally Durable Design: Objects, Experiences and Empathy, Earthscan.
- Norman, D.A. (2004). Emotional Design: Why We Love (or Hate) Everyday Things, New York, Basic Books.
- Chapman, J. (2005) Emotionally Durable Design - objects, experience and empathy, Earthscan Publications Ltd, London, UK.
- Muis, H.,Odding, A., Bonekamp, L., Van Hinte, E. (eds.) (1997) Eternally Yours. Visions on product endurance. 010 Publishers, NL.

5.4. ESTIMATION OF CURRENT CONTRIBUTIONS TO MATERIAL SAVINGS FROM DESIGN

Table 5-4 presents the assumptions made to calculate the current contribution of design to material productivity. The total amounts of savings in relation to the various types of materials are presented in Table 5-5. Implementing measures for lighting under the Ecodesign Directive have resulted in the phasing out of incandescent light bulbs. Although the replacing technology, compact fluorescent lighting (CFL), uses more material per light bulb, its life time is also much longer.[106]

Table 5-4: Overview of the assumptions used to estimate the current amount of material savings achieved through product design

Instrument	Material savings
Ecodesign	Indirect material savings from the change from incandescent to compact fluorescent lamps (CFLs)
Ecolabel	5% market uptake
Packaging	50% reduction of material use
EEE	50% reduction of material use

In Table 5-5 this can be seen as negative savings (increased material consumption). Currently, the increasing purchases of CFLs represents an annual increase in the consumption of glass, plastic and other materials, however in the coming years as the lighting stock is replaced with CFLs, this will lead to much less annual demand for light bulbs (see Annex E for calculations).

Table 5-5: Summary of material savings from current design-related policies and measures (all amounts in ktonnes)

	Ecodesign	Ecolabel	Packaging		EEE		*Total*
Material	**Material savings**	**Material savings**	**Amount put on market**	**Material savings**	**Amount put on market**	**Material savings**	**Amount**
Metals	**0.228**		**4 903**	**4 903**	**5 232**	**5 232**	**10 135**
Iron and steel			3 922	3 922	4 709	4 709	8 631
Aluminium	0.228		834	834	392	392	1 226
Copper			147	147	131	131	278
Titanium dioxide		25.110					25
Granite		233.810					234
Glass	-7.923		16 597	16 597			16 589
Chemicals		**60.790**					**61**
Pesticide		1.580					1.6
Fertiliser		45.410					45
Hazardous substances		13.800					14

[106] MTP (2008) Impact Assessment of EuP Implementing Measures of Domestic Lighting. Defra, UK.

	Ecodesign	Ecolabel	Packaging		EEE		*Total*
Material	**Material savings**	**Material savings**	**Amount put on market**	**Material savings**	**Amount put on market**	**Material savings**	**Amount**
Plastic	-10.375		14 950	14 950	2 378	2 378	17 318
Paper & board			31 771	31 771			31 771
Wood			12 852	12 852			12 852
Peat		113.300					113
Other	-10.784	111.490	233	233	1 903	1 903	2 237
Total	**-28.9**	**544.5**	**81 306**	**81 306**	**9 513**	**9 513**	91 335

The estimated total current contribution of design improvements to material savings is 91.3 Mt. EU design-related policies such as Ecolabelled products constitute only a small part of these savings. General ecodesign strategies such as lightweighting in packaging and EEE (helped by miniaturisation and digitalisation) are assessed to have contributed with the greatest amounts of material savings. The savings come from the materials traditionally used for packaging (i.e. cardboard, glass, plastic, wood and metals) and EEE (i.e. metals and plastic).

Regarding Ecolabelled product's contribution it should be noted that it is not clear whether the reduction in using the avoided hazardous substances and titanium dioxide actually result in a net reduction of materials. It is not known what amounts of other materials are used instead to replace these materials. Peat is replaced by biowaste.

5.5. ESTIMATION OF POTENTIAL CONTRIBUTIONS TO MATERIAL SAVINGS FROM DESIGN

Currently only a limited amount of material savings can be attributed to the existing policies in place. Although the evidence provided in this section is fragmented, it clearly demonstrates that improvements in design have the potential for significant material savings in the future. This is mainly due to increasing the material intensity of products (lightweighting), but also by using design to support more recycling and reuse.

The Ecodesign Directive does hold the potential to increase the material productivity through implementing measures that directly address the use of materials in products as well as extending the scope of the Directive to include any kind of product (i.e. not just those considered energy-related). A review of the on-going preparatory studies commissioned for the product groups covered by the Ecodesign Directive does not provide any specific evidence on improvement potentials related to non-energy carrying materials. In general, resource savings have only been linked to energy savings especially in the use phase. The strong (and often only) focus on energy consumption during the use phase in implementing measures for previous product groups under the Ecodesign Directive is increasingly subject to criticism from stakeholders. This could lead to future implementing measures also taking into account the material productivity of products through any of the described design principles treated in this chapter: design for recyclability; product lightweighting; and, design for longevity.

The potential for expanding the Ecodesign Directive was considered in the report for the Commission on "Technical support to identify product categories with significant environmental impact and with potential for improvement by making use of ecodesign measures"[107]. The report considers what opportunities the inclusion of new product groups in the Ecodesign workplan might provide for material savings. It analysed eight main product groups (food, building occupancy, transport, construction materials, electronics and tools, paper products, clothing/textiles and chemicals) and found that the improvement potential for some categories could have an effect on material savings through product design. Unfortunately, the potential for material savings was presented qualitatively as possible actions without any quantification of material savings:

- **Food**: The link to material savings is found in actions to improve food packaging that can extend product lifetime and prevent food waste.
- **Transport**: Car weight reduction actions have been quoted in the range of 5%, 12% and up to 30%. Possibilities for material substitution are also presented.
- **Construction materials**: Including building materials from recycled products (e.g. windows from recycled glass, boards from recycled paper, etc.) and preventing coatings from hazardous substances could present opportunities for material savings.
- **Textiles**: Material savings could be achieved by reducing agrochemical use and replacing cotton with alternative natural fibres (e.g. hemp, flax, etc.).

Based on the above and due to the lack of other studies and quantitative estimates on the effects of product design on material productivity, rough assumptions were made to calculate potential material savings from product design (see Table 5-4).

Table 5-6: Overview of the assumptions used to estimate the current amount of material savings achieved through product design

Instrument	Material savings
Ecolabel becomes Ecodesign	100% market penetration
Packaging	5% material reduction through lightweighting and changing materials
EEE	10% less material
Vehicles	30% less materials

[107] BIO Intelligence Service (2010); "Technical support to identify product categories with significant environmental impact and with potential for improvement by making use of ecodesign measures" Final report.

If in the future, the EU Ecolabel is made mandatory by its incorporation into the Ecodesign Directive, this would correspond to 100% market penetration of Ecolabelled products. All of the above assumptions would seem economically feasible given the evidence presented in relation to lightweighting packaging, electrical and electronic equipment, and vehicles. The (indirect) contributions from product design to increasing recycling and reuse have already been accounted for in previous chapters. The resulting material savings are presented in Table 5-7.

Table 5-7: Summary of potential material savings achieved from increasing material intensity through ecodesign (all amounts in ktonnes)

	Ecodesign	Ecolabel	Packaging		EEE		ELV		*Total*
	Amount	Amount	Amount put on market	Material savings	Amount put on market	Material savings	Amount put on market	Material savings	Amount
Metals	**5.63**		**4 903**	**245**	**5 232**	**523**	**11 400**	**3 420**	**4 194**
Iron and steel			3 922	196	4 709	471	10 200	3 060	3 727
Aluminium	5.63		834	42	392	39	1 020	306	393
Copper			147	7	131	13	180	54	74
Minerals		**5 178.4**							**5 178**
Titanium dioxide		502.2							502
Granite		4 676.2							4 676
Glass	42.13		16 597	830			500	150	1 022
Chemicals		**1 215.8**							**1 216**
Pesticide		31.6							32
Fertiliser		908.2							908
Hazardous substances		276							276
Plastic	-13.30		14 950	748	2 378	238	1 500	450	1 423
Paper & board			31 771	1 589					1 589
Wood			12 852	643					643
Peat		2 266							2 266
Other	-13.80	2 229.8	233	12	1 903	190	1 800	540	2 958
Total	**20.65**	**10 890**	**81 306**	**4 065**	**9 513**	**951**	**15 200**	**4 560**	**20 487**

The potential for design to contribute with material savings is estimated to be about 20.5 Mt. Most of the savings are due to the expansion of scope of the Ecodesign Directive and making current Ecolabel criteria mandatory for all products sold in the EU. Lightweighting vehicles and purchasing smaller cars also represents a significant potential for reducing material consumption. The largest savings are minerals followed by metals and biomass (peat).

The above assumptions and estimates are based on what could be achieved with current available technologies. Technological development in new (bio) materials and nanotechnology could result in further reductions of material intensity. Although not considered in this study, design also holds the potential of increasing the added-value and competiveness of products.[108] Product design is not just about the functional utility and technical performance of the product, but also involves consideration of the perceived emotional benefits of products. These 'soft' factors often determine the premium manufacturers can command for their products on the market, e.g. as is the case of unique or branded goods.

[108] Design Council (2008) The impact of design on business. Design Council briefing. October 2008.

6. OVERALL IMPLICATIONS

In support of the European Commission's work towards a 'Resource Efficient Europe'[109], this study aims to make a first comprehensive estimate of the contribution of different policy measures in the EU to material savings and material productivity. Throughout the study a data and information has been sought to develop an evidence base quantifying to what extent different policy measures, related to recycling, waste prevention and ecodesign, lead to greater material productivity. Hence, the study provides the Commission with an initial assessment of the material savings which have been and can be gained, as well as the economic, environmental and social impacts, generated by existing and possible future policies and measures. The findings of this study inform of future policy measures and possible targets for material saving and resource efficiency policy in the EU. Figure 6-1 is a diagram showing where the various types of EU policies considered in this study focus on in relation to the general material flows in the economy.

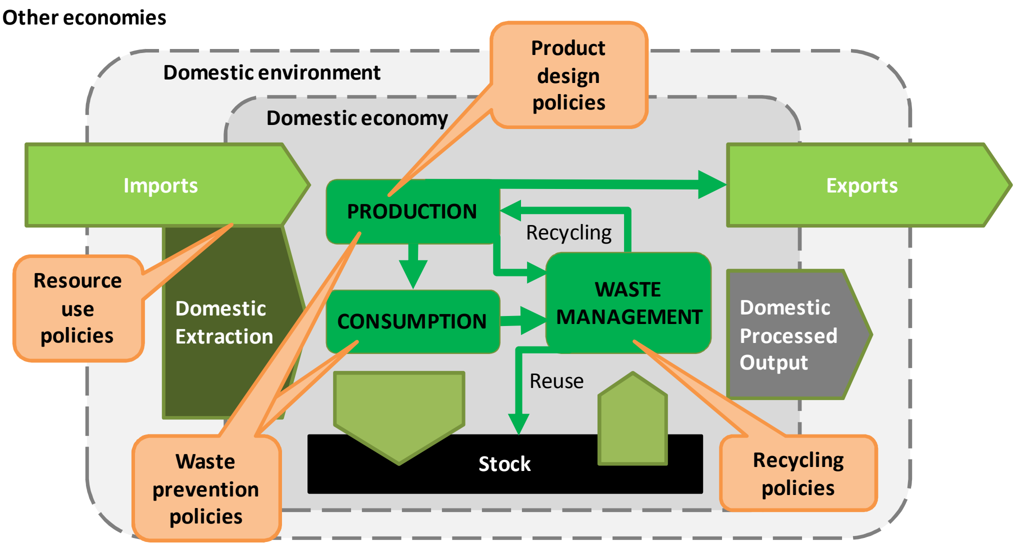

Figure 6-1: An overview of where the different resource efficiency policy areas contribute to material flows

[109] European Commission (2010) Europe 2020. A European strategy for smart, sustainable and inclusive growth.

6.1. OVERALL MATERIAL SAVINGS AND MATERIAL PRODUCTIVITY GAINS

In the investigation performed in this study of how much recycling, waste prevention and product design contribute to resource savings and efficiency, recycling has by far the largest contribution. This is partly because it is easily measured and actually tracked in companies and sectors, where waste statistics make the data available. The resource savings from waste prevention measures and product design are more difficult to measure and currently not tracked in a systematic manner. The data for waste prevention and product design is limited, and based on their recent implementation, there is a lack of measurement and no economy wide estimates exist. The estimates for waste prevention and product design are mainly based on case studies of resource savings from local initiatives.

