Assessment of resource efficiency indicators and targets

Final report

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Table of Contents

List of Tables

List of Figures

Executive summary

Our successful economic development over the past century is based on the ever increasing use of natural resources over time. Nonetheless, if we continue with our current patterns of consumption, it would be inevitable to avoid irreversible damage to the planet's natural environment and jeopardise its very ability to provide these resources and the ecosystem services that we are so dependent upon. Resource efficiency is seen as the path where economic development and human well-being can progress with lower resource use and environmental impacts. To know whether we are on the path of resource efficiency, we need good indicators - and possibly also specific targets - to guide us on the way. This study investigates how indicators and targets of resource use can be used to increase resource efficiency in the EU as part of the European Commission's Flagship Initiative for a Resource Efficient Europe.

The study analysed several existing indicators that track the different types of resource flows in the economy, such as materials (abiotic and biotic), energy, water and land use. The selected indicators were then evaluated for their appropriateness for target setting at the EU policy level. The outcome of the study is a framework for a set (or basket) of indicators for resource use and their associated environmental impacts. This basket of indicators was used as a basis for proposing a corresponding set of targets for the EU in 2020 and 2050. The implications of setting resource use targets were evaluated to provide the Commission with possible ideas on how to concentrate their efforts towards setting medium and long-term resource efficiency targets.

Existing indicators and targets related to resource use

Although hundreds of indicators for tracking resource use exist, not many of them are used to set concrete and quantitative targets. A review was performed of resource use and resource efficiency related targets in EU Member States and third countries such as Australia, Canada, China, Japan, Switzerland, and USA. This revealed that the strategic objectives for resource use in environmental policy tend to be general in nature, with the exception of GHG emissions and renewable energy. Such objectives are often defined in sustainable development strategies or climate action plans. The typical areas covered by targets are related to materials, waste, energy, water and land. In the EU Member States, most of the climate change, energy and waste (recycling) targets are driven by the EU legislation.

In general, there is little political consensus among national governments for setting targets both nationally and globally. This could partly be due to the lack of scientific evidence and a clear understanding of the planet's sustainability thresholds. Non-governmental organisations and some academics are pushing for more targets to be set and have even proposed specific targets to be integrated into policy. However, most countries are hesitant. Governments often formulate sustainable development strategies without any time-bound quantitative targets on resource use.

Framework for resource efficiency indicators

The proposed framework covers four key categories of resource use that can be directly related to the economy: materials, energy (and climate), water and land use (Table 1). It provides a structure to track the progress of resource use in the EU from two perspectives: domestic (territorial) use, and global (life-cycle) demand. The framework also allows both the quantities of resource use as well as their environmental impacts to be monitored. All these perspectives are essential for developing a successful resource policy.

Table 1: The basket of resource use relevant indicators

	Resource use-oriented		Environmental impact-oriented	
	Domestic resource use *(resources directly used for domestic production and consumption)*	*Global resource demand* *(domestic resource use plus resource use embodied in trade)*	*Environmental impacts related to domestic resource use*	*Environmental impacts related to global resource demand*
Material use	Domestic material use Domestic Material Consumption	Global material demand Raw Material Consumption	*Territorial part of* Life-Cycle Resource Indicator (of *Environmentally-weighted Material Consumption*)*	Life-Cycle Resource Indicator (*Environmentally-weighted Material Consumption*)*
Energy use and climate change	Domestic energy use Gross Inland Energy Consumption	Global energy demand Energy Footprint	Domestic GHG emissions Territorial GHG Emissions	Global GHG emissions Carbon Footprint
Water use	Domestic water use Water consumption *(Water abstraction)**	Global water demand Water Footprint	Domestic water exploit. Water Exploitation Index	Global water exploit. Global Water Consumption Index
Land use	Domestic land use Domestic Land Demand	Global land demand Actual Land Demand (Land Footprint)	Domestic LU intensity Human Appropriation of Net Primary Production	Global LU intensity *eHANPP, LEAC and other indicators on ecosystem quality*

Note: * ... short-term proxy indicator for the medium-term desired indicator

A set of currently available aggregated headline indicators were selected to represent each resource category and perspective in the most comprehensive manner possible. A second level of indicators addressing specific questions within each resource category (e.g. fisheries in the category of materials, built-up land in the category of land use) were also presented, but not analysed in detail during the study. An evaluation of the individual headline indicators and the basket as a whole suggests that:

- the proposed basket of indicators provides comprehensive information on EU's use of natural resource and its corresponding environmental impacts.
- there is a need to further harmonise the methodologies that calculate indicators, in particular related to the consideration of resources embodied in internationally-traded products.
- the indicators suggested for the basket are consistent in terms of boundary setting and accounting principles.

- all indicators suggested for the basket can be linked to economic data to establish indicators on resource efficiency.
- the basket of resource use indicators would need to be complemented by other indicators on natural stocks (e.g. availability of freshwater, resource depletion) and environmental risks (e.g. consequences of nuclear energy and genetically modified organisms (GMOs)).

Setting targets related to resource use

A target sets a clear orientation, it provides concrete guidance and helps prioritise actions to achieve a policy objective. If properly enforced and supported by an appropriate mix of policy measures to ensure fair global market conditions and a level playing field, it can be a powerful approach to addressing environmental issues. Long-term objectives provide actors in society, e.g. governmental organisations and companies, certainty, stability and time to achieve the target in the most efficient manner.

Scientific knowledge about environmental thresholds and carrying capacity can serve as a starting point for defining acceptable levels of risk and environmental impact on which a target could be set. For resources such as fossil fuels, land, water and fish stocks, there is some understanding of the limits to when long-term depletion and degradation occurs. For other energy and material resources, the limitation of the resource base is less clear. Instead, the knowledge of the absorption capacities of nature's ecosystems could be used for target setting. A clear example of this is the limit of a maximum 2°C rise in global mean temperature, or 350 ppm CO_2 in the atmosphere, which is used to define EU's GHG emissions targets.

An important aspect when proposing targets is determining the most appropriate level to set the target. The majority of indicators in the proposed basket of indicators have strong links to socio-economic activities and entities, e.g. material consumption and GHG emissions. Some of the indicators are however more relevant on a specific ecosystem scale rather than a national/ economy-wide level, e.g. river basins are more suitable for water indicators, human harvest or HANPP (Human Appropriation of Net Primary Production) is more relevant for agro-ecological zones. Another important consideration is how EU-wide targets could be disaggregated to Member State level or across different sectors of the economy. Some possible approaches include disaggregation according to equity of effort sharing, relative ease/difficulty to achieve the target, demographic characteristics, economic structure and features of the ecosystems including climate.

The cost-effectiveness of setting a target is an important aspect of any target-setting exercise. Although the Flagship Initiative recommends a clear vision and objectives to guide resource efficiency policy in the EU, target oriented policy may not always be the best approach. Depending on how a target and its associated indicator are defined, the mix of supporting policy instruments, and how they are implemented, target setting could lead to unintended consequences. This is of particular importance when considering how the use of resources is interlinked. For example, the targets set for biofuels in transport can have significant consequences for global land use.

Whatever the approach chosen to set targets for resource use and efficiency, it is advisable that the targets are based on relevant existing indicators, and that the knowledge of resource use and its environmental impacts is well developed. The figure below shows an example of how targets in one area are linked to other resource use targets.