6.1.1. RECYCLING

The data for recycling was compiled from waste statistics for the year 2004 (see Chapter 3.). First of all the national waste statistics were used as a baseline, then studies into the recycling rates of the various EU policies (e.g. WEEE, ELV, etc.) were scrutinised for more detailed information. With this information four scenarios were developed:

- **Current situation** in the year 2004 with the recycling situation as it was at that time
- **Targets fully reached** means that all present recycling targets are achieved already in 2004
- **Potential** stands for maximum recycling rates according to expert judgement are achieved in 2004
- **100% recycling** is a hypothetical scenario and represents 100% recycling of the respective waste stream in 2004

For these scenarios the following recycling amounts and recycling rates could be compiled and calculated.

It needs to be mentioned that data taken from waste statistics have a very high uncertainty. Just to mention a few examples taken from the C&D waste data (the most significant material stream): The figures provided for the recycled amounts of masonry are between 20 Mt and 135 Mt. Another example is the sub-category called miscellaneous, which ranges from minimum 5 Mt to a maximum of 90 Mt. In order to deal with these figures, what seemed like the best estimate was checked with waste experts and then used. The data uncertainty of the material saving estimates is discussed at the end of this section. Additionally global savings for some materials are estimated in order compare them with the results estimated for EU-27.

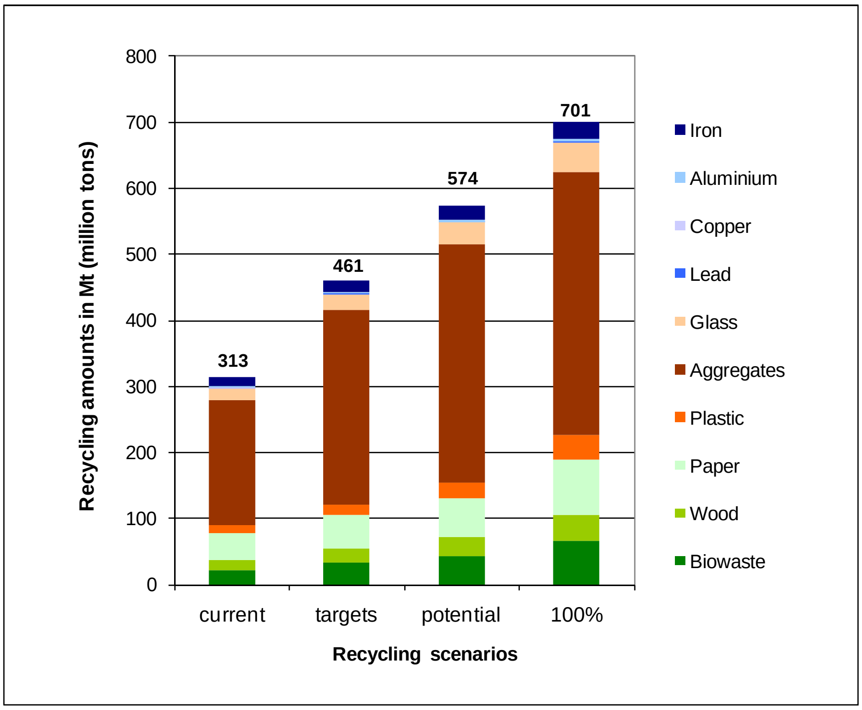

Figure 6-2: An overview of recycling amounts for all material categories EU-27 based on waste statistics for current situation, targets reached, potential and 100% recycling, all values in million metric tonnes (Mt)

The recycling amounts for all materials are 313 Mt[110] for the current scenario, and the DMC_c in 2004 was 7,714 Mt. In the scenario "targets fully reached" 461 Mt of materials are recycled, in the scenario "further potential for recycling" 574 Mt are recycled and with 100% recycling rates 701 Mt can be recycled. In all the scenarios, the aggregates (C&D waste minerals) are the highest share of recycling amounts, accounting for more than 50% of the total recycled materials. In the current situation, the estimated recycling rate for aggregates is 47%, which means 188 Mt recycled in 2004. The potential for the hypothetical scenario in which 100% recycling rate is reached is 399 Mt.

Paper has the second highest recycling amount, with a 49% recycling rate in the current situation (amounting 41.3 Mt) and a maximum of 8.7 Mt in the scenario in which 100% recycling rate is achieved. Biowaste, glass, wood, iron and plastics also have significant recycling rates and amounts in all the scenarios, whereas recycled amounts of other metals such as aluminium, copper and lead are small compared to the other materials studied.

[110] Excluding material categories that are unaccounted for e.g. "other", "misc"

Table 6-1: Detailed recycling amounts (in million metric tonnes, Mt) and recycling rates (RR) for EU-27 based on waste statistics for current situation, targets reached, potential and 100% recycling

Material categories	current		targets		potential		100%	
	Mt	RR	Mt	RR	Mt	RR	Mt	RR
Metals								
Iron	13.9	55%	18.3	71%	22.8	82%	26.2	100%
Aluminium	1.7	52%	2.1	64%	2.5	76%	3.3	100%
Copper	0.3	48%	0.4	67%	0.4	83%	0.6	100%
Lead	0.2	15%	0.7	65%	0.7	64%	1.1	100%
Non-metallic minerals								
Glass	19.3	43%	24.9	56%	33.6	76%	44.4	100%
Aggregates	187.5	47%	294.4	74%	360.7	90%	399.2	100%
Fossil fuels								
Plastics	11.8	33%	16.1	44%	22.3	60%	36.7	100%
Biomass								
Paper	41.3	49%	50.3	59%	58.6	69%	84.7	100%
Wood	15.1	41%	20.8	56%	29.1	78%	37.3	100%
Biowaste	22.3	33%	33.5	50%	43.5	65%	67.1	100%
Sum	**313.4**		**461.4**		**574.2**		**700.5**	

In the table it can be seen that 13.9 Mt of iron and steel was recycled in 2004 (current scenario). This represents a recycling rate of 55%. In the scenario where all recycling targets are fully achieved, the recycling rate of ferrous metals is 71%, which corresponds to 18.3 Mt. Based on expert judgement 22.8 Mt can be collected corresponding to a recycling rate of 82%. As a hypothetical reference in a 100% recycling scenario 26.2 Mt of ferrous metals can be recycled.

Based on these recycling amounts, material savings were calculated employing the methodology described in section 2.2. Due to methodological reasons, a fifth baseline scenario had to be introduced in order to calculate material savings and efficiency increases. This scenario represents the hypothetical situation in which there is “no recycling”. The calculated material savings and efficiency increases are shown in Figure 6-3 and Figure 6-4.

The scenario “no recycling” is a baseline scenario denoted by DMC_o. This scenario represents the consumption of materials that there would have been in the year 2004 without any recycling. Therefore the hypothetical DMC_o is 8,027 Mt. The bar shows the composition by major material categories. Due to recycling, it was possible to reduce DMC in 2004 by 312 Mt (the actual DMC in 2004 with recycling (DMC_c) was 7,715 Mt). If targets are fully reached, this would reduce DMC_o with 466 Mt. If all materials were recycled according to the recycling rates of current best practices, this could reduce DMC_o with 578 Mt, and finally, if all waste materials were recycled (100% recycling) 701 Mt of material would be saved annually.

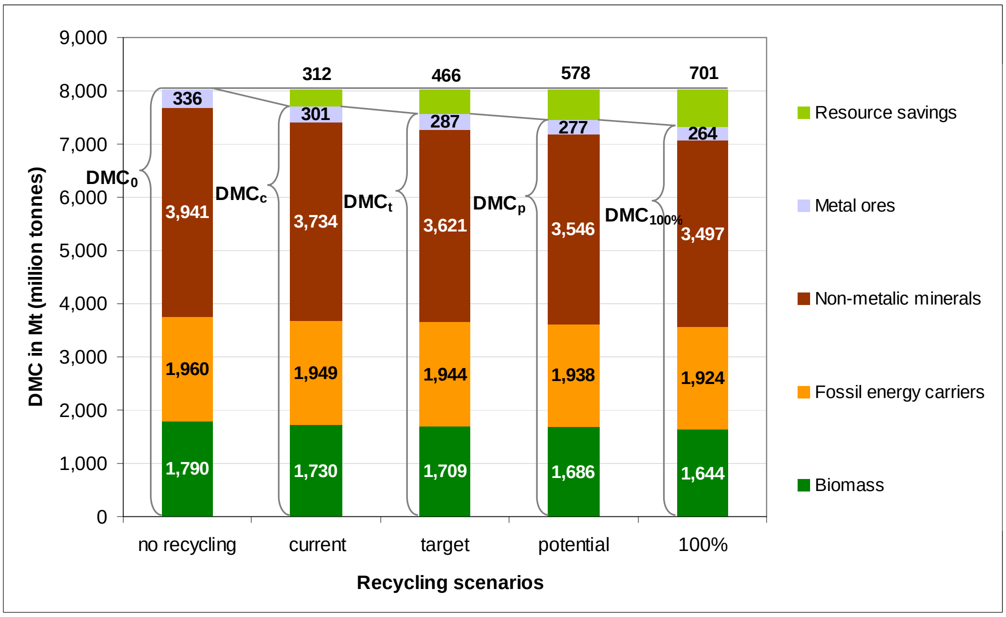

Figure 6-3: An overview of the Domestic Material Consumption (DMC) for major material categories in EU-27 for the scenarios: no recycling (DMC_o), current situation in 2004 (DMC_c), targets fully reached (DMC_t), potential recycling (DMC_p) and 100% recycling ($DMC_{100\%}$), all values in million metric tonnes (Mt)

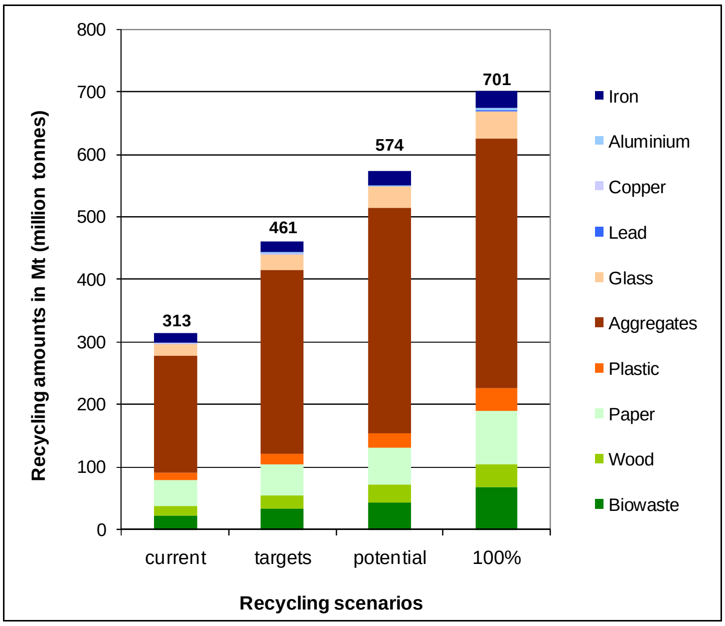

Figure 6-4: An overview of material savings for all material categories in the EU-27 based on waste statistics for current situation (2004), targets reached, potential and 100% recycling, all values in million metric tonnes (Mt)

Depending on the material category, recycling can result in various reductions in the DMC. The recycling of 1 kg of copper saves in general about 20 kg of copper ores.

Since copper is mostly imported to the EU-27, on average recycling currently saves about 8 kg of DMC (less material imported and less domestically extracted). The figures for iron are in general 2.2 kg savings in ores and 1.8 kg less imports and domestic extraction. For minerals, such as glass and aggregates, as well as for plastics, wood and biowaste an approximate 1:1 reduction is assumed (1 kg recycled material reduces imports and domestic extraction with 1 kg). Only in the case of paper 1 kg recycled paper replaces just about half a kilogram of wood. Since there are high uncertainties in these values, the uncertainly of this data will be discussed at the end of this section. Recycling amounts, material saving and efficiency increases for each material stream can be found in Annex F.

- **Global material savings compared to EU-27 material savings**

To give an idea of what the material savings at global level (here all materials have to be extracted) compared to EU 27 are the average ore grade was used to determine the raw material requirements (see Table 6-2).