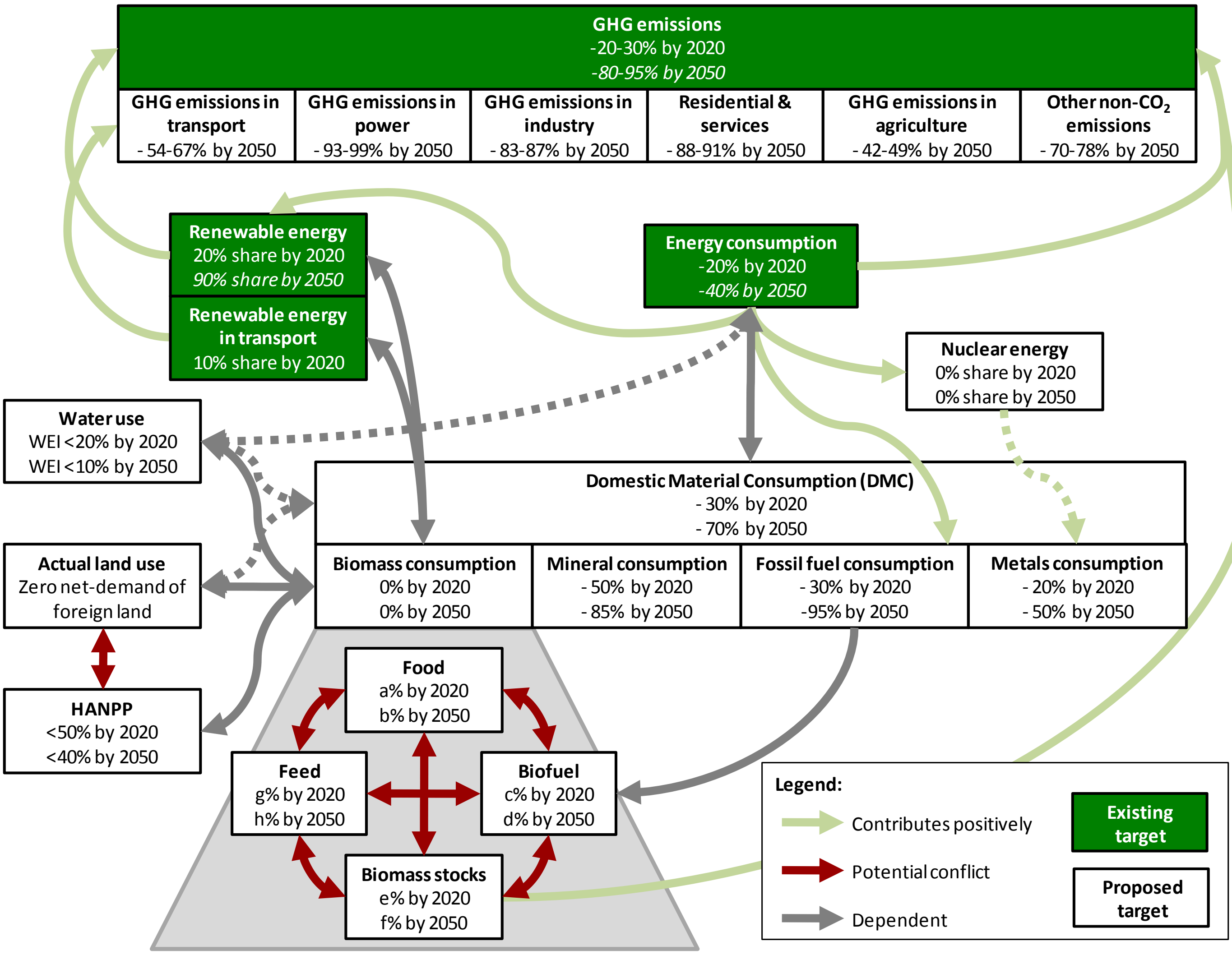

Figure 1: The proposed resource use targets and their links

Analysis of the proposed targets

The fact that the use of natural resources is closely interlinked was obvious in the process of defining resource use related targets. For example, biomass is directly dependent on land and water. Furthermore biomass serves four main purposes for society: (1) feeding humans, (2) feeding livestock, (3) providing energy (e.g. biofuels, wood fuel), and (4) building biomass stocks (in vegetation and soils), which provide vital ecosystem services, e.g. climate regulation such as carbon sinks.

Starting from the existing targets related to GHG emissions and energy use, and based on knowledge about links and plausibility, a set of aggregated headline targets were proposed to match the basket of resource use related indicators (Figure 1). The latest trends show that the EU is on track in meeting its 2020 target for GHG emissions. It is now considering extending this to a more ambitious target for 2050. Following are the key findings:

- **GHG emissions**

The Commission has already assessed the impacts of an 80% reduction of GHG emissions by 2050 compared to 1990. It showed that this target could be achieved by maintaining (and in some cases even increasing) activity levels. Depending on early investment in different (known) technology assumptions and global action, this could be cost-effective and lead to lowering fuel costs. High investments are required, but this offers opportunities for economic growth and job creation. A reduction of domestic GHG emissions would encourage the diffusion of renewable energy and thereby increase security of energy supply. Furthermore, a reduction of GHG emissions would also reduce SO_2, NO_x and PM emissions that would benefit the environment and human health.

A less ambitious target would increase fuel costs and supply risk, besides aggravating the effects of climate change. A more ambitious target (e.g. 95% reduction of GHG emissions by 2050 compared to 1990) is technically and economically feasible, but would require greater infrastructure investments and a lower demand and modal shift in the transport sector.

- **Energy consumption**

A target for GHG emissions would also drive energy efficient technologies and thereby lead to a reduction in energy consumption. The 80% GHG emission reduction target by 2050, would lead to a 30% reduction in (gross inland) energy consumption in 2050 (compared to 2000). This GHG emission target will also require the EU to abandon fossil fuels and instead rely on renewable energy sources. Biomass would provide about two thirds of the renewable energy until the other renewable energy technologies establish themselves over the next two decades. The share of biomass energy will then decrease but remain the principal renewable energy source well into the future.

- **Material consumption**

Reductions in fossil fuel energy consumption would be proportional to reductions in domestic material consumption (DMC) and imports. Due to the increase in demand for bioenergy, it would be difficult to reduce DMC of biomass. However, due to favourable biogeographical conditions (climate and soils) and a high availability of productive land per capita, the EU has the potential of being self-sustaining with regard to food and other uses of biomass. There is evidence that Europe has sufficient sources of domestic 'environmentally compatible' bioenergy to cover its demand. Without adequate policies in place, this would undoubtedly compete against food production and put pressure on global land use change resulting in unintended negative environmental and social consequences. A possible response to decreasing the demand of biomass production is to lower the amount of animal based products in the EU average diet and thus lower demand for animal fodder.

Although metals only constitute a small share (under 4%) of overall DMC, they contribute significantly to the EU economy and global environmental impacts. Setting ambitious targets to encourage more efficient use of metals would be cost-effective, environmental beneficial and limit dependence on foreign imports (particularly for the critical raw materials). It is possible to reduce the DMC of metals, but only to a certain extent as they are required for the construction and production of energy efficient products and infrastructure. Many of the rare earths which have been identified as critical raw materials for the EU are needed for many low carbon technologies.

Construction minerals (even excluding sand and gravel) constitute the greatest share of non-metallic mineral DMC. At present it seems difficult to set very ambitious targets to reduce DMC as the majority of construction materials are needed to maintain the existing building stock and infrastructure. The shares of the input flows needed for replacement at end-of-life are estimated at about 63-90% for the transportation network and 88% for buildings - much larger than the ones related to infrastructure expansion. Even when applying the full (theoretical) potential of construction and demolition waste recycling, only 25% of current construction minerals DMC would be reduced. Given the known technologies and level of (economic) activity, further reductions of DMC might not be cost effective.

- **Land use**

It is evident that without greater yields, it will not be possible to increase biomass production without increasing land use. There is evidence to support that it is possible to increase yields in the EU without putting more pressure on the environment (e.g. without increasing water abstraction, mineral fertiliser use and nutrient loss). As mentioned, the EU is capable of being self-sufficient in biomass, but the target for zero net demand of global land should not compromise the competitive trade advantage of growing crops in the biogeographic regions that are most productive and best suited. The proposal to halt the (net) increase of artificial land is feasible and would support the other resource use targets. Densification of existing built-up land can increase energy efficiency and reduces the demand for construction metals and minerals. It would further reduce the negative impacts on the environment such as soil sealing and fragmentation of natural habitats.

- **Human harvest**

HANPP (Human Appropriation of Net Primary Production) – a measure for the amount of biomass removed from the land - varies across different land use categories. Cropland is typically characterised by high HANPP levels at or above 85%, whereas forests have low HANPP values below 30%. Depending on land cover patterns and the intensity of land use, domestic HANPP across European countries differs widely. The overall target for the EU-27 of stabilising average HANPP at 50% or reducing it to 40% should not be applied equally to individual Member States. Countries with less favourable conditions for intensive land use (e.g. Sweden, Finland and Slovenia) should maintain low levels of HANPP, whereas countries with productive land suitable for agricultural production (e.g. the Netherlands, Hungary, Denmark and the Czech Republic) should still engage in agriculture – and thus can have levels above the target level. However, HANPP in regions with high suitability for intensive cropland agriculture should not exceed 75% in order to stay within sustainable limits. In other words, stabilising or reducing average HANPP in Europe may require a stabilisation or increase in extensive land use types, and a sustainable intensification on the best agricultural land. Although targets for HANPP need to take the specific agro-ecologic areas into consideration, it can lead the way to more sustainable agriculture practices by improving soil quality and determining environmental thresholds.

Water use

Major methodological gaps do not allow a target based on water abstraction to be formulated at the moment. The Commission is currently developing appropriate indicators to set water efficiency targets. To complete the basket of indicators, the project team referred to the EEA recommendations that water abstraction should stay below 20% of available renewable freshwater resources (Water Exploitation index). There are many existing solutions and best practices that would allow this target to be achieved without compromising agricultural yields and fulfilling the needs of the economy. But due to a lack of data and understanding of water use at a river basin level, it is not clear how cost effective such a target would be.

Table 2: Overview of the assessment of the economic and technical feasibility of achieving the proposed range of targets

	Ambitious	Moderate	Conservative
GHG emissions (baseline 1990)	-30% by 2020 -95% by 2050	-20% by 2020 -80% by 2050	-20% by 2020 -50% by 2050
Energy consumption (GIEC) (baseline 2005)	-20% by 2020 -40% by 2050	-15% by 2020 -30% by 2050	-10% by 2020 -20% by 2050
Material use (DMC) (baseline 2005)	-30% by 2020 -70% by 2050	-10% by 2020 -30% by 2050	-5% by 2020 -20% by 2050
Land use	Zero net demand of foreign land by 2020	Zero net take of artificial land by 2020	Limit annual net increase of artificial land to 200 km^2 by 2020
Water use **Water Exploitation Index (WEI)**	<20% WEI by 2020 <10% WEI by 2050	<25% WEI by 2020 <20% WEI by 2050	<30% WEI by 2020 <25% WEI by 2050

Legend for feasibility:	Possibility to achieve targets with significant changes in levels of activity and significant advancement from known and future technologies	Possibility to achieve targets with slight changes in levels of activity and greater investments in known technologies	Possibility to achieve targets while maintaining current levels of activity and cost effective investments in known technologies

Multi-return strategies

During the analysis of the targets, strong links between the use of different resources prompted an alternative approach to setting resource efficiency targets. These so-called 'multi-return' strategies address multiple resource categories and several issues related to resource efficiency by identifying the one key driver behind them all. This approach aligns various resource use targets and captures them through one focussed policy intervention. The following multi-return strategies were identified in this study:

- **Changing the human diet towards a lower share of animal-based food**. Tackling this will have several effects:
    - Positive effects on human health; less livestock lowers the pressure on land and water resources; it also reduces GHG emissions from ruminants; less demand for cooling and transportation of meat will reduce energy consumption.
- **Steady stocks of built-up infrastructure and densification of settlements, reducing urban sprawl** will have following effects:
    - Decreasing material consumption; facilitating a continuous recycling of construction materials; decreasing energy use for the construction of infrastructure, in transport and in the use phase; decreasing use of land area and sealing of land.
- **Product re-design for longevity and recycling.** This is not really one strategy, but a bundle of strategies, to be developed for groups of products. Tackling this will have several effects:
    - Reducing the use of toxic materials; increasing the use of bio-degradable materials; increasing longevity, repair-friendliness and re-use of products; increasing recyclability by design; improving energy efficiency in production and use of products.

Multi-return strategies could be an approach for target based policy that would require less action, but would have broader effects.

Recommendations

The European Commission has made it clear in its Europe 2020 strategy the direction in which the EU should be moving. Indicators and targets are important tools to guide, coordinate and encourage progress in the right direction. Although the study has demonstrated that many of the available indicators desperately need to be improved or developed further, this should not deter the Commission in continuing their work by discussing and considering possible resource use and resource efficiency targets. There is too much at stake to wait for a perfect set of indicators. Many of proposed indicators can already be adopted for use in resource policy development. In the case of limitations, other supporting indicators and experts should be consulted.

The project team identified the following areas where the Commission would benefit from further development:

- **Continue improving and developing resource related indicators**
    - *Indicators and data on resource use embodied in trade* - further develop and harmonise different data and methodological approaches to

calculate resource use embodied in international trade of the EU-27 and EU Member States.

- *Indicators and data on the environmental impacts of resource use* - further strengthen and test currently developed methodologies and improve the underlying databases for their calculation.
- *Indicators on the impacts on ecosystems and biodiversity* – support the development of approaches to link land cover and land use change to indicators on ecosystem quality and biodiversity.
- *Indicators on the natural capital stock* – support the development of approaches for indicators and databases that can monitor scarcity and overexploitation of resources.
- *Level 2 indicators* - refine the understanding of the interlinkages between level 1 (headline indicators) and level 2 (supporting indicators addressing specific questions within a resource category) indicators, as well as support the further development of specific level 2 indicators that are not yet available.

- **Develop the knowledge base in order to better assess the impacts of resource efficiency targets**
  - *Multi-return strategies* – investigate how improving resource efficiency for several resources at the same time can be achieved through focused policy interventions.
  - *Methodologies to better assess the impacts of (policy) responses* (e.g. environmental taxes, R&D spending in eco-innovation areas and subsidies for resource-efficient technologies) on resource quantities and related environmental impacts, in order to prioritise policy and business action, e.g. marginal abatement curves for resource use.
  - *Build-up the policy "business case"* – find socio-economic evidence to justify setting a target, when the scientific evidence on the environmental rational is missing, e.g. emphasise the benefits of securing supply and competitiveness.

- **Involve external actors and stakeholders in the process of target setting**
  - *Communication of indicators* - rethink how the indicators could be better communicated and more easily understood by everybody. Many of the current resource related indicators use unclear language and terminology, e.g. embodied water, actual land demand and virtual footprint. Consider renaming or harmonising the terminology.
  - *Establish open multi-party debates* - extensive consultation allows all viewpoints to be heard on an equal level and is a good starting point for building consensus.

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Chapter 1: Introduction

Natural resources are fundamental for our society and its prosperity. They are needed in all human activities, and their use forms the basis of our economy. Resources such as raw materials, energy, food, water and land are directly extracted from nature to produce products and services that create economic growth. In addition to the resources that are directly valued by the economy, other natural resources, such as ecosystems, provide environmental and social services that humans greatly depend on.

While humankind continues to develop and improve the quality of life, **the natural resources on this planet are limited**. Our current rate of extraction and depletion of natural resources is jeopardising our current ability to meet some of the world's basic needs, let alone the ability of future generations to meet their needs. Some renewable resources are already harvested beyond the planet's reproductive capacity. Many non-renewable resources are becoming scarce. The depletion of natural resources affects countries' economic development, supply 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) affects the natural environment (e.g. air, water, soil, biodiversity, landscape) and the proper functioning of life sustaining ecosystem services.[1]

One of the greatest challenges of this century will be to balance the demands of a growing global population with the planet's carrying capacity. One approach to do this is to "do more with less", or in other words, become resource efficient. Despite (or maybe due to) technological advancement our society's use of resources is not very efficient. This is evident when comparing the total amounts of resources that are extracted from nature, with the amount of resources that are actually used and finally the amount ends up as waste and pollution.

1.1 Background

In March 2010, the European Commission put forward a **Flagship Initiative for a Resource Efficient Europe** as part of its 'Europe 2020 Strategy'[2]. The Initiative will guide policy development related to resource use in Europe over the next ten years. The strategy called for a shift towards a resource-efficient, low-carbon economy. Sustainable growth will be achieved by decoupling economic growth from resource use and environmental impacts (see Figure 2). In this context, the Commission needs indicators for resource use and resource efficiency to track the EU's progress towards this objective.[3] Furthermore, encouraged by both the European

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

[2] European Commission (2010) Europe 2020 – A strategy for smart, sustainable and inclusive growth. COM(2010) 2020 final. March 2010.

[3] European Commission (2011) A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy. COM(2011) 21 final. January 26, 2011.

Parliament and the Council, the Commission is considering setting medium and long-term targets to steer the efforts towards resource efficiency.

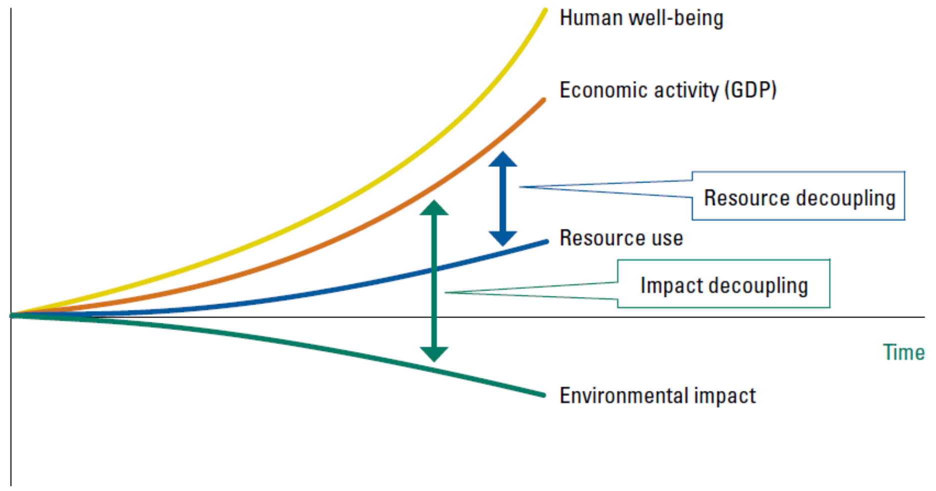

Figure 2: Representation of double decoupling: resource and impact decoupling (UNEP, 2011)[4]

It is possible to measure the rate of decoupling by comparing the growth of resource use with economic growth. Relative decoupling occurs when the growth rate of resources used (or environmental impacts) is lower than economic growth. But the real aim is to achieve absolute decoupling, where resource use (or environmental impacts) is stable or decreasing whilst the economy is increasing.

The concept of resource efficiency in environmental policy is relatively new, but it is very linked to the general concept of sustainable development. Sustainable development is however a broader concept, which besides aiming to develop the economy, is also concerned with preserving the environment and improving social issues (e.g. human health, social inclusion, equity, etc.). **Resource efficiency is more focused on the use of resources and how they contribute to our well-being and economy**. It is more **concerned with the pressures put on the natural environment**, than the state of the natural environment (unless this affects the supply of resources). Besides reducing environmental impacts, another important aspect of resource efficiency is that it aims **to limit the risks linked with scarcity and the security of supply of resources**.

The concepts of sustainable consumption and production (SCP) and green growth are also very interlinked with resource efficiency. Although the terms can often mean the same thing, resource efficiency encompasses more than SCP as it has a stronger focus on the extraction of natural resources (beginning of the life cycle) and the management of waste (end of the life cycle). Green growth and resource efficiency go hand in hand (reducing the environmental impacts of the economy), but green growth tends to emphasise the growth opportunities for income and employment from investments in environmental goods and services[5].

[4] UNEP International Resource Panel (2011) Decoupling natural resource use and environmental impacts from economic growth.

[5] UNEP (2010) Green Economy Report. Available at: www.unep.org/greeneconomy/

1.2 Objectives of the study

This study investigates how indicators and targets of resource use can be applied in policy to increase resource efficiency in the EU. The objective of this study is to identify and assess indicators related to resource use and their environmental impacts and to evaluate the possibility of setting corresponding targets. Ultimately, the study aims to present recommendations for the implementation of indicators and targets in the EU policy context.

It must be noted that this study was conducted in parallel with the development of the Commission's Road to a Resource Efficient Europe[6].This study provided input to the Commission's work, but followed its own objectives and schedule. The findings of this study are not necessarily, and did not intend to be, consistent with the Roadmap.