Table 6-2: Global material savings compared to material savings within EU-27 (all values in metric tonnes)

	Recycling amount in Mt	Average ore grade in %	Global material savings in Mt	EU-27 material savings in Mt	EU-27 material savings in % of global material savings
Iron	13.9	46%	30.2	25.5	84%
Aluminium	1.7	24%	7.1	4.3	61%
Copper	0.3	6%	5.0	4	80%
Lead	0.2	5%	4.0	1.3	33%
Total	**16.1**		**46.3**	**35.1**	**76%**

The calculated global material savings based on waste statistics are about 46.3 Mt. The material savings within EU-27 countries amount up to more than 35.1 Mt. These figures estimate that recycling in EU-27 saves 46.3 Mt globally of which 76% occurs within the EU-27 countries.

Based on our calculation the hypothetical domestic material consumption (DMC_o) without any recycling activity would be 8,029 Mt for EU-27 in 2004. With recycling activities as they were in 2004 the DMC was reduced by material savings to DMC_c of 7,715 Mt. With GDP for the EU-27 in 2004 at 9,879 billion Euro, material productivity is then calculated to be 1,230 €/t if there was no recycling and 1,280 €/t with current recycling amounts. This means a calculated material productivity increase for the current situation of 4.1%.

Table 6-3: An overview of increases of material efficiency due to recycling based on waste statistics from current policies and potentials

	Current policies	Targets reached	Feasible potential	100% recycling rates
DMC_0 (Mt)	8 029	8 029	8 029	8 029
$DMC_{c,t,p,100\%}$ (Mt)	7 715	7 563	7 449	7 329
RE_0 (€/t)	1 230	1 230	1 230	1 230
$RE_{c,t,p,100\%}$ (€/t)	1 280	1 306	1 326	1 348
Material productivity increase due to recycling %	**4.1%**	**6.2%**	**7.8%**	**9.5%**

Potentially the efficiency can increase to 6.2% with full implementation of policies and recycling targets reached. It is estimated based on current best practice that material productivity could increase to 7.8%. Finally even if 100% recycling rate was possible for the materials considered, recycling would only amount to about 9.5% of a material productivity increase. Due to the assessment of the data uncertainties, it is assumed that the increased rates for material productivity are in a range of +/-30% of the values presented.

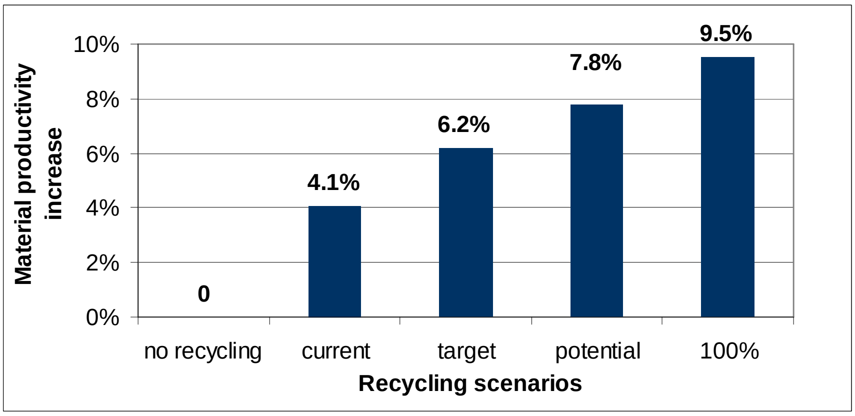

Figure 6-5: An overview of the efficiency increases in EU 27 for the scenarios no recycling, current situation (2004), targets fully reached, potential recycling and 100% recycling (all percentages)

The most significant material savings are from recycling of non-metallic minerals (glass and aggregates). This represents about 66% of the total material savings throughout all scenarios. In 2004 roughly 5% of the DMC of non-metallic mineral is recycled. Potentially this could be doubled. The core benefits of recycling of these materials are less disposal of waste and a reduction of extraction. Further potential for improvements can be achieved if recycled material could replace processed materials like concrete instead of raw materials.

Biomass recycling (biowaste, paper and wood) contributes about 20% to the total material savings. Roughly 3.5% up to 6% (potential) of biomass can be recycled. However, in the case of biowaste under a scientific point of view it is under dispute if this is recycling or downcycling (e.g. compost or biogas).

Material savings due to metal recycling add up to about 11% of the total material savings. In 2004 roughly 10% of DMC for metal was recycled. With increased recycling activities this could be increased up to 18% (potential). Metal recycling does not just save raw materials like ores, it can decrease import dependency and thereby increase supply security.

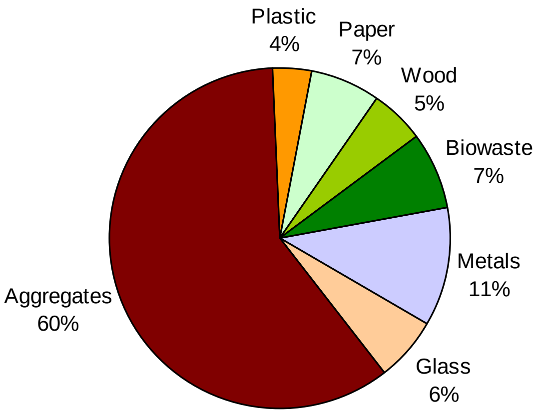

Figure 6-6: Material savings EU-27 of metals, non-metallic minerals (glass and aggregates), plastic and biomass (paper, wood, biowaste) for current situation in 2004 (100% equals 314 Mt)

It should be noted that the material saving results provided here involve high uncertainties due to unreliable waste data and due to many assumptions necessary for calculating material savings. With more accurate information the following materials could gain higher significance for their contribution to the total material savings (if only one material is altered to the highest plausible value):

- metals (from 11% to 22%, if energy savings are considered up to 26%)
- C&D waste (from 60% to 70%),
- paper (from 7% up to 13%).

The critical review of the data calls for an effort of improving data quality. Only this would allow for a more differentiated analysis in future. One way is to improve waste statistics. Another way is to develop a more reliable estimation procedure using triangulation, where different methods and information sources (e.g. MFA, trade statistics, industry estimates, etc.) are used to derive more reliable data.

6.1.2. Waste prevention

The only readily data available on the contribution of waste prevention to resource savings was related to the hazardous substances banned under the RoHS Directive. It is however not clear what the banned substances were replaced by (both in quantity of material and their environmental impact). Instead an estimate based on case study evidence on the following waste prevention strategies: efficient use of materials, reuse and more sustainable consumption behaviour, was provided.

Currently, lean manufacturing and reuse strategies in manufacturing, e.g. remanufacturing, leasing, preventive maintenance, etc. provide the greatest contribution to material productivity from waste prevention (almost all of the 6.3 Mt). With stronger waste prevention measures and a broader uptake of lean manufacturing and construction, reuse and more sustainable consumption, it was assessed that 156 Mt of materials could be prevented from becoming waste. Most of this would come from the construction sector with greater reuse of materials and more efficient building processes. The potential for waste prevention in this study is assessed to be about a tenth of the theoretical scenario of 'zero waste'.

In the *"Preparatory study on food waste across EU-27"*[111] a conservative estimate for the feasible reduction of food waste from waste prevention measures was given. It was estimated that 1.8% of all food waste could be avoided, corresponding to 1.6 Mt. The study only estimated that 8% of municipal solid waste is food waste. As several sources quote shares of food waste to be higher in the range of 20-30% of municipal waste, this study estimates that 4.5 Mt of food waste (corresponding to 5% of all food waste) could potentially be avoided. Based on this an attempt was made to calculate the biomass savings from food waste prevention (see Table 6-4).

[111] BIO Intelligence Service, AEA, Umweltsbundesamt (2010) Preparatory study on food waste across EU-27. Study commissioned by the European Commission, DG Environment.

Table 6-4: Biomass resource savings from food waste prevention assuming that 5% of food waste is avoided. All amounts in million tonnes.

<table>
<tr><th>Material</th><th colspan="2">Biomass consumed for food</th><th>Food consumed</th><th>Distribution of types of food consumed and waste</th><th>Waste generated</th><th>Waste prevented</th><th>Amount loss in food supply chain[112]</th><th>Reduced food demand (savings)</th><th>Food demand without waste prevention</th><th>Biomass demand without waste prevention</th><th>Reduction of biomass demand</th></tr>
<tr><td>Food from primary crops</td><td colspan="2">698.544</td><td>698.544</td><td>93.7%</td><td>83.352</td><td>4.179</td><td></td><td>6.097</td><td>704.640</td><td>704.640</td><td rowspan="13">0.82%</td></tr>
<tr><td>Cereals</td><td colspan="2">319.613</td><td>319.613</td><td>42.9%</td><td>38.137</td><td>1.912</td><td>33%</td><td>2.854</td><td>322.467</td><td>322.467</td></tr>
<tr><td>Roots and tubers</td><td colspan="2">73.016</td><td>73.016</td><td>9.8%</td><td>8.712</td><td>0.437</td><td>30%</td><td>0.624</td><td>73.640</td><td>73.640</td></tr>
<tr><td>Sugar crops</td><td colspan="2">137.716</td><td>137.716</td><td>18.5%</td><td>16.433</td><td>0.824</td><td>30%</td><td>1.177</td><td>138.893</td><td>138.893</td></tr>
<tr><td>Pulses</td><td colspan="2">6.031</td><td>6.031</td><td>0.8%</td><td>0.720</td><td>0.036</td><td>30%</td><td>0.052</td><td>6.082</td><td>6.082</td></tr>
<tr><td>Nuts</td><td colspan="2">1.077</td><td>1.077</td><td>0.1%</td><td>0.129</td><td>0.006</td><td>30%</td><td>0.009</td><td>1.086</td><td>1.086</td></tr>
<tr><td>Oil bearing crops[113]</td><td colspan="2">6.477</td><td>6.477</td><td>0.9%</td><td>0.773</td><td>0.039</td><td>35%</td><td>0.060</td><td>6.536</td><td>6.536</td></tr>
<tr><td>Vegetables</td><td colspan="2">70.191</td><td>70.191</td><td>9.4%</td><td>8.375</td><td>0.420</td><td>30%</td><td>0.600</td><td>70.791</td><td>70.791</td></tr>
<tr><td>Fruits</td><td colspan="2">84.422</td><td>84.422</td><td>11.3%</td><td>10.073</td><td>0.505</td><td>30%</td><td>0.722</td><td>85.144</td><td>85.144</td></tr>
<tr><td colspan="11">Food from meat</td></tr>
<tr><td>Fodder crops incl. grassland harvest</td><td>300.949</td><td rowspan="4">Corresponds to meat a)</td><td rowspan="4">37.096</td><td rowspan="4">5.0%</td><td rowspan="4">4.426</td><td rowspan="4">0.222</td><td rowspan="4">15%</td><td rowspan="4">0.261</td><td rowspan="4">37.357</td><td>303.067</td></tr>
<tr><td>Fodder crops</td><td>161.921</td><td>163.060</td></tr>
<tr><td>Biomass harvested from grassland</td><td>139.016</td><td>139.995</td></tr>
<tr><td>Grazed biomass</td><td>205.308</td><td>206.753</td><td>0.70%</td></tr>
<tr><td>Fish capture</td><td colspan="2">9.907</td><td>9.907</td><td>1.3%</td><td>1.182</td><td>0.059</td><td>80%</td><td>0.296</td><td>10.204</td><td>10.204</td><td>2.99%</td></tr>
<tr><td>Hunting and gathering</td><td colspan="2">0.330</td><td>0.330</td><td>0.0%</td><td>0.039</td><td>0.002</td><td>15%</td><td>0.002</td><td>0.332</td><td>0.332</td><td>0.70%</td></tr>
<tr><td>Total</td><td colspan="2">1,215.04</td><td>745.876</td><td>100%</td><td>89.000</td><td>4.462</td><td></td><td>6.656</td><td>752.533</td><td>1,224.997</td><td></td></tr>
</table>

a) Meat data from Eurostat (2008) Food: from farm to fork statistics

[112] Food lost in the supply chain from UNEP (2009) The environmental food crisis – The environment's role in averting future food crises. A UNEP rapid response assessment. United Nations Environment Programme, GRID-Arendal.

[113] According to the FAO, approx 12% of oil bearing crops are available for human consumption (www.fao.org/economic/ess/chartroom-and-factoids/chartroom/36-world-cropped-area-yield-and-production-of-oil-bearing-crops/en/)

The estimated amounts of avoided food waste were related to the consumption (DMC) of biomass that is used as food (primary crops) or feed (for meat production). It was assumed that the distribution of different food types in waste was the same as that consumed. Food loss in the food supply chain was accounted for using data from the preparatory study and UNEP[114]. Compared to the amount of food consumed (1,215 Mt of biomass consumed for food), the savings achieved are minor (around 10 Mt), but as this can be directly related to land use it should still be considered.

There are several points in the food related biomass flows where screws can be set in order to increase resource efficiency.

- In the food production improvements can reduce biomass waste by developing further options to use them as by-products. The replacement of other biomass would reduce biomass extraction.
- The concept of cascading offers further opportunities for down-cycling and therewith it would replace other biomass extracted.
- A specific application of cascading is composting bio-waste. In this case compost from bio-waste would substitute the extraction of top soil (humus) for gardening.

6.1.3. PRODUCT DESIGN

Although there is considerable case study evidence of material savings due to improvements in design, there are no studies that have assessed the total amount of material savings in the economy due to reducing material intensity (lightweighting). Design strategies such as *design for recycling*, and *design for longevity* do also contribute to material productivity, but in this study these have already been accounted for in recycling and reuse's contributions.

This study estimates that of the two main design-oriented product policies in the EU: the Ecodesign Directive and Ecolabel Directive, the Ecolabel Directive has resulted in most material savings so far. About 0.5 Mt of materials (mostly granite and peat) have been saved due to Ecolabel criteria. The Ecodesign Directive has not had any direct impact on material savings, but changes in lighting technology will indirectly also result in metal and glass savings in the future. Besides product policies, there is evidence that considerable material savings have been achieved through lightweighting of packaging and electronic and electrical equipment (due to technological development: miniaturisation and digitalisation). Taking this into account, this study estimates that 91.3 Mt of material is currently saved each year due to improvements in design. The savings come mostly from the typical packaging materials, e.g. cardboard, plastic, glass, wood and metal.

[114] UNEP (2009) The environmental food crisis – The environment's role in averting future food crises. A UNEP rapid response assessment. United Nations Environment Programme, GRID-Arendal.

If current Ecolabel criteria were to become mandatory for all products in the EU and ecodesign strategies were further applied to EEE and vehicles, it was estimated that an additional 20.5 Mt of materials could be saved each year through design. Minerals and metals would represent most of these materials that potential could be saved. The estimate of potential contribution of improvements of design may seem low, but this is because only lightweighting design strategies were accounted for. Design for recycling and design for longevity both support increased recycling and reuse, but the effects of these were accounted for separately.

The analysis of design strategies that could lead to greater material productivity showed that design is key to achieving greater amounts of recycling and waste prevention. At the same time some of the design strategies can be in direct conflict with each other, e.g. product lightweighting is often opposed to design for longevity as products which use more materials and are typically stronger and more durable. Table 6-5 shows an overview of how the various material productivity strategies considered in this study can either support or contradict each other.

Recycling is supported by lean production, sustainable behaviour and design that restricts hazardous substances and allows materials to be easier recycled. Although different design strategies may be applied to achieve greater material productivity, they manifest themselves differently and need to be carefully considered in relation to the entire life cycle of the individual product. For example, increasing the material efficiency of a product may result in a less durable product with a shorter functional life. Furthermore, lighter materials are not necessarily less material intensive than heavier materials (e.g. many small portable electronic devices have large "hidden material flows" that are necessary to produce them).

Table 6-5: Synergies and conflicts between key strategies for material productivity

	Recycling	Lean production	Reuse strategies	Sustainable behaviour	Restriction of haz. substances	Design for recyclability	Product lightweighting	Design for longevity
Recycling	Not applicable							
Lean production	Strong synergy	Not applicable						
Reuse strategies	Weak synergy	Weak synergy	Not applicable					
Sustainable behaviour	Strong synergy	Strong synergy	Strong synergy	Not applicable				
Restriction of haz. substances	Strong synergy	Strong synergy	No effect	Strong synergy	Not applicable			
Design for recyclability	Strong synergy	Weak synergy	Weak synergy	Strong synergy	Strong synergy	Not applicable		
Product lightweighting	Potential conflict	Weak synergy	Potential conflict	Strong synergy	No effect	Potential conflict	Not applicable	
Design for longevity	No effect	No effect	Strong synergy	Strong synergy	No effect	No effect	Potential conflict	Not applicable

Legend

- Not applicable (black)
- Strong synergy (green)
- Weak synergy (light green)
- No effect (white)
- Potential conflict (yellow)

6.1.4. DATA UNCERTAINTIES, RELEVANCE OF ASSUMPTIONS AND CALCULATION UNCERTAINTIES

As discussed at the beginning of this section waste statistics have a very high range of uncertainty. In many cases experts provided estimates that vary by a range of 2 to 18 times for minimum and maximum figures. Since these uncertainties are extremely high – even for the waste streams of high significance (e.g. C&D waste) – other methods were employed to check the plausibility of the data. For this purpose the material flow accounts (MFA) were used. The MFA is based on a very simple, but reliable approach with a reasonable statistical foundation. It accounts all the in and out flows with other economies (e.g. import and export statistics) and all inputs extracted from nature (e.g. various statistics like agricultural and forestry statistics, mining statistics, etc.). The use of the MFA as a framework was linked with production statistics (see section 2.2. on the methodology for calculating material savings). Since this approach is already used to model the material streams, it could also be used to check the plausibility of data.

The feasibility and plausibility check provides the following results:

- C&D waste recycling is by far the most important recycling activity relevant for material savings.
- Metal recycling is plays a major role since it substitutes very material intensive up-stream processes.
- The calculation of the potential based on production statistics assumes an increase of the recycling rate for copper from 41 to 95%. This has a significant effect due to the material intensity of the up-stream processes (the average ore grade is below 18%).

Comments to differences in data for specific materials:

- **Metals**: Iron, aluminium and copper recycling amounts seem to be too low. This could be due to data provided by industry associations include internal recycling of production scrap that never gets registered as waste management. The waste statistics rarely provide specific data on the different types of metals, which is the reason why data for nickel and zinc are missing. Lead is assumed to have a recycling rate (according to the data sources used) of 14%, but in opinion of the experts this rate could be around 49%, and the International Lead Association claims recycling rates between 60%-90%.
- **Non-metallic minerals:** The glass recycling amount seems to be too high. As the reporting mechanisms for C&D waste are not well in place and registration is not systematic, the data on this is very uncertain. The estimates for C&D amounts range between 309 Mt and 727 Mt, whilst recycling rates are suggested to be between 30 to 60%[115].

[115] BIO Intelligence Service, Arcadis & IEEP (2010) Study on management of construction and demolition waste in the EU. Study commissioned by the European Commission, DG Environment.

- **Plastics**: The recycling amount from the waste statistics seems to be overestimated by a factor two. This is probably due to the double counting of packaging waste recycling in municipal solid waste and packaging waste (packaging waste constitutes the greatest portion of plastic waste).
- **Biomass**: Paper recycling amounts from the two different data sources seem to correspond and would therefore seem plausible. The amounts of recycled wood according to the waste statistics seem to be too high compared with production statistics. This again could be attributed to double counting of municipal and packaging waste data (after C&D, the two greatest contributors). For biowaste the estimated amounts seem to correspond to the assessment of other studies[116].
- **Total amounts**: The total amount of recycling estimated in this study is much less compared to the amount that the Prognos study states[117]. The Prognos study estimates recycling to be up to a factor 2.7 greater than what was found in this study. The sum of recycling amounts from waste statistics and MFA/production statistics is in the same range with less than 2% difference (mainly due to the C&D waste dominating). However, since the composition is different according to the two sources, it matters. While metals in waste statistics seem to be underestimated, the categories glass, plastic and wood seem to be overestimated. Since metals cause higher material savings than other categories the material savings need to be checked as well. The difference in material savings between calculations based on waste statistics and MFA/production statistics is higher than the one in recycling amounts, however, it is still below 7%.

The conclusion of this sensitivity analysis is that considering a mix of possible changes the current scenario has an uncertainty range of 3.9% +/- 20% (assuming that only half of the assumptions might become effective at the same time). The uncertainties with the highest significance are the replacement factor (how much recycled material replaces extracted material); aggregates (other waste and miscellaneous); and, metal recycling. For a deeper discussion on uncertainties, see Annex F.

For waste prevention, the estimates for lean production, reuse strategies and sustainable consumption could be higher. To provide an upper estimate for potential resource savings some of the assumptions made were changed (e.g. 20% reduction of waste or material consumption through waste prevention measures). This increased the potential considerably. Regarding product design, even by changing some of the assumptions made (e.g. 20% material savings still possible through lightweighting, etc.) this did not change the results considerably.

[116] Arcadis & Eunomia (2009) Assessment of the options to improve the management of bio-waste in the European Union

[117] Prognos (2008) Resource savings and CO2 reduction potential in waste management in Europe and the possible contribution to the CO2 reduction target in 2020.

6.1.5. SUMMARY OF CONTRIBUTIONS TO MATERIAL PRODUCTIVITY

Of the three main approaches to material productivity, recycling contributes by far with the largest contribution. This study estimated that recycling currently contributes with 313 - 886 Mt of reduced need for materials (mostly construction minerals). Recycling also has the greatest potential for greater material productivity (see Figure 6-7). If recycling targets were achieved and current best practices fully implemented, 467 – 1,015 Mt of materials could be saved annually. The effects of waste prevention to contribute to material productivity have not been very apparent yet (this study estimates 8.2 Mt of waste avoided), but there is evidence that this could be increased considerably to 147 Mt of waste avoided (and thereby 147 Mt less materials needed in the EU). It is in particular greater reuse strategies and more sustainable consumption behaviour that could reduce waste.

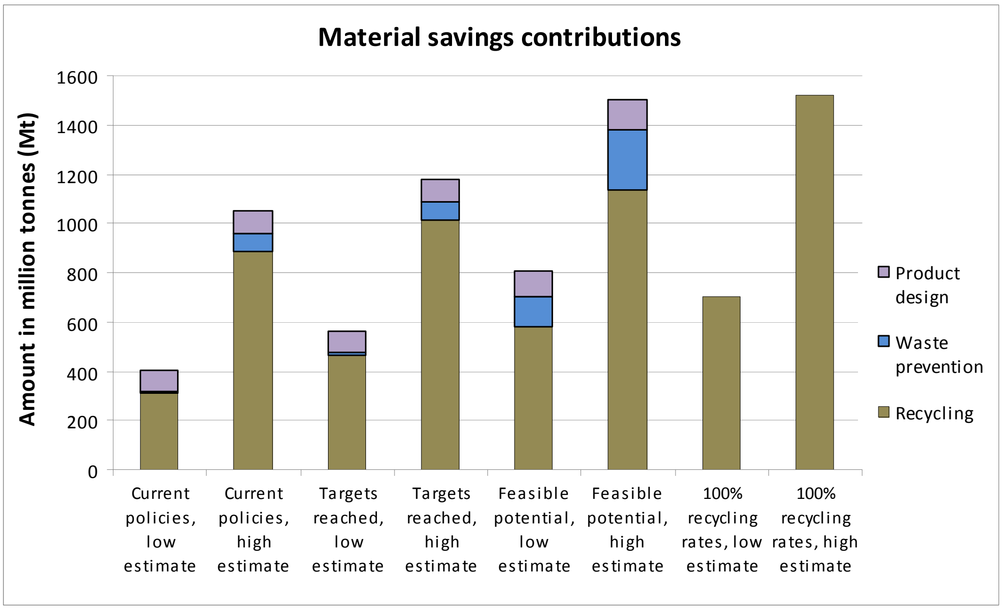

Figure 6-7: An overview of material savings due to recycling, waste prevention and product design from current practices and policies as well as future potentials.

Improvements in design have already demonstrated significant increases in material productivity through lightweighting. In this study about 90 Mt less materials are currently needed each year to produce the same amount of products with the same or better functionality. Although current EU product policies do not contribute much to material savings, they have a potential to do so with more ecodesign requirements addressing material use. With the use of current best technologies and manufacturing methods, it was estimated that a further 20-32 Mt of less materials would be necessary to produce products with the same functionality. This would mainly be a reduced need for metals and minerals to produce the same amount of products with equivalent functionality. The analysis of contributions to material productivity did however identify product design as key to achieving greater amounts of recycling and waste prevention through design for recycling and design for longevity.