1.3 Scope

At present there is no clear and pragmatic definition of natural resources shared between the EU, Member States and international organisations[7]. Although the EU, OECD and UNEP have advanced the concept of sustainable management of resources, **the understanding of resources has been interpreted in a multitude of ways**. European Commission documents have left the definition of natural resources open to be all encompassing, e.g. *"including raw materials such as minerals, biomass and biological resources; environmental media such as air, water and soil; flow resources such as wind, geothermal, tidal and solar energy; and space (land area)".*[8] The Council in a later document has further considered ecosystems and biodiversity to also be considered as natural resources.[9]

The OECD defines specifically natural resources in relation to economic purposes as *"natural assets (raw materials) occurring in nature that can be used for economic production or consumption"* [10]. These can be subdivided into mineral and energy resources, soil resources, water resources and biological resources. The International Resource Panel first uses a broad definition *"that includes anything that occurs in nature that can be used for producing something else"*[11], but then distinguishes between immaterial (e.g. the song of a bird) and material resources. Immaterial resources are characterised by the fact that their use has no effect on the qualities that make them useful, and that they cannot easily be given economic value. The use of material resources

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[6] European Commission (2011) Roadmap to a Resource Efficient Europe. COM(2011) 571 final. September 20, 2011.

[7] European Environment Agency (2011) Resource efficiency in Europe. Policies and approaches in 31 EEA member and cooperating countries. Initial findings from the analysis of draft national reports on resource efficiency policies and instruments. EEA Report No 5/2011.

[8] European Commission (2005) Thematic Strategy on the sustainable use of natural resources. COM(2005) 670 final

[9] Council of the European Union (2010) Council conclusions on sustainable materials management and sustainable production and consumption: key contribution to a resource-efficient Europe, 20 December 2010.

[10] OECD (2010) OECD Global Forum on Environment, focusing on sustainable materials management. Summary Paper 2: Summary of SMM linkages. Working document, OECD Environment Directorate. Available at: www.oecd.org/dataoecd/23/19/46114406.pdf.

[11] UNEP International Resource Panel (2011) Decoupling natural resource use and environmental impacts from economic growth.

on the other hand can eliminate at least some of the qualities that render them useful for certain applications. In other words, the state of material resources can be transformed into something where their potential usefulness for the same purpose is no longer available.

Instead of attempting to address all types of resources, this study proposes for practical reasons a more specific definition in line with International Resource Panel and the preparatory study for the Commission's Review of the Thematic Strategy on the Sustainable Use of Natural Resources[12]:

Resources are defined as the natural physical assets deliberately extracted and modified by human activity for their utility to create economic value.

The above definition specifies resources as physical assets that are *extracted* from the natural environment to produce goods and services, or modified to provide economic services to society. Here a distinction is made between resources such as minerals, metals, biomass and water; and ecosystems, which provide these resources as well as a variety of other benefits humans obtain from the natural environment (i.e. ecosystem services). The natural environment is seen as both a 'source' for natural resources to be used in society, and a 'sink' that absorbs wastes and emissions, and reintegrates the substances into natural cycles. In this study natural resources are therefore seen as the physical inputs to the economy. Their use involves impacts to the environment in the form of emissions to air, water and soil (i.e. outputs of the economy) and their effects on ecosystems and their functioning. **This distinction is consistent with the three 'areas of protection' given by Life Cycle Assessment** methodology.[13] Here human health, the natural environment and natural resources are listed as separate areas of protection.

Although the title of this report is 'Assessment of resource efficiency indicators and targets', **the scope of the study is limited to natural resources that are directly used as inputs to the economy**[14]. The study does not assess resource efficiency indicators as such (e.g. by relating resource inputs with physical or economic outputs[15]), but focuses on the total amounts of resource inputs to the economy. At the end of the day, it is the total amounts of resource use that threaten the environment and cause resource depletion. As all the resource use indicators can be directly linked to their economic value, they can be used to calculate resource efficiency / productivity indicators. This study is therefore focused on the following natural resources:

- **Materials** (biotic and abiotic)
- **Energy** (fossil fuels, nuclear and renewables[16])
- **Air**

[12] BIO Intelligence Service, IEEP, IFF and Umweltbundesamt (2010) Preparatory study for the Review of the Thematic Strategy on the Sustainable Use of Natural Resources. Study commissioned by the European Commission, DG Environment.
[13] Institute for Environment and Sustainability (2010) ILCD Handbook: General guide for Life Cycle Assessment – Detailed Guidance. DG Joint Research Centre, European Commission.
[14] SERI (2009) How to measure Europe's resource use. An analysis for Friends of the Earth Europe.
[15] An example of such an indicator is resource productivity, which compares Gross Domestic Product (GDP) with Domestic Material Consumption (DMC) [EUR/tonne]
[16] Includes all the flow resources: wind, geothermal, tidal and solar energy.

- **Water**
- **Land** (spatial dimension including terrestrial, inland water and sea areas)

The use of these resources is linked with impacts on the natural environment and human health (see Figure 3). The figure shows that the **use of resources** (through all life cycle stages) **results in the generation of waste and emissions**. In this study of resource use indicators and targets, the impacts on the natural environment and humans will also be considered via the physical exchanges through environmental media. These include air, soil, water and solid waste.

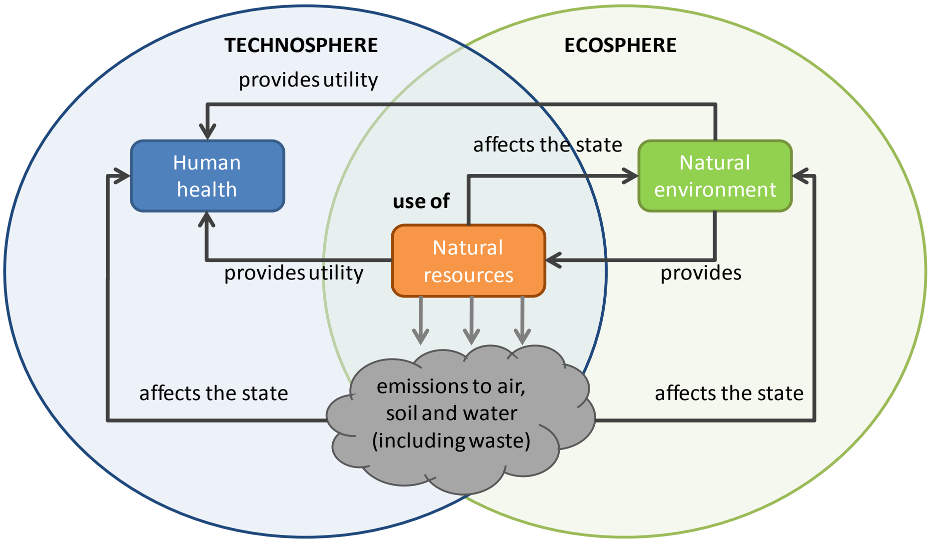

Figure 3: Inter-linkages between the use of natural resources and the state of human health and natural environment

Using the limited scope of natural resources mentioned above, it is possible to **relate these to the pressures asserted on the ecosystems** that provide life supporting services to humans, e.g. biodiversity, natural stocks of minerals, etc. This in turn affects the ecosystem services provided, which condition both human health and the long-term supply of natural resources (stocks). In this report impacts on human health are to be included in the definition of environmental impacts and understood as part of the term "environmental impact-oriented indicators".

The study only identifies and assesses potential resource related indicators. It does not attempt to develop or propose new indicators, but it does highlight the areas where indicators are lacking or need further development.

1.4 Methodology

The project team started by **reviewing indicators for resource use and resource efficiency that could be used to set targets**. Indicators were identified at EU level, in Member States a as well as in six non-EU countries (Task 1 and 2). Following the review of resource use and resource efficiency indicators, the project team (together with the Commission) proposed a shortlist of indicators to be investigated as to whether they would be appropriate to monitor the objectives of the Flagship Initiative "Resource-efficient Europe" [17] and for setting corresponding targets. The project team analysed each of the resource related indicators against the **RACER framework**[18] and a **set of specific criteria related to key EU resource policy requirements**. Based on the strengths and weaknesses of each of the indicators across all the criteria, the project team proposed a "basket of indicators" to monitor resource efficiency performance in the EU (Task 3). The basket of indicators covers the resource use and associated environmental pressures of the four main resources: materials, energy, water and land. In parallel, the project team **proposed a set of quantitative targets for 2020 and 2050 using the basket of indicators** (Task 4). **Different approaches to setting targets were considered** and the **linkages between the targets were analysed**. A preliminary **assessment of the feasibility and consequences of applying the proposed targets** was then performed (Task 5).

Representatives from DG Environment, Eurostat, the Joint Research Centre (JRC) and the European Environment Agency (EEA) followed the study throughout its duration and provided valuable comments. Furthermore, an **Expert Workshop with external experts was organised to scrutinise the preliminary findings of the study** (Task 6).

1.5 Structure of the report

This first chapter introduces the concept of resource efficiency and its policy context. It defines the objectives and scope of the study. Chapter 2 summarises the findings from the review of resource related indicators and targets in various countries. This provided inspiration for which resource related indicators were selected for further investigation in the study. The results of the evaluation of indicators are presented in Chapter 3 together with a proposal for structuring the selected indicators (the so-called 'basket of indicators'). Chapter 4 discusses various approaches to setting resource use targets. The rationale for proposing different resource use targets is presented and the linkages between targets are elaborated. Chapter 5 presents the baseline scenario for future resource use trends based on current policy, which is used to analyse the potential impacts of setting resource use targets. Chapter 6 discusses the findings of the study and provides recommendations to the Commission on how to set targets for resource efficiency. An 'Annex Report' complements this report.

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

[18] RACER stands for "Relevant, Acceptable, Credible, Easy, Robust". For more information see Ecologic, SERI & Best Foot Forward (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. Report to the European Commission, DG Environment. Brussels.