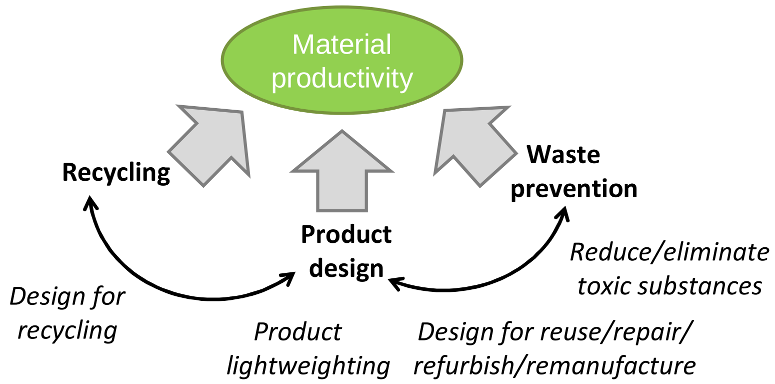

Figure 6-8: Recycling and waste prevention is supported by product design to achieve greater material productivity

Construction materials constitute the largest material flow in the economy. The demolition waste flows are comparatively small to material inputs, as most of the materials go into stock (buildings and infrastructure) for the benefit of future generations. This still results in construction materials representing the most significant share of recycled materials and increasing the recycling of construction materials would be effective to reduce C&D waste.

Recycled metal replaces between 1.5 to 10 times the amount of virgin resources, but the absolute amounts of recycled metals compared to all recycled materials is not significant. However, as many of the recycled metals have a high value – particularly rare metals, that are essential to increasing material productivity. Waste prevention in the form of more sustainable consumption patterns is most suitable for addressing increasing the 'productivity' of food (food packaging however can benefit from recycling and design).

There are large variations across the different types of materials regarding their contribution to material productivity (see Figure 6-9). In relation to the amounts of raw materials consumed, 10% to more than 50% (depending on metal) of the demand for metals is reduced through recycling, waste prevention and product design. There is potential to increase this further. Material savings from recycling, waste prevention and product design of aggregates, plastics and food are much smaller compared to current material consumption, but their percentage potential is significant (almost double).

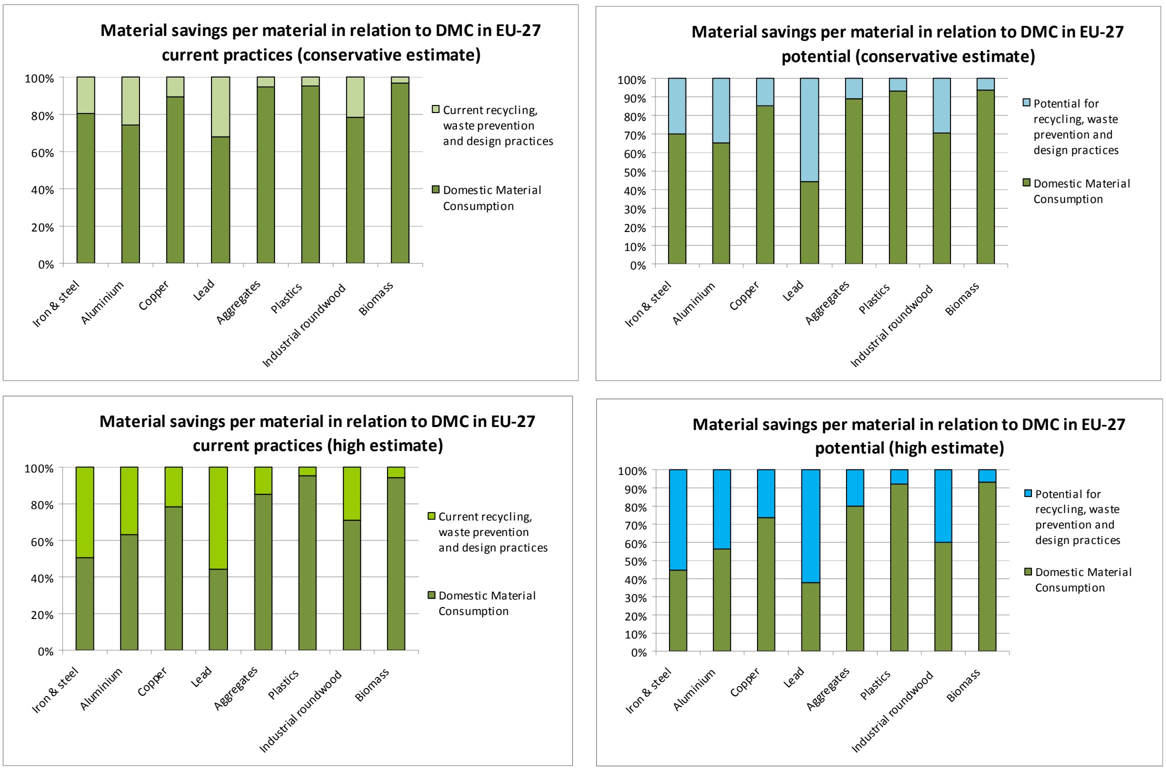

Figure 6-9: Material savings for selected material streams in relation to Domestic Material Consumption for current practices and future potential with best practices implemented.

6.2. ENVIRONMENTAL IMPACT REDUCTIONS

According to the current framework of sustainable resource management, the environmental impacts of the total life cycle of materials should be taken into account. This sub-task presents the results of calculating the reduction of environmental impacts of resource savings from existing and possible future policy scenarios. Based on the method for calculating environmental impacts defined in section 2.3. , the reduction of environmental impacts from resource savings from existing and possible future policies and measures are determined by using the EMC, Ecological Footprint, and looking at the effects on land use.

6.2.1. ENVIRONMENTALLY-WEIGHTED MATERIAL CONSUMPTION

This section assesses the environmental impacts of less use of materials, specifically the avoided environmental impacts of the materials savings that were calculated in section 6.1. In order to do that, the calculation of environmental impacts of material use as proposed by van der Voet et al., 2009 by means of the environmentally weighed material consumption (EMC) is used. The last version 1.7 (updated May 2010) was kindly provided by the Institute of Environmental Sciences at the Leiden University. The EMC is calculated only for those material streams where material savings were achieved under the current policy scenarios analysed in previous sections: recycling, waste prevention and product design.

The factors relating environmental impact categories to materials provided by the EMC can be used to calculate the effect of more than 55 different types of materials. For this study only the effect of non-energy carriers and a selected list of materials were assessed. An assessment of the environmental impacts of the entire EU economy would require the DMC of all material streams to be assessed. Instead only the major materials, where data of contributions were found were assessed (e.g. plastics, aluminium, copper, iron and steel, lead, nickel, zinc, glass, concrete, wood, biowaste, paper and board)[118].

The factors provided by the EMC were applied to all the four recycling scenarios used in this study (current, targets fully achieved, potential and 100% recycling rate) and the comparison is done by environmental impact category. When assessing environmental impacts using the EMC methodology, there are three different types of factors to carry out the calculation:

1. *Characterised impacts per kg of material*: these factors provide a direct translation of materials used (in kg) to each of the environmental impact categories provided in the EMC. The assessment per material stream is then given in the units of the environmental indicator (GWP in kg of CO_2 eq., stratospheric ozone depletion in kg CFC 11 eq., freshwater ecotoxicity in kg 1.4 DCB eq., etc.). As an example, the use of 1 kg of iron and steel produces 747 kg 1,4-DCB eq. in marine aquatic ecotoxicity.
2. *Normalised and characterised results per kg of material*: a normalising factor is used in order to present the results of material use as a fraction of the world problem and thus the environmental indicators are unitless.
3. Weighted, normalised and characterised results per kg: a weighting factor is used in order to compare or weight the effect of the different environmental indicators to be able to aggregate them in a unique value.

For this study, the assessment was done by using the 'characterised' factors so that the effect of material savings in each individual environmental impact category could be studied. The results presented in Figure 6-10 correspond to the reductions achieved in the major environmental impact categories. The avoided impact potentials are only shown for the material streams under study. The rest of the impact categories, in which some uncertainties or reliability of the relevance can be questioned, are shown in Annex F. The main observations are:

- Metals are the material stream with the highest current contribution to impact savings in 4 of 12 impact categories: human toxicity, marine aquatic ecotoxicity,

[118] About 80-90% of the estimated material savings could be assigned to a material category available in EMC. Recycled materials or prevented waste that was classified as "other" or "unknown" were not included in the EMC calculations.

terrestrial aquatic ecotoxicity and photochemical oxidation, with non-ferrous metals the most important in 4 of them.

- Plastics are the material stream with the highest contribution to impact savings in 3 of 12 impact categories: abiotic resources depletion (plastic is mainly made from fossil fuel, a limited resource), freshwater aquatic ecotoxicity and climate change.
- Biomass is the material stream with the highest contribution in 4 of 12 impact categories: land use competition, ozone depletion potential, eutrophication potential and Ionising radiation, with paper the most important in 3 of them.
- Glass is the material stream with the highest contribution to acidification potential impact reductions.
- Other minerals contribute in a significant manner to impact savings in acidification potential and ozone depletion potential, and construction minerals are significant in climate change, ozone depletion potential and ionising radiation.
- In some cases (eutrophication potential, land use contribution) the "maximum potential" scenario reaches higher environmental impacts savings than the "100% recycling rates" scenario. This is because some specific material streams (ferrous metals, copper and food waste) present slightly higher material savings in the "maximum potential scenario" due to the contribution of waste prevention and product design measures, than in the "100% recycling rates" scenario, where no contribution from waste prevention and product design is accounted.

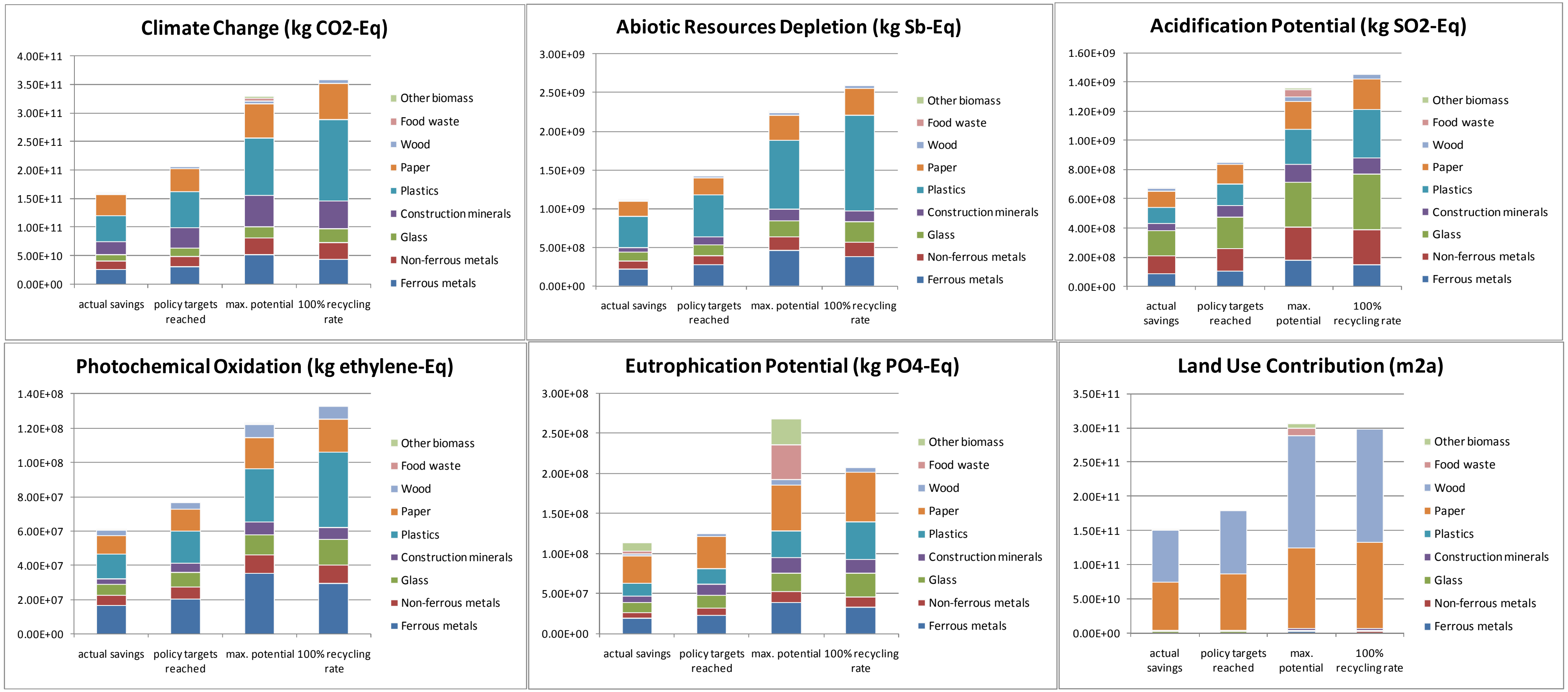

Figure 6-10: The estimated avoided environmental impact potentials of current and future contributions to material productivity

Regarding climate change, 135 Mt of CO_2 equivalent is saved annually in the current situation due to the contributions to material productivity from recycling, waste prevention and product design. In 2004 the total GHG emissions of the EU-27 was 5,148 Mt CO_2 equivalent (GHG emissions under the Kyoto Protocol)[119]. The avoided impacts of global warming potential due to current contributions to material productivity are significant as it represents almost 3% of the total GHG emissions. Plastics, biomass and metals are the material streams with the highest contribution to reductions in this impact category. If all the policy targets identified are reached, 176 Mt of CO_2 equivalent (3.4% of total annual GHG emissions) would be saved annually. In the cases of the maximum recycling potential and 100% recycling rates achieved, the amount of CO_2 equivalent emissions saved would be of 278 Mt (5.4% of total annual GHG emissions) and 315 Mt (6.1% of total annual GHG emissions), respectively. Plastics are the material stream with the highest reduction potential in this impact category in both these scenarios.

The greenhouse gas emissions reduction due to material savings is slightly higher in the case of plastics than for metals, even though the material saving amount is higher in the latter. This can be explained by the lower greenhouse gas emissions per kilogram of material associated to the most common metals (iron and steel) compared to the average factor for plastics (2.9 times higher). The emissions factor for aluminium is 1.8 times higher than for plastics, but the saving amounts are lower in this case. These emissions factors are calculated from a life cycle perspective, and take into account all the CO_2 equivalent emissions during all the life cycle of the material.

The results should be regarded bearing in mind that the material flows analysed are only those for which significant savings or saving potential were found. The metals taken into consideration were steel, iron, aluminium, copper, zinc, lead and nickel. Precious and rare metals such as gold, indium or platinum are not investigated. The use of these metals would have a higher environmental impact on abiotic resources depletion, but the amounts consumed and the saving potential were not found significant. Plastics, in spite of not representing the largest material savings by weight, have a higher impact on abiotic resources depletion because of the use of fossil fuels in the production. The abiotic resources depletion potential of paper is slightly lower than for metals, but the recycled amounts are slightly higher and the environmental impacts are similar. The construction minerals have a little environmental impact in this category although having the highest recycling amounts, due to their lower impact indicator.

The material stream that achieves higher savings in acidification potential is glass, even though the material saving amounts are not the highest of the materials under study. Construction minerals have little impact in this category in spite of having the

[119] Eurostat (ten00072)

greatest material saving amounts in all the scenarios. Plastics, paper and non-ferrous metals also have important environmental impact savings in this category.

The highest photochemical oxidation savings are achieved by ferrous metals, whereas the highest environmental impact saving potential in the "100% recycling rate" scenario for this category is achieved by plastics, even though the material amounts saved are higher for ferrous metals. Construction minerals, despite their higher material saving amounts, have a little importance in the environmental impact savings in this category.

The greatest eutrophication potential savings are reached by paper in all the scenarios analysed, although the material saving amounts are not the highest. This is due to the high organic material emissions and residues of the paper making industry, which have a high chemical oxygen demand. The case of food waste and other biomass waste in the "maximum potential" scenario is similar to paper, but these material flows were not accounted in the "policy targets reached" and "100% recycling rate" scenarios. Ferrous metals and plastics also have a relative importance for impact reduction in the theoretical scenarios "maximum potential" and "100% recycling rates".

Figure 6-11 shows the environmental impact reductions due to recycling, waste prevention and product design, calculated using the EMC methodology and the average weighting method EPA/BEES/NOGEPA explained in Annex F.

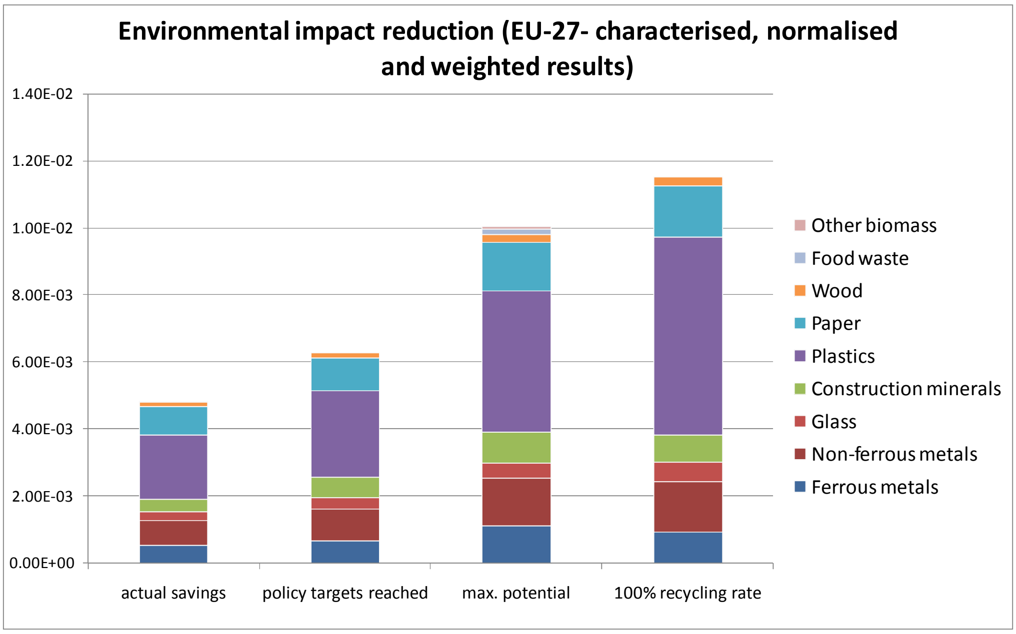

Figure 6-11: Environmental impact reductions (weighted results)

According to the weighted results of the EMC analysis, 'plastics' is the material category with the highest contribution to reduced environmental impacts as a result of greater material productivity. Paper and metals (ferrous and non-ferrous) also contribute significantly to reducing environmental impacts. The improvement potential is considerable compared with the current situation, with impact reductions for feasible potential around double as high as for the current savings. If all the current policy targets were reached, the environmental impacts saved would increase in around 30%.

6.2.2. LAND USE

The reduction of land use in the EU due to material savings was only calculated for biomass materials. The direct land use for mining, production and landfill sites is very small in the EU and changes to this are considered insignificant.

Regarding land use, if best practices in recycling, waste prevention and ecodesign were implemented, reductions for forestry, potential material savings of wood and paper would reduce the demand for industrial roundwood with a further 21% compared to current consumption. Based on the same assumptions as before this corresponds to a reduction of 28 million hectares of forests for wood and paper supply (see Table 6-6).

For agriculture land use, the reduction of biomass demand from food waste savings was translated into land use savings assuming the same average yields of land in the EU-27. The 5% reduction of food waste corresponded therefore to 0.82% of the total consumption of crops and 0.70% of biomass for grazing. As the production of crops and biomass for grazing on average is proportional to the land needed to grow them, this amounts to a reduction of about 1,141,000 ha of cropland and 411,000 ha of grazing land. This corresponds to about 1% of EU-27's utilised agricultural area[120].

Table 6-6: Potential land use reductions due to material productivity[121]

	EU-27 areas in 2004	Potential % reduction of biomass demand				Potential for freeing bio-productive area
Type of land use	**(1000 ha)**	**due to recycling**	**due to waste prevention**	**due to design practices**	**Total**	**(1000 ha)**
Cropland	138 806		0.82%		0.8%	1 141
Grazing land	58 463		0.70%		0.7%	411
Forest [a)]	132 124	14%	7%	1%	21.1%	27 922
Water, coastal flats and salines	13 160		2.99%		3.0%	394
Built area	18 277					
Other natural areas	73 656					
Total	**434 486**					**29 868**

[a)] Based on the material savings for wood and paper. It was assumed that 1.16 kg of industrial roundwood is needed to produce 1 kg of paper.

[120] Eurostat (2010) Agricultural statistics. Main results — 2008–09.

[121] Based on CORINE land use data

The Environmentally weighted Materials Consumption (EMC) methodology used in the previous section suggests that the land use savings from the current situation is about 15 million hectares (see Figure 6-10), whilst the potential with best practices fully implemented is around 30 million hectares (using the characterisation factors from Guinée et al., 2002[122]). The results from the two calculation methods are almost the same.

6.2.3. Ecological Footprint

The reduction of Ecological Footprint is estimated using the same data for the reductions in land use data and the reduction of greenhouse gases calculated using EMC.

Table 6-7: Estimation of Ecological Footprint for EU-27 with and without the contribution of recycling, waste prevention and eco-design as well as the future potential

	Ecological Footprint with current recycling, waste prevention and eco-design practices		Ecological Footprint without recycling, waste prevention and eco-design			Ecological Footprint with future potential for recycling, waste prevention and eco-design			Biocapacity	
Land type	Global ha per person	Global ha (million)	% increase of demand	Global ha per person	Global ha (million)	% reduction of demand	Global ha per person	Global ha (million)	Global ha per person	Global ha (million)
Cropland	1.17	570.1	0.1%	1.2	570.4	0.8%	1.16	565.4	1	487.3
Grazing land	0.19	92.5	0.1%	0.19	92.5	0.7%	0.19	91.8	0.21	102.3
Forest	0.48	233.9	47.4%	0.71	344.7	21.1%	0.38	184.5	0.64	311.9
Fishing ground	0.1	48.7	0.2%	0.10	48.8	3.0%	0.10	47.2	0.29	141.3
Built-up land	0.17	82.8		0.17	82.8		0.17	82.8	0.17	82.8
Carbon	2.58	1257.2	2.5%	2.65	1 289.1	5.4%	2.44	1 189.3		
Total	**4.7**	**2 285.4**	**6.0%**	**5.0**	**2 428.3**	**5.6%**	**4.3**	**2 161.1**	**2.3**	**1 125.7**

According to the calculations, without current practices in recycling, waste prevention and design in the EU the Ecological Footprint would be 6% higher. It is particularly the reductions of paper and wood from recycling and design improvements that contribute to less need for commercial forest land. If best practices in material productivity were to be fully implemented this could reduce the EU's Ecological Footprint by 5.6%. The reductions would come mostly from additional recycling and waste prevention of wood and paper.

[122] Guinée, J.B., M. Gorrée, R. Heijungs, G. Huppes et al. (2002) Handbook on Life Cycle Assessment. Operational Guide to the ISO Standards. Dordrecht: Kluwer Academic Publishers.

6.2.4. DISCUSSION OF RESULTS OF ENVIRONMENTAL IMPACTS

There have been other studies that have attempted to assess the environmental benefits of resource efficiency. The results of these are discussed here compared to the findings of this study.

A WRAP study[123] concluded that resource efficiency could reduce greenhouse gas emissions in the UK by 4-8% by 2050 without any significant negative effect on UK GDP. The cumulative reduction of greenhouse gas emissions from 2010 to 2050 in the UK due to waste reduction are estimated in the study at around 250 Mt of CO_2 equivalent, and of 60 Mt of CO_2 equivalent due to waste recycling. Lean production and material substitution would contribute to an overall emissions reduction of around 390 Mt of CO_2 equivalent in the same period of time in the UK.

These results clearly show a higher importance of product design practices (lean production, material substitution) than waste reduction or waste recycling practices. However, it has to be noted that these amounts are cumulative reductions of greenhouse gas emissions due to resource efficiency strategies applied to all the goods and service sectors in the UK, using theoretical scenarios based on quick wins and best practices. This approach is slightly different than the used in the present study: improvement practices are assumed to be applied gradually in all the economic sectors and the reduction of environmental impacts are calculated based on actual emissions, while in the present study resource savings are calculated based on existing statistics only for a selection of the most important material flows excluding energy carriers, assuming zero improvement when data is not available, and the environmental impact assessment is calculated using the material amounts saved.

An Ökopol study estimated that an increase in recycling rate of MSW to 53% (currently 33%) in the EU-27 would save 89 Mt CO2 equivalent annually, and if this was further increased to 65%, then the EU would save 145 Mt CO2 equivalent annually[124].