Chapter 2: Review of indicators and targets

Indicators are used to address important issues and bring attention to them - or, in other words: ***"what gets measured gets managed"***. In the context of resource use, there is a need to monitor the progress towards absolute decoupling of resources use and consequent environmental degradation from economic growth ("double decoupling"). Resource use indicators should provide information on the total amounts of resource used in the economy. Ultimately, the resource use indicators should allow environmental impact and socio-economic indicators to be linked to them in order to provide resource efficiency indicators.

It should be noted that it is not always possible to actually measure what one is really interested in, e.g. it is difficult to measure damage to natural resources. Proxies of related aspects are therefore often used as indicators, if no direct indicator can be found.

Targets are specific policy objectives. They are given by a defined performance indicator that can be measured or quantified, e.g. a reduction of domestic material consumption by x % compared to a reference year. In the context of environmental policy, setting quantitative and binding targets can be a powerful approach for policy implementation. It **shows a strong commitment and gives a clear direction** to Europe, Member States and economic sectors on what needs to be achieved. Based on the precautionary principle, the setting of targets also helps defining acceptable levels of risk and environmental quality in society.

2.1 DPSIR framework

The DPSIR framework[19] is used to classify and structure environmental indicators for policy use. It is useful in describing the relationships between the use of natural resources, its impacts on the natural environment and the challenges of resource efficiency (see Figure 4). It starts by first describing the **key drivers** of resource use (e.g. economic growth, technological changes, etc.); the type of **pressures** exerted on the natural resources and the natural environment throughout its life cycle stages (e.g. energy or water consumption in extraction, production, use, etc.); the **state of the ecosystem** providing or sustaining the resource (e.g. depletion, degradation, etc.); the actual or expected **impact of these pressures** on stocks of natural resources and the natural environment (e.g. climate change, loss of biodiversity, etc.); and finally the policy actions (e.g. energy efficiency standards, recycling targets) that are the **responses** to the challenges.

[19] EEA (2003) Environmental Indicators: Typology and Use in Reporting. Internal working paper.

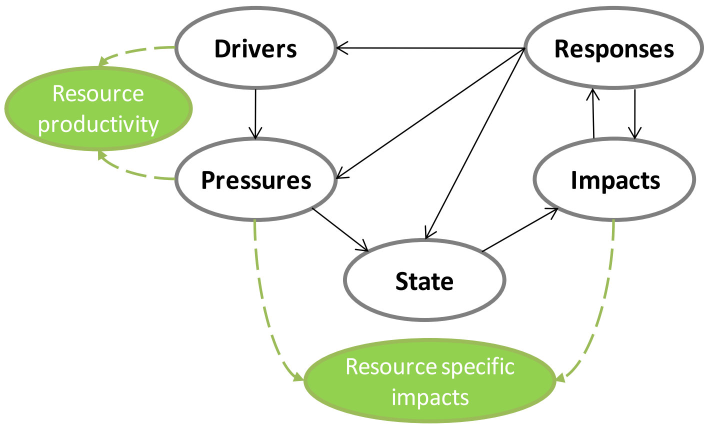

Figure 4: The DPSIR framework (EEA, 2003)

Resource productivity indicators are typically derived from the relationship between drivers and pressures, e.g. water consumption per capita. Resource specific impacts can be calculated based on the relationship between pressures and impacts, e.g. GHG emissions per unit of primary energy supply.

2.2 Resource efficiency indicators

The Commission's Thematic Strategy on the Sustainable Use of Natural Resources defined **three types of indicators needed to measure resource efficiency** (see (Figure 5)[20]:

- Indicators to measure progress in **productivity of the use of resources (resource productivity)**, e.g. €/kg
- Indicators to evaluate the **environmental impact of the use of specific resources**, e.g. impact/kg
- Indicators to measure progress in reducing the **ecological stress of resource use (eco-efficiency)**, e.g. €/impact

These indicators are based on three sets of knowledge: the sources and amounts of resource use, the socio-economic benefits we derive from them, and the environmental impacts caused from all of the life cycle stages. Each knowledge set uses a wide variety of indicators on their own. Unless specified all indicators are based on a time period of a year.

Resource use indicators

The **main issues regarding unsustainable resource use are the abundance, availability and quality of the resource in nature**. The use of resources is also related via production and consumption processes, e.g. materials need energy and water to be processed. Indicators of resource use should inform not only on the quantities of resources extracted, but also their quality, abundance (e.g. renewable, non-renewable, exhaustible, non-exhaustible), availability and location.

[20] European Commission (2005) Thematic Strategy on the sustainable use of natural resources. COM(2005 670 final).

Environmental impact indicators

In addition to impacting the stocks of natural resources**, resource use also impacts the environment and human health through a sequence of changes in the state of the natural environment**. Life cycle assessment (LCA) methodology provides a framework for describing environmental impacts. A LCA quantifies all physical exchanges with the environment, whether these are inputs (materials, water, land use and energy), or outputs (waste and emissions to air, water and soil). These inputs and outputs are then assessed in relation to specific environmental impact potentials (e.g. climate change, eutrophication, ecotoxicity). These so-called midpoint impacts can then again be related to endpoint impacts such as human health, the natural environment and natural resources.

Socio-economic indicators

Resources have **traditionally been valued in terms of economic market value**, which is determined by supply and demand. The **value of ecosystem services and the impact resource use could have on human well-being** is increasingly gathering attention. Indicators accounting for these externalities seem crucial to provide a consistent picture of resource efficiency in a sustainable global economy. Hence, they should inform of the environmental, economic and social aspects. Indicators of socio-economic benefits are not only limited to the market value of resources, but also the aspects of resource use related to well-being and quality of life that are not measured within the economy.

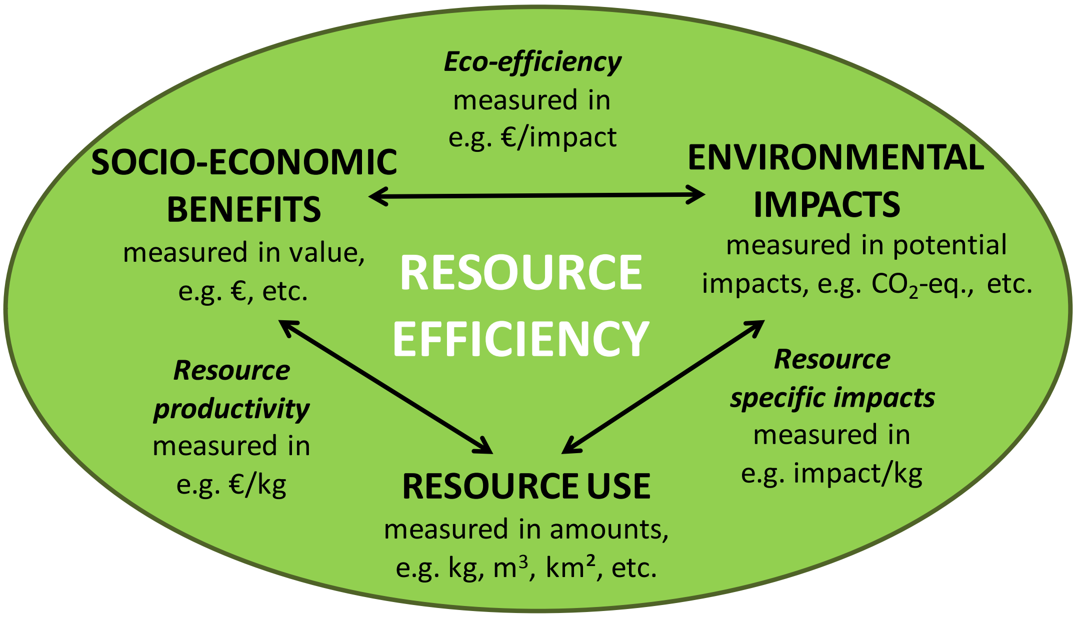

Figure 5: The three indicator categories needed to measure resource efficiency

See Annex A in the Annex Report for a more detailed review of the three types of resource related indicators.

2.3 Existing resource use and resource efficiency targets

Although hundreds of indicators for tracking resource use have been developed, only a few are used to set concrete, quantitative targets. A review of resource use and resource efficiency **related targets in EU Member States, Australia, Canada, China, Japan, Switzerland, and USA**[21], indicate that **the strategic objectives for resource use tend to be general in nature**, with the exception of **GHG emissions and renewable energy.** These are often part of sustainable development strategies or climate action plans. The typical areas covered by targets are related to **sustainable use of natural resources, waste, energy, water and land**. For the EU Member States, most of the **climate change, energy and waste (recycling) targets are driven by EU legislation**.

Based on the Kyoto Protocol, the EU climate and energy package set the "20-20-20" targets.[22] All reviewed countries have set targets related to renewable energy. **Denmark is the first country to set the goal to be fossil fuel independent by 2050**. **Austria, Germany, Italy, Sweden and Japan have specific objectives for material consumption and resource productivity** (based on Material Flow Analysis (MFA) indicators). Japan has been the most advanced and successful in setting targets for resource productivity, cyclical use rate and amount of waste generated. In addition to reuse and recycling targets, some countries such as **Sweden, Finland and France have also set targets for reducing waste generation**.

Besides general national objectives, **some countries have set specific requirements for certain industries and products**, e.g. by share of food and construction products from sustainable sources, energy efficiency of buildings and vehicles. **Targets for the share of agricultural land for organic farming are common in many countries**. **Denmark and Germany have further objectives for land use regarding forest land cover and artificial surfaces**. To promote the conservation and wise use of water, **Canada intends to achieve a 30 % reduction in water use in various sectors by 2025** (based on 2009 water use levels).