Hasimoto *et al.*[125] studied the factors that changed the resource-use intensity (defined as the inverse of resource productivity) in Japan from 1995 to 2002. According to the conclusions of this work, the effects of recycling are not great, but the increased recycling of non-metallic minerals contributed to the decline in

[123] WRAP (2009) Meeting the UK climate change challenge: The contribution of resource efficiency. WRAP Project EVA128. Report prepared by Stockholm Environment Institute and University of Durham Business School.

[124] Ökopol (2008) Climate protection potentials of EU recycling target. This report states that most of the valuation factors used in literature as well as the market value of carbon trading fall within this range. However, some methodologies documented in the literature use higher values, for example the EPS method uses 108.

[125] Hasimoto et al. (2008) What factors have changed Japanese resource productivity? A decomposition analysis for 1995-2002. Journal of Industrial Ecology, Volume 12, Numbers 5/6, 657-668.

resource use intensity. This resulted from progress in the recycling of cement concrete and asphalt concrete rubble. Metallic minerals experienced an increased influence on resource use intensity because of a decrease in recycling. Changes in the structure demand, such as decrease in construction and increase in machinery and services, produced the largest contribution to a reduction in resource use intensity. In this study no theoretical scenario was built up or environmental impact assessment was carried out, and all the results were calculated from existing statistics.

A study carried out by Prognos AG in co-operation with Ifeu and INFU[126] on the contribution of waste management to resource savings and CO_2 emissions reduction showed emission reduction in year 2004 by means of recycling, recovery or energy recovery of approx. 206 Mt CO_2 equivalent. The study also analysed several theoretical scenarios and improvement options and concluded that waste management in Europe can achieve an additional reduction in CO_2 emissions of between 146 Mt and 244 Mt, which corresponds to between 19%-31% of the EU climate reduction targets until 2020.

Allwood *et al.* (2010)[127] carried out a study analysing the worldwide carbon emissions from industry and the options to reduce them in order to meet the emissions reduction targets for 2050. According to the conclusions of the study, all existing and emerging efficiency measures in the actual scenario cannot provide sufficient reduction to meet the 50% emissions reduction for 2050. The global carbon savings estimated by Allwood *et al.* for existing known technologies (best practices) for improving energy and carbon efficiency for five key materials (steel, cement, plastic, paper and aluminium) are of 1,840 Mt of CO_2 equivalent. A theoretical scenario in which best practices are further improved (so called beyond best practices) would reduce the worldwide emissions in 1,880 Mt of CO_2 equivalent.

This study and other related studies demonstrate that increased material productivity does go hand in hand with energy (and GHG emission) reductions, it should however be noted that in some cases the opposite is more true[128]:

- lighter materials are not necessarily more environmentally friendly than heavier materials;
- smaller products are not necessarily less material efficient, e.g. many small portable electronic devices have large “hidden material flows” that are necessary to produce them. Furthermore, in some cases, smaller products are consumed in greater quantities, cancelling out material savings;

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[126] Prognos (2008) Resource savings and CO_2 reduction potential in waste management in Europe and the possible contribution to the CO_2 reduction target in 2020.

[127] Allwood, J.M., Cullen, J.M., Milford, R.L. (2010) Options for achieving a 50% cut in industrial carbon emissions by 2050.Environmental Science and Technology 2010, 44 (6), pp. 1888-1894

[128] CML (2003) Dematerialisation: Not just a matter of weight – Development and application of a methodology to rank materials based on their environmental impacts.

- using less material may cause side-effects due to reduction of life span, need for more transportation (if alternative or less expensive technology to produce these products is only available further away), tendency to throw away instead of repair, reduced recyclability, less material used in buildings decreases energy performance, more damaged/spoilt goods/food due to less packaging used, etc.;
- lengthening of the life span may lead to energy inefficient products that are kept in use for too long instead of replacing them with newer more energy efficient models.;
- lengthening of life span may cause stock building in society, which may lead to a “time bomb” of delayed waste generation;
- digitalisation, instead of reducing material requirements, leads to new possibilities that may increase material flows and energy use (e.g. the quite considerable energy use of electronic networks);
- recovery and recycling may have unwanted side effects due to extra transportation and energy use;
- "rebound effects" where increased efficiency leads to cost savings that incite consumers to shift behaviour or use money on other more environmentally harmful activities.

This study estimates that current recycling, waste prevention and product design practices correspond to 134 Mt of greenhouse gas CO_2 equivalent annually (calculated based on data for 2004). If material productivity were to increase further to a level where current best practices were implemented in all Member States, the annual potential for greenhouse gas reduction would be 278 Mt CO_2 equivalent or about 25% of the EU’s 2020 reduction target[129].

6.3. ECONOMIC AND SOCIAL IMPACTS

Fostering material savings through waste prevention, eco-design, and recycling is undoubtedly fundamental to reducing environmental impacts, but to be fully implemented and successful in the long run it must also be economically and socially beneficial. Increasing material productivity is partly a ‘natural phenomenon’ inherent in the continuous process of economic and technological development, but also due to less construction of infrastructure in developed countries and the displacement of resource intensive industries to less developed economies. [130]

[129] GHG emissions in EU-27 under the Kyoto Protocol was 5,567 Mt CO_2 equivalent in the base year of 1990. The target of 20% reduction by 2020 corresponds to a reduction of 1,113 Mt CO_2 equivalent. The annual potential reduction of 278 Mt CO_2 equivalent is therefore represents 25% of the 2020 target.

[130] Bringezu, S. & Bleischwitz, R. (editors) (2009) Sustainable Resource Management. Global trends, visions and policies. Greenleaf Publishing.

Improvements in material savings and productivity often leads to environmental improvements, but the question remains whether these are desirable from a welfare and development perspective.[131] In the following the benefits and costs due to material savings are assessed in terms of employment and competitiveness based on current state of the art findings of the relations between material savings and its socio-economic impacts.

6.3.1. Employment impacts of material productivity

This section clarifies to what extend changes in material productivity (through recycling, waste prevention and product design) impact on future employment opportunities, and whether such initiatives create more jobs than they eliminate (net jobs creation). The assessment of job losses, transformation, and substitution is difficult to determine because no data is readily available.

However, in a communication[132] the European Commission pointed out that the environmental labour-intensive sectors, which the recycling industry is among, will experience an increase in jobs[133]. This was confirmed by a ECORYS study which found that in 2008 the direct employment in all EU-27 eco-industries reached approximately 3.4 million, whereas it was at 2.8 million in 2004[139]. Moreover, while the average growth in nominal terms was about 2% p.a. in previous reports, this study estimates a rate of 7% to 8% p.a.

It was possible to calculate the correlation between recycling rates, and the level of employment in the recycling sector (see Table 6-8).

Table 6-8: Compilation of recycling rate and employment rate in selected countries

	Approximate recycling rate of municipal waste in 2001 and 2005 (in % of generated amount)[134]		Employment rate in the recycled materials and waste management sectors in 2008 (in % of eco-industries employment)	
	2001	**2005**	**Recycled materials**	**Waste management**
Italy	≈ 20%	≈ 25%	≈ 10%	≈ 59%
France	≈ 25%	≈ 25%	≈ 14%	≈ 38%
UK	≈ 10%	≈ 25%	≈ 33%	≈ 28%
Germany	≈ 55%	≈ 65%	≈ 30%	≈ 17%
EU-15	-	-	≈ 10%	≈ 55%
EU-27	**-**	**-**	**≈ 12%**	**≈ 35%**

131 CE Delft (2009) Resource productivity, competitiveness and environmental policies, Delft.
132 European Commission (2005) Commission staff working document on the links between employment policies and environment policies, 17, SEC(2005) 1530. ec.europa.eu/environment/integration/pdf/sec_2005_1530_en.pdf
133 See ec.europa.eu/environment/integration/employment_en.htm
134 Compilation on the basis of: ETC/RWM (2008) based on national reports and statistics.

It can be seen from the table that in countries such as Germany where the rate of waste recycled is high (in comparison to other MS), the rate of employment in this sector is also high. However, in the UK the rate of employment in the recycling and recycled materials field is high, although its rate of waste recycled is equal to those of France and Italy (around 25%). Countries with lower recycling rates seem to have less employment rates in the recycled materials sector and rates in the waste management sector.

It is likely that with the increased investment in sectors related to material savings efforts, that new employment opportunities may become available in the future. If there is a creation of direct and indirect jobs due to material savings in various sectors, the number of jobs created needs to be compared to possible job losses in order to provide an assessment of the overall balance, which results in net jobs creation. Some important effects on employment in the materials production phase are presented hereafter[135]:

- Recycling has impacts on all phases of process stewardship (from exploration to smelting and refining), which means that it conduces to jobs losses in those sectors.
- Remanufacture goes a step further than recycling in terms of jobs short-circuit, for the fabrication level is overtaken.
- Re-use, at last, is definitely the greatest “jobs-killer” because it does not only short-circuit all the process activities, but also remanufacturing and recycling. In fact re-use implies only the “use” phase. Nevertheless the recycling phase cannot totally be short-circuited as once a product is no more re-usable, it still can be recycled.
- Improvements in product design is not expected to have any influence on employment as it is expected that designers are able to integrate environmental concerns in the design of products with little extra training.

It is important to remember that these aspects can also have transboundary effects. A distinction must be made between activities developed inside or outside the EU. Eliminating jobs outside the EU while creating jobs inside will have positive effects for the EU employment rates, even if more jobs are destroyed than created. This is particularly true as far as extraction activities are concerned. If they mainly concern employment outside the EU then they are less detrimental for the EU employment than the jobs losses in the waste management sector. For example, it is claimed that material recycling of WEEE creates 5 to 7 times more jobs than disposal by incineration and 10 times more jobs than disposal in landfills[136].

[135] Source: Dr John Atherton – Senior Programme Director, *Resource efficiency in the minerals and metals sector*, UNEP/OECD Workshop – Paris 23-25 April 2008, www.oecd.org/dataoecd/13/6/40798769.pdf

[136] Commission of the European Communities (2008) Commission staff working paper accompanying the Proposal for a Directive of the European Parliament and of the Council on waste electrical and electronic equipment (WEEE), COM(2008) 810 final, www.eur-

6.3.2. COMPETITIVENESS DUE TO MATERIAL PRODUCTIVITY

This section aims to assess if waste prevention, eco-design and recycling have helped the EU in its effort to become a more competitive economy. It is thus important to first specify the way competitiveness will be understood and how competitiveness could result from restrictive environmental measures.

Competitiveness is a complex notion. According to a Delft study, it can be applied to firms and to nations, referring respectively to the ability of a firm to maintain its operations in a given market and the ability of a nation to ensure future productivity growth and wealth creation[137]. Being competitive would mean *"having a high rate of productivity growth".* While it was usual to consider that environmental regulation imposes costs on companies and thereby affecting their competitiveness and having negative socio-economic effects such as lower employment and welfare. However, more stringent environmental policies can lead, if correctly implemented, to the opposite outcome: higher productivity, or a new comparative advantage, which can lead to improved competitiveness or in other words a win-win situation. The complexity of this subject mean it is not always possible to quantify the effects of changes on the competitiveness of businesses.

Waste prevention emphasises the reduced use of materials (not more that what is necessary) and leads principally, when applied by companies, to the use of less material to produce goods with the same functionality. This is certainly true in the case of lean production and construction, where cost savings follow the material and waste savings. Another aspect of waste prevention is the process of re-use, which also leads to reduced use of materials. Thus, waste prevention can lead to more competitiveness thanks to savings by the reduced amount of materials used.

The assessment of recycling participation to competitiveness is more subtle. First, a distinction must be made between recycling and recycled materials use: the former refers to a firm recycling its materials, products, substances rather than disposing of them. The latter means that a firm uses recycled materials. The distinction is in the production chain level: recycling is concerned with output of a company whereas recycled materials deals with input to a company.

- **Recyling**

At first sight, and without any regulation, recycling is a net cost for companies. It is easier and less expensive to dispose waste than recycle it. In this sense, recycling is a barrier to competitiveness, since it entails additional costs.

Nevertheless, this is highly dependent on legal regulations. If there is a tax or a fine on firms which do not recycle, it can become more attractive, from a financial point of view, to recycle than to pay taxes. The same applies for subsidies where recycling

lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2933:FIN:EN:PDF

[137] CE Delft (2009) Resource productivity, competitiveness and environmental policies, Delft.

can become a source of revenue for the firm. These facts highlight the importance of incentives (either positive or negative).

- **Recycled materials use**

The financial interest of using recycled materials rather than raw materials depends on the raw materials prices. If it is less expensive for a company to use raw materials, using recycled materials decreases competitiveness. On the contrary, as it happened during the 2003 material crisis, when the use of raw materials is more expensive than the use of recycled materials, then the use of recycled materials enhances competitiveness.

In conclusion, recycling and using recycled materials can both influence competitiveness negatively unless there are legal measures (positive or negative) to support more resource efficient behaviours. This emphasises the importance of legal measures, but it also raises the imbalance between states created by differences in legislations that lead to environmental or social dumping.

In this line, the prices of the raw materials play an important role in the decision of recycling, not only for the companies involved but for the competitiveness and productivity of the economy. Hagelüken and Meskers (2008)[138] analysed the current practices, improvement options and impacts of precious metals recycling in WEEE. According to the conclusions of this study, metals recycling in WEEE has positive impacts in the metals market, resource consumption and emissions.

This practice is already common in the industry, but the WEEE stream has an important content of precious metals that is not always recovered. With a systematic recycling of the most expensive materials, the material productivity would increase considerably. The issue then is to assess the relevant weight of these materials within the economy. The metal content of the total amount of mobile phones and personal computers sold globally in 2007 add up to 3% of the world mine supply of Au and Ag, 13% of Pd and 15% of Co[138], and the monetary value of the annual metals use in EEE worldwide in the same year represented 45.4 billion dollar. The total value of gold and silver put in the market in 2007 is in the order of iron or lead, but for the rest of precious metals no specific data has been found, and the production data available show little metal amounts puts on the market per year (see Annex F).

There are substantial differences among sub-sectors of the eco-industry in terms of their driving forces. All eco-industries in the EU are well developed, but waste management sector performs particularly well[139]. Policies and regulations as well as prices and availability of raw materials are key driving factors. The same is true for technological development, but its role is less important in the waste management and recycling sub-sectors than in the other sub-sectors. Moreover, several sub-

[138] Christian Gagelüken, Christina Meskers (2008) Mining our computers – Opportunities and challenges to recover scarce and valuable metals from end-of-life electronic devices.

[139] ECORYS (2009) Study on the Competitiveness of the EU eco-industry, Final Report – Part 1.

sectors are starting to become commercially viable and thus of interest for private investments. This is a trend which is already underway in the US where investments in eco-industries have until quite recently mostly been inspired by economic reasons and less by ecological considerations. In the EU, investors interested in green businesses are becoming more common and appear to be doing better in the current economic crisis.

The recycling sector is expected to experience increase demand, at least in the medium term, as integrated chain management becomes more prominent among suppliers and customers of the recycling industry (especially with the WEEE Directive) and raw materials extraction is becoming increasingly uneconomical as regard to the recycling option. The same is true for the waste management sector, where demand is also expected to increase.

6.3.3. Scarcity and material security

Whilst material savings targets aim to decouple resource use and its environmental impacts from economic growth, a sustainable economy is only really achieved when non-renewable resources are not wasted and renewable sources are only exploited in a way that allows the resource stock to regenerate itself in order to provide for the needs of future generations. A danger with focusing on material savings as an indicator, the threat of resource depletion still remains, because any progress made through efficiency is offset by increasing volumes of consumption and growth[140].

In the case of material security, however, material savings become a crucial strategy towards preventing material scarcity. For example, metal ores and industrial minerals are a mixed group from the very scarce and precious elements or gems down to the ubiquitous minerals. For some of these materials scarcity issues play a major role, but the scarcity constraints cannot easily be translated into policy targets. One classical argument that applies here makes reference to recycling. By accumulating previously extracted primary resources in our infrastructure and our waste deposits, we create potential new sources for extraction. This argument, though, does not apply to all minerals. Recycling is particularly difficult for the often precious metals (used in very small but crucial quantities, for example in electronic equipment or minerals which are used in a dissipative way such as fertilizer minerals. These small and often rare materials are those under greatest threat of scarcity. Additionally, the recycling of dispersed materials requires significant amounts of energy. More generally speaking, as long as overall resource use is continuously rising, the potential for recycling will always run short of demand.

Finally, abundant materials may also be affected by scarcity; For example, sand, gravel and stone, and limestone for cement production, may be considered unlimited, even though they are not exactly renewable resources and do not present a scarcity challenge, except in perhaps some localities. However, increasing use of

[140] OECD (2009) Eco-innovation in industry – Enabling green growth

land area for infrastructure for example, creates indirect scarcity for construction minerals. Disregarding the need for construction minerals and thus sites to extract them can turn these abundant minerals into a scarce resource. What we see today as an abundant resource may become scarce in the near future. For these reasons, material savings efforts may help to reduce the risk of scarcity in future, or mitigate the effects of current material security issues.

The achievement of a more resource efficient economy will demand in the medium to long term a radical and fundamental restructuring of economic activity and societal structures.[141] It is important to develop environmentally related skilled jobs in the EU labour market, especially in the field of recycling, where the EU has proven to be a leader. In terms of exploiting technological opportunities, the EU is in a leading global position on water supply (30%), renewable energy (40%) and above all on recycling (50%)[142]. It is thus important to avoid skills shortages and to promote waste and material efficiency through adapted policies. Markets need guidance and incentives to tap into the potential of eco-efficient technologies. Without clear and ambitious policies, there will be under-investment in R&D and marketing of technologies.

6.4. GENERAL IMPLICATIONS AND CONSEQUENCES

Waste prevention and product design policies considered in this study revealed that:

- Contributions from current waste prevention policies to material savings and productivity have been difficult to track mainly for two reasons: i) they have been implemented recently thus it is too soon to account for any measurable effects so far, and ii) concrete actions are only requested after 5 years of being adopted. Specifically, the Waste Framework Directive was adopted in 2008 and the requirements of concrete actions by MS through waste prevention programmes are only due to 2013.
- The European Ecolabel has proved to be an effective action for resource savings through better product design; the impacts measured as materials saved in certain material streams were quantified. In order to increase the potential savings from this action in the future, the market share of Ecolabeled products needs to be increased. Options for doing this can include increasing consumer awareness and the number of products labelled.
- In relation to recycling and waste prevention, increased ecodesign practices can actually lead to greater recycling and waste prevention. If recycling is carefully considered in the design process by enabling quick and easy disassembly, proper marking of components and their material composition or allowing parts of the product to be easily replaced so consumables or components can be reused or

[141] European Commission, DG EMPL, Employment in Europe 2009.
[142] ECORYS (2009) Study on the Competitiveness of the EU eco-industry, Final Report – Part 1.

refurbished. Ecodesign can also apply design strategies to ensure the long life of products or reduce their toxicity and in this way contribute to waste prevention. Furthermore ecodesign can also increase the demand for recycled materials by designing parts in a manner that allow recycled material to be used without compromising the quality and performance of the product.

- The effect of having fully implemented policies that aim to increase material productivity should be a reduction in material use. However, current implementation trends show little improvement in terms of material productity from waste prevention and product design. Rather than less material use in order to provide the same functionality from the three main policy blocks (waste prevention, product design or recycling), it seems that waste streams have been effectively diverted from landfill (by increasing recycling and recovery) and thus the effect of recycling is the only one having a measurable impact in material use. Effects of the other two policy blocks would be measurable if a reduction in the waste stream was occurring but there is no evidence that this is the case.

In the study it is assessed that recycling has by far the largest contribution to material productivity and still holds the greatest future potential, but also waste prevention through reuse and consumption behaviour has a significant potential to increase material productivity. In order for material productivity to increase, product design is the key to achieve greater amounts of recycling and waste prevention.

To increase material productivity through recycling, waste prevention and product design policies, one must consider the various material streams and their application:

- Construction materials constitute the largest material flow, but most go into stock (buildings and infrastructure) for the benefit of future generations
- Waste prevention is most suitable for addressing food, whilst recycling and product design can address the supporting systems (e.g. packaging) surrounding the food cycle
- Rare metals play a critical role in high-tech products (incl. environmental technologies), efforts should be made to ensure that these materials are never wasted

Other policies studied revealed the following:

- Targets are set in order to increase reuse/recycling without prioritising any of the options. Recycling is the 'easiest' action to achieve targets, leaving the potential for reuse untapped.
- In general, the effect of recycling actions encouraged by those policies seems to be more significant and measurable than those from waste prevention or product design actions
- Effective actions in enhancing product design are lightweighting and/or extending the product lifetime. However by implementing one of these options,

a negative effect seems to appear on the other one. The case of cars serves as an example: light weighting has been done by increasing the amount of parts from plastic. However in lighter cars, users tend to think that these parts will wear out sooner than in heavier cars[143]. A sense of lightness can also affect user's perception of safety and the market share of these products has actually gone down.

- Although there has been a general trend towards smaller and lighter products particularly in electronics industry, the "ecological backpack" of the product must be taken into consideration. Even though an end product only weights a few hundred grams, it could very well represent much more in terms of the total of material used over its life cycle to produce the product

Additional consequences and implications are:

- Resource efficiency and material productivity are indicators that measure the input and output of natural resources in the economy in relation to GDP. EU's Resource Strategy has the dual objective of decoupling resource use from economic growth and decoupling environmental impacts from resource use. This study has investigated the contributions of recycling, waste prevention and eco-design polices and measures that contribute to the overall resource efficiency and reduction in environmental impacts. When considering whether targets for resource efficiency should be put forth like they have been done for energy efficiency, it should be noted that as resource efficiency is based on the relationship of the input and output, it is possible to achieve this by focusing more on the economic aspects than the actual reduction of overall resource use. This is what seems to be the case in many Member States as the emphasis of the promotion of resource efficiency is to achieve competitiveness rather than limit the use of certain resources.[144]
- If the real goal of sustainability is to ensure that the non-renewable resources are not wasted and the renewable resources are only exploited in a way that allows the resource stock to regenerate itself and continue to fulfil the needs of future generations, then the focus should be on the actual amounts of resources that enter and leave the economy. Likewise resource efficiency cannot be used as a proper proxy for reducing environmental impacts on for example biodiversity as these often depend on actual amounts of emissions locally. The amount of natural resources we have and the endpoints of environmental impacts are absolute, whilst resource efficiency is relative.

[143] Morley N. et al (2007) Product Lightweighting. A Strategy to deliver a sustainable economy. Resource Efficiency Knowledge Transfer Network (RE-KTN).

[144] Mudgal S., Fischer-Kowalski M., Krausmann F., Chenot B., Lockwood S., Mitsios A., Schaffartzik A., Eisenmenger N., Cachia F., Steinberger J., Weisz U., Kotsalainen K., Reisinger H., and Labouze E. (2010) Preparatory study for the review of the thematic strategy on the sustainable use of natural resources. Contract 07.0307/2009/545482/ETU/G2, Final report for the European Commission (DG Environment). Available at: ec.europa.eu/environment/natres/pdf/BIO_TSR_FinalReport.pdf

- It should also be clear that resource use should take into account in which sector the resources are actually being used. For example resources for food are needed for short term consumption, whilst resources for construction (e.g. buildings and infrastructure) can be of benefit for many generations to come. Each of the different sectors of the economy have different patterns of material flow, some, such as food, do not add much to societal stocks, whilst others, such as construction, contribute intensively to what is added to the national stocks.

This study has only considered existing proved technologies and approaches for recycling, waste prevention and product design that can be directly applied more widely. Recycling might be higher still as industrial recycling is not accounted for in the waste statistics.

The environmental impact analysis shows that:

- A further reduction in the need of raw materials such as plastics, paper and metals will result in a significant reduction in the total environmental impacts derived from materials use in the economy. This effect will be considerable in impact categories related to climate change, photochemical oxidation and acidification potential.
- The reduction in the use of raw materials in the metals stream (e.g. aluminium, copper, lead, nickel, iron and steel) has been attributed in previous sections to current policies that have led to increased recycling rates. These policies account for the major contributions in the reduction of adverse environmental impacts, as assessed by the EMC.
- Regarding climate change, the reduction of metals, biomass and plastics consumption by means of recycling, waste prevention and product design contribute in a similar percentage to greenhouse gas emissions reduction, leading to an overall annual saving of 135 Mt of CO_2 equivalent. Plastics are the material stream with the highest impact saving potential. If policy targets are increased, the overall emissions saved annually would be about 278 Mt of CO_2 equivalent. These calculations for greenhouse gas reduction do not take into consideration any additional savings of fuel savings from reduced transport or lighter vehicles.