Finland, Scotland, Wales, Switzerland and Japan have formally adopted the use of **Ecological Footprint** as an indicator[23]. Many other countries have considered using the indicator officially, but none of the reviewed countries uses it to set targets.

In general, there is little political consensus among national governments for setting targets both nationally and globally. This could partly be due to the **lack of scientific evidence and general agreement on the planet's sustainability thresholds** (see Table 3). Non-governmental organisations and academics are pushing for more targets to be set and have even proposed

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[21] See Annex A for a more detailed review of resource related indicators and targets in EU Member States and selected other countries.

[22] Climate change and energy targets to be met by 2020 (from the EU climate and energy package, 2007):

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
- 20% of EU energy consumption to come from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

[23] Global Footprint Network. www.footprintnetwork.org/en/index.php/GFN/page/ten_in_ten_campaign

specific targets to be integrated into policy. However, most countries are hesitant. Many governments formulate general sustainable development strategies without any time-bound quantitative targets. Although many countries are more concerned about the security of supply for certain critical raw materials than the environmental issues, no targets linked to security of supply have yet been set on national level (China does however set export restrictions on some raw materials).

Table 3: Overview of targets with clear links to environmental thresholds

Target	Suggested threshold
Reduce GHG emission to 80-95% below 1990 levels by 2050	**IPPC:** 350 ppm CO_2 in the atmosphere / 450 ppm CO_2 eq.
Fishing under the Maximum Sustainable Yield (MSY) by 2015	A fish stock is considered to be within safe biological limits (SBL), if the spawning stock biomass is more than approximately 17 % of an unexploited stock.
Water Exploitation Index (WEI)	**EEA:** 10% < WEI < 20% = "low water stress" 20% < WEI < 40% = "stress on water resources" WEI > 40% = "severe water stress".
Land use	**Stockholm Resilience Centre:** up to 15% of global land cover converted to cropland

2.3.1 Resource use related environmental impact indicators

Environmental accounts and indicators using life cycle inventory data are the most common indicators to report on the environmental impacts of resource use. Although life cycle inventory based indicators (e.g. EMC and recent indicators developed by JRC) provide a very comprehensive of environmental impacts, their **main weakness is the quality of current Life Cycle Inventory (LCI) data**. As there are several different environmental issues, it is often desired to have a single indicator to inform of the totality of environmental impacts. However, **every time an indicator is aggregated information is lost** resulting in abstract values and less transparency, particularly if subjective weightings of environmental issues are used. Impact indicators related to environmental thresholds, e.g. Ecological Footprint, Water Exploitation Index, Total Allowable Catches, Environmental Impact Load, Environmental Performance Index; or existing targets, e.g. Sustainability Society Index, are effective when communicating with the general public. The **thresholds themselves are however more interesting to consider for setting resource efficiency targets** than the constructed indicators themselves.

2.4 Approaches to proposing targets for policy

Target oriented policy can be a powerful approach to addressing environmental issues. **A target sets a clear orientation, provides concrete guidance and helps prioritise actions to achieve the policy objective**. If properly enforced and supported by an appropriate mix of policy measures, this can drive policy effectively. Long-term objectives provide actors in society, e.g.

governmental organisations and companies, certainty, stability and time to achieve the target in the most efficient manner. There are several approaches to target setting, among those, four perspectives have been identified[24]:

- The perspective of limitations to the resource base
- The perspective of limitations to absorption capacities of the earth's ecosystems
- The perspective of efficient and equitable resource supply for people
- The perspective of efficient and equitable resource supply for economies

Where knowledge gaps exist, the precautionary principle allows for defining acceptable risks and environmental quality based on the available scientific knowledge on environmental **thresholds and carrying capacity**. For resources such as land, water and fish stocks there is some understanding of the limits to when long-term depletion and degradation occurs. For energy and material resources the limitations of the resource base is not so clear. Instead **the knowledge of the absorption capacities of nature's ecosystems could be used to set a target**. A clear example of this is the limit of a maximum 2°C rise in global mean temperature, or 350 ppm CO_2 in the atmosphere, was used to define EU's GHG emissions targets.

For resources that have global impacts, equity is a central feature. When trying to determine targets that will entail a certain distribution of the benefits of resources, or obligations to carry environmental burdens, it is challenging to determine what is fair. Equity can be seen from the perspective of **'intergenerational equity'** (i.e. not compromising the ability of future generations to meet their needs) and **'intragenerational equity'** (i.e. the fairness of distributing wealth and burdens among communities and countries within one generation). Discussions on equity tend to be ethical (and political), and often lead to great disputes. For example, should policy dictate whether the limited supply of rare earths should be used to produce environmental technologies, medical equipment or mobile phones?

An element often used to determine targets is **the cost-effectiveness of setting a target** and introducing new policy measures (widely used for energy efficiency measures). The relative cost-efficiency of policy measures is typically estimated in impact assessments through the use of cost-benefit analysis, which quantifies the consequences of a measure in monetary units to assess the net present value of costs and (market and non-market) benefits.

An **approach to the target setting process is to arrange open multi-party debates** where representatives of the main stakeholders are brought together to define concrete objectives and plan of actions. The 'Grenelle de l'environnement' process that France instigated in 2007 is an example of such a process[25]. Extensive consultation in this way allows all viewpoints to be heard on an equal level and is a good starting point for building consensus.

As there often is no clear guideline or evidence to set a target, actors acknowledge that the **setting of targets and implementation of measures best can be conceived as a trial and error**

[24] BIO Intelligence Service, IEEP, IFF and Umweltbundesamt (2010) Preparatory study for the Review of the Thematic Strategy on the Sustainable Use of Natural Resources. Study commissioned by the European Commission, DG Environment.

[25] Website for the 'Grenelle' Environment Round Table: www.legrenelle-environnement.fr

process[26]. Sometimes ambitious targets may not be reached due to a number of uncertainties beyond the control of the actors or the lack of successful implementation of the chosen measures. It is then a discussion on **whether it is better to set an ambitious target and only reach it partly, or to set a less ambitious target to be sure it can be achieved**.

Although there is a strong drive to set clear targets to guide resource efficiency policy in the EU, it should be noted that **target oriented policy is not necessarily the best approach**. Depending on how the target is defined, the mix of supporting policy instruments; and how they are implemented, **target setting could lead to unintended negative consequences**. This is of particular importance when considering how the use of resources is interlinked. For example, the targets set for biofuels in transport have significant consequences for land use.

Whatever the approach to setting targets for resource use and efficiency, it is **essential that the targets are based on relevant existing indicators**, and that **the knowledge of resource use and its environmental impacts is well developed.** Indicators representing these two types of indicators are investigated further in the study.

[26] Stockholm Environment Institute and Aarhus University (2011) Implementability of agro-environmental targets in Denmark. Study for the Baltic Sea Region.

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Chapter 3: Evaluation of indicators

The chapter presents the results of the evaluation of the shortlist of indicators most relevant for tracking resource use and the associated environmental impacts. Based on the results from this evaluation, the project team derived a basket of indicators. The strengths and weaknesses of each of the indicators in the basket are provided. Finally, a baseline based on historical data of each of the main indicators is presented to provide an idea of trends, and to compare Member States with each other.

3.1 Methodology

In order to perform the assessment of indicators, the project team developed an evaluation methodology, which contained three parts:

1) A **general evaluation** of the overall robustness of the potential indicators in the portfolio using the so-called **"RACER"** framework. RACER stands for "Relevant, Acceptable, Credible, Easy, Robust" and allowed the general value of scientific tools for use in policy making to be assessed. The RACER framework has already been applied in previous studies on indicators for the Resource Strategy for DG Environment[27]. The "RACER" evaluation provided an overview of the general indicator properties and qualities. Each RACER sub-criterion was answered with a short descriptive text plus a three-level scoring (green: criterion completely fulfilled; orange: criterion partly fulfilled; red: criterion not fulfilled), supporting the visual presentation of the results.
2) A **"specific evaluation"** focusing on key issues related to the implementation of the portfolio of indicators in the context of the Europe 2020 Flagship Initiative and the Resource Strategy. This part comprised a set of specific questions, which were also answered through short descriptive texts. No scoring was applied to this part of the evaluation. The specific evaluation supported the identification of indicators suitable for the basket.
3) An **evaluation summary**, which addressed the question whether the indicator is regarded as a potential candidate for the basket and how it complements other potential indicators in the basket.

Annex B in the Annex Report provides an overview over the applied structure of the evaluation scheme as well as the questions addressed in each part of the evaluation. If the team has specified the allocation of a green, orange or red score, these specifications are also listed in the table.

From an initial list of 47 resource use and resource efficiency indicators collected by the project team, the project team (in discussion with the Commission) selected 29 indicators, which were

[27] Best, A., Giljum, S., Simmons, C., Blobel, D., Lewis, K., Hammer, M., Cavalieri, S., Lutter, S., 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. Report to the European Commission, DG Environment. Brussels.

evaluated with the scheme described above. The full list of evaluated indicators can be seen in Table 4. The initial list of indicators can be found in Annex B in the Annex Report.

Table 4: List of indicators covered in the evaluation

Category	Resource/Issue	Indicator
Materials	***Aggregated materials***	
	Material consumption	**Domestic Material Consumption (DMC) [absolute / per capita]**
		Raw Material Consumption (RMC) [absolute / per capita]
	Environmental impacts	
	Environmental impacts of material consumption	**Environmentally-weighted consumption (EMC)**
		Overall environmental impacts indicator
	Biomass	
	Animal biomass	**Animal products in nutritional energy**
	Biomass trade	**$PTB_{biomass}$**
		$RTB_{biomass}$
	Fisheries	**Fish capture production per Total Allowable Catch (TAC)**
	Metal ores	
	Reuse, recycling, recovery	**Recovery/reuse/recycling rates for specific metals**
	Minerals	
	Reuse, recycling, recovery	**Secondary construction minerals per $DMC_{construction\ minerals}$**
	Waste	
	Waste generation	**Municipal Solid Waste**
	Hazardous waste	**Generation of hazardous waste**
Energy & GHG emissions	***Energy***	
	Energy consumption	**Gross inland energy consumption [total, by energy source]**
	GHG emissions	
	GHG emissions	**Territorial (production-based) GHG emissions [absolute / per capita]**
		Carbon Footprint (consumption-based) GHG emissions [absolute / per capita]
Water	Water abstraction	**Water Exploitation Index**
	Water consumption	**Water Footprint of countries**
Land and soil	Global land use	**Actual land demand**
	Land conversion	**Net-growth of built-up land / of soil sealing**
	Ecosystem quality	**Indicators on ecosystem quality / biodiversity**
		Intensity of land use/HANPP
	Soil	**Carbon content; nutrient balances (N, P)**
		Soil erosion
Response indicators	Taxes	**Environmental taxes (% of government budget)**
	Subsidies	**Energy (plus potentially material) subsidies**
	Eco-innovation	**Innovations with positive environmental effects**
	Investments	**New investments in green technologies**

Note: Energy subsidies were initially planned to be evaluated, however, due to lack of any reliable and recent data, this indicator was dropped from the list by the team. Note also that the two recycling indicators (metals and construction minerals) were evaluated within one evaluation scheme.

In addition to the evaluation of the single indicators, also the basket of indicators was evaluated using the three-part evaluation framework.

3.2 Results from the RACER evaluation

The following two pages present the summary evaluation tables generated through the RACER-part of the evaluation. Note that the columns with the big RACER letters illustrate the un-weighted average score of all sub-categories within the respective RACER pillar. Note also that the criteria on "acceptance" could not be evaluated for the Life-Cycle Resource Indicator by JRC, because the indicator is only now being developed. The full results of the detailed evaluations for all indicators can be found in Annex B in the Annex Report.

The third last column in the summary tables illustrates whether an indicator is comprehensive, i.e. whether it includes several or all relevant aspects related to the respective resource use category. For example, in the case of material use, the first two indicators (DMC and RMC) include all types of materials, whereas the other indicators (e.g. animal products in nutritional energy, fish capture, or recycling rates) focus on specific issues related to selected material flows. This separation according to comprehensiveness was important for deriving the basket of indicators (see below). The headline indicators suggested for the basket (Level 1; marked blue in the following table) are all comprehensive indicators, which cover all respective aspects. The indicators on Level 2 complement the headline indicators by focusing on specific issues.

The last two columns in the table show whether an indicator is mainly focused on resource use (i.e. environmental pressures) or oriented towards measuring environmental impacts related to resource use. This distinction was also crucial for deriving the basket of indicators, which contains both resource use-oriented and environmental impact-oriented indicators (see Table 7).

The summary table illustrates that the indicators perform very differently across the set of RACER criteria. No indicator completely fulfilled all criteria. In general, the headline indicators selected for the basket (Level 1) perform well, with most evaluation criteria being completely or partly fulfilled. Exceptions are the indicators on environmental impacts of resource use, which lack acceptance with regard to several groups of actors (partly because the environmental impact indicator by JRC is still in the stage of development). Another exception are those indicators, which apply a fully territorial perspective (e.g. territorial GHG emissions, Water Exploitation Index and HANPP) and are therefore not able to illustrate burden shifting through international trade.

Table 5: Summary results from RACER evaluation

Resource category / Issue	Indicator	R	R.1: Policy support	R.2: Policy support	R.3: Sensitiveness	R.4: Rebound effects	R.5: Past trends	R.6: Future trends	R.7: Early warning	A	A.1: Policy makers	A.2: Statistics	A.3: Business / Industry	A.4: Academia	A.5: Civil society	C	C.1: Unambiguous results	C.2: Transparency	E	E.1: Availability of data	E.2: Availability of calculated indicator	E.3: Technical feasibility	R	R.1: Data quality	R.2: Level of aggregation	R.3: Reproducibility	R.4: Geographical scale	R.5: Burden shifting	Sufficient comprehensiveness
Material use																													
Material consumption	***Domestic Material Consumption (DMC)***	Green	Green	Green	Green	Orange	Green	Green	Orange	Green	Green	Green	Orange	Green	Orange	Green	Green	Green	Green	Green	Orange	Green	Green	Green	Green	Green	Green	Orange	Green
	Raw Material Consumption (RMC)	Green	Green	Green	Orange	Green	Orange	Green	Orange	Orange	Orange	Orange	Orange	Green	Orange	Orange	Green	Orange	Orange	Green	Orange	Orange	Green	Green	Green	Orange	Green	Green	Green
Environmental impacts of material consumption	***Environmentally-weighted consumption (EMC)***	Orange	Green	Orange	Orange	Green	Orange	Orange	Orange	Red	Orange	Red	Red	Orange	Red	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Green	Green
	Life-cycle resource indicator	Orange	Green	Orange	Orange	Green	Red	Orange	Orange		Orange					Orange	Orange	Orange	Orange	Orange	Red	Orange	Orange	Orange	Orange	Orange	Orange	Green	Green
Animal biomass	**Animal products in nutritional energy**	Green	Green	Green	Orange	Orange	Green	Green	Orange	Green	Orange	Green	Orange	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Green	Green	Green	Green	Green	Red	Red
Biomass trade	**PTB** biomass	Green	Green	Green	Green	Orange	Green	Orange	Orange	Orange	Green	Green	Red	Green	Orange	Orange	Orange	Green	Green	Green	Orange	Green	Green	Green	Green	Green	Green	Orange	Red
	RTB biomass	Orange	Green	Green	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Red	Green	Red	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Green	Green	Green	Red	Green	Green	Red
Fisheries	**Fish capture production per Total Allowable Catch (TAC)**	Green	Orange	Green	Green	Orange	Green	Orange	Green	Green	Green	Green	Green	Orange	Green	Green	Green	Green	Orange	Green	Orange	Orange	Green	Green	Green	Green	Green	Orange	Red
Reuse, recycling, recovery	**Recycling Input Rate (RIR)**	Orange	Orange	Green	Orange	Red	Red	Orange	Orange	Orange	Orange	Red	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Red	Red	Green	Orange	Red	Green	Red	Green	Red	Red
Waste generation	**Municipal Solid Waste**	Green	Green	Green	Green	Green	Orange	Orange	Orange	Green	Green	Green	Green	Green	Green	Orange	Orange	Orange	Green	Green	Green	Green	Orange	Orange	Green	Orange	Green	Red	Red
Hazardous waste	**Generation of hazardous waste**	Green	Green	Green	Green	Green	Orange	Orange	Orange	Green	Green	Green	Green	Green	Green	Orange	Orange	Green	Green	Orange	Green	Green	Green	Green	Green	Green	Green	Red	Red
Energy use & GHG emissions																													
Energy consumption	***Gross inland energy consumption (GIC)***	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Green	Orange	Orange	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green
GHG emissions	***Territorial (production-based) GHG***	Green	Green	Green	Green	Orange	Green	Green	Green	Orange	Orange	Green	Green	Orange	Orange	Orange	Orange	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red	Green
	Carbon Footprint (consumption-based GHG emissions)	Green	Green	Green	Green	Green	Orange	Orange	Green	Orange	Orange	Orange	Green	Orange	Green	Orange	Green	Orange	Orange	Orange	Green	Orange	Orange	Orange	Green	Orange	Green	Green	Green

Green	... criterion completely fulfilled
Orange	... criterion partly fulfilled
Red	... criterion not fulfilled
Blue (in italics)	... indicator selected for the basket

Resource category / Issue	Indicator	R	R.1: Policy support	R.2: Policy support	R.3: Sensitiveness	R.4: Rebound effects	R.5: Past trends	R.6: Future trends	R.7: Early warning	A	A.1: Policy makers	A.2: Statistics	A.3: Business / Industry	A.4: Academia	A.5: Civil society	C	C.1: Unambiguous results	C.2: Transparency	E	E.1: Availability of data	E.2: Availability of calculated indicator	E.3: Technical feasibility	R	R.1: Data quality	R.2: Level of aggregation	R.3: Reproducibility	R.4: Geographical scale	R.5: Burden shifting	Sufficient comprehensiveness
Water use																													
Water abstraction	***Water Exploitation Index***	Orange	Green	Orange	Green	Orange	Orange	Orange	Green	Orange	Green	Green	Orange	Orange	Orange	Orange	Orange	Green	Green	Orange	Green	Green	Orange	Orange	Orange	Orange	Orange	Red	Green
Water consumption	***Water Footprint***	Green	Green	Orange	Green	Green	Orange	Orange	Green	Green	Orange	Orange	Green	Green	Green	Green	Green	Green	Orange	Orange	Orange	Green	Orange	Orange	Orange	Green	Orange	Green	Green
Land and soil																													
Global land use	***Actual land demand***	Orange	Orange	Orange	Green	Green	Green	Orange	Orange	Orange	Orange	Orange	Orange	Green	Orange	Green	Green	Green	Orange	Green	Orange	Orange	Green	Green	Green	Orange	Green	Green	Green
Land conversion	**Net-growth of built-up land / of soil sealing**	Orange	Orange	Green	Red	Green	Orange	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Green	Green	Orange	Orange	Red	Green	Green	Green	Orange	Green	Green	Red	Red
Ecosystem quality	**Abundance and distribution of selected species**	Green	Green	Green	Orange	Orange	Green	Green	Green	Green	Green	Green	Orange	Green	Green	Orange	Orange	Orange	Orange	Orange	Green	Orange	Orange	Green	Green	Orange	Orange	Orange	Green
	Intensity of land use	Orange	Orange	Orange	Orange	Orange	Green	Orange	Orange	Orange	Orange	Green	Red	Green	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Green	Orange	Green	Orange	Green	Green	Red	Green
	HANPP	Orange	Orange	Orange	Red	Orange	Green	Orange	Orange	Orange	Green	Orange	Orange	Green	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Green	Orange	Green	Orange	Green
Soil	**Carbon content**	Orange	Orange	Green	Orange	Green	Red	Orange	Green	Green	Green	Orange	Orange	Green	Green	Orange	Green	Orange	Orange	Orange	Red	Orange	Orange	Green	Orange	Orange	Orange	Orange	Green
	Nitrogen balance	Orange	Orange	Green	Green	Orange	Orange	Green	Green	Green	Green	Orange	Orange	Green	Green	Orange	Orange	Green	Green	Green	Green	Green	Orange	Orange	Orange	Green	Orange	Orange	Red
	Phosphorus balance	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Green	Orange	Orange	Orange	Orange	Green	Orange	Orange	Orange	Orange	Green	Green	Green	Green	Orange	Orange	Orange	Green	Green	Orange	Red
	Soil erosion	Orange	Orange	Green	Orange	Green	Red	Orange	Orange	Green	Green	Orange	Green	Orange	Green	Orange	Orange	Orange	Orange	Red	Orange	Orange	Orange	Orange	Orange		Orange	Orange	Red
Response indicators																													
Taxes	**Environmental taxes (% of government budget)**	Green	Orange	Green	Green	Orange	Green	Orange	Green	Green	Green	Green	Orange	Green	Orange	Orange	Orange	Green	Green	Green	Green	Green	Orange	Orange	Green	Green	Orange		Red
Eco-innovation	**Innovations with positive environmental effects**	Orange	Green	Green	Orange	Red	Orange	Orange	Green	Orange	Orange	Green	Orange	Green	Red	Orange	Orange	Green	Green	Orange	Green	Green	Orange	Orange	Green	Green	Orange		Red
Investments	**Investments in green technologies**	Orange	Green	Green	Green	Red	Orange	Orange	Green	Orange	Orange	Red	Green	Red	Red	Orange	Green	Red	Orange	Orange	Orange	Green	Orange	Orange	Green	Green	Orange		Red

Green	... criterion completely fulfilled
Orange	... criterion partly fulfilled
Red	... criterion not fulfilled
Blue (in italics)	... indicator selected for the basket

3.3 General structure of the basket

Before presenting the suggested basket and its indicators, the general properties and the structural composition of the basket are explained.

3.3.1 Two levels: headline indicators and specific indicators

The suggested basket comprises a set of aggregated headline indicators on the top level and is accompanied by more specific indicators on a second level. The basket of indicators was split into two levels. Level 1 contains a core set of headline indicators, which provide information on the general direction of development of the EU with regard to the four key categories of resource use: material use, energy use and climate, water use and land use. The indicators on Level 1 are therefore those indicators, which represent each resource category in the most comprehensive manner. This set of headline indicators is accompanied by a second level, which comprises indicators addressing specific questions *within* each resource category (e.g. fisheries in the category of materials, built-up land in the category of land use, etc.). Table 6 illustrates the basic two-level structure.

Table 6: The two-level structure of the basket of indicators

	Issues covered by Level 1 indicators	Issues covered by Level 2 indicators
Material use	• Aggregated material use	• Material use by major material group • Material use by economic activities • Recycling of materials • Waste generation
	• Aggregated environmental impacts of material use	• Environmental impact by impact categories (e.g. eutrophication, toxic impacts, resource depletion, etc.)
Energy use and climate	• Aggregated energy use	• Energy use by fuel type • Energy use by economic activities
	• Aggregated GHG emissions	• GHG emissions by GHGs (e.g. CO_2, CH_4, NH_3, etc.) • GHG emissions by economic activities
Water use	• Aggregated water use	• Water use by water source (e.g. blue/green water) • Water use by economic activities
	• Aggregated water scarcity	• Water scarcity by region
Land use	• Aggregated land use	• Land use by land type • Land conversions / land cover changes
	• Aggregated impacts of land use	• Soil indicators (e.g. carbon content) • Nutrient balances • Ecosystem quality indicators

For target setting, Level 1 indicators reflect the overall policy objectives, while Level 2 indicators allow monitoring the measures to achieve those overall objectives. The two-layer structure thus of the basket has clear implications for monitoring targets. For Level 1 indicators, overall targets for aggregated resource use can be defined (e.g. reduction of EU's material consumption by x% until the year 2030; reduction of EU's Carbon Footprint by x% by 2050, etc.; see Task 4). Achieving those overall objectives requires implementing (policy) measures, such as measures to increase recycling rates or market-based instruments (such as environmental taxes). Those measures can be monitored with the indicators on Level 2.

The following concentrates on the headline indicators on Level 1. A complete analysis and description of the Level 2 indicators is beyond the scope of this project.

3.3.2 Two modules: resource use-oriented and environmental impact-oriented indicators

Both resource use-oriented and environmental impact-oriented indicators are required to monitor a successful resource use policy in Europe. The basket of indicators is therefore split into two parts. The part with resource use indicators closely relates to the drivers of resource use in the socio-economic system, monitoring e.g. material consumption or energy use of a country or the EU. Addressing issues such as resource scarcities, access to resources, import dependencies and increased competitiveness driven by improved resource productivity require measuring Europe's resource use in absolute physical amounts. Also issues of international distribution and a global fair share of different types of natural resources can only be addressed with indicators in absolute amounts.

From an environmental perspective, however, reducing the negative environmental impacts associated with our resource use (including issues such as climate change, ecosystem quality and biodiversity, toxic impacts on humans and ecosystems, etc.) is the key policy objective. The environmental impact-oriented indicators suggested for inclusion in the basket therefore have a stronger link to the state of the environment. Table 7 summarises the main arguments for considering both resource use-oriented and environmental impact-oriented indicators in the basket.

Table 7: Issues addressed by resource use-oriented and environmental impact-oriented indicators

Resource use-oriented indicators	Environmental impacts-oriented indicators
• **Absolute amounts of resource use (quantity)** • **Close link to socio-economic drivers** • **Issues: access and scarcity, competitiveness, import dependency, global distribution** • **Necessary for designing and monitoring measures to achieve reduction of impacts**	• **Environmental impacts of resource use (quality)** • **Close link to ecosystem functioning and environmental thresholds** • **Issues: climate change, biodiversity, toxic impacts on humans and ecosystems, etc.**

3.3.3 Two perspectives: domestic resource use and global resource demand

Another line of distinction of the indicators suggested for the basket is the differentiation between indicators reflecting domestic resource use versus indicators illustrating the global resource demand. Indicators in the former category comprise all resources, which are directly used for domestic production and consumption activities. Thus they include domestically extracted resources plus direct imports and exports, which actually cross the country border (in the case of land use, this category comprises only domestic land use, as land is not physically crossing borders). The latter group of indicators additionally includes resources embodied in internationally-traded products.[28] Those indicators are therefore suitable to monitor the total global resource demand associated with European production and consumption, including resources used outside the EU borders to produce imported goods. Those indicators with a global scope are in line with EU policy documents, which ask for applying a life-cycle perspective in environmental policy, in order to reflect possible outsourcing of environmental burden from the EU to other world regions. At the same time, this approach poses challenges to EU resource policy making, as the policy sphere is extended to a level beyond EU borders. Issues on whether and how to share environmental responsibility between producing and consuming countries are brought on the agenda through those types of indicators, as the debate on climate change illustrates.

3.3.4 Other important features of the basket

The indicators suggested for the basket are consistent in terms of boundary setting and accounting principles. All resource use-oriented indicators in the basket and some of the environmental impact-oriented indicators (e.g. energy/climate and water) are derived from environmental accounts and thus have a strong link to the statistical system and integrated economic-environmental accounting frameworks such as SEEA or NAMEA. They share a common understanding of where to draw the accounting line between the natural and the socio-economic system.

All indicators suggested for the basket can be linked to economic data to establish indicators on resource efficiency. As agreed with the Commission, the focus of the evaluations in this project was put on indicators in absolute numbers. These indicators are the relevant ones to monitor for whether pressures and impacts on the environment are increasing or decreasing. However, all suggested indicators can be linked to economic data, such as GDP on the country level or output/value added on the sectoral level, in order to assess the resource efficiency/productivity of Europe's resource use. Also when assessing whether de-coupling can be observed between economic growth and resource use and environmental impacts, respectively, this requires linking indicators in physical units with indicators on economic value in monetary units.

The basket of resource use indicators needs to be complemented by other indicators informing about environmental risks. The suggested basket informs about EU's resource use in a very comprehensive manner, covering all main resource use categories. However, it is important to emphasise that issues related to some environmental risks cannot be covered, which are particularly important in a long-term and intergenerational perspective. The most prominent examples are risks due to the use of chemicals, nuclear energy and the use of genetically-modified organisms (GMOs). None of the suggested indicators can reflect the risks

[28] Those resources are also called "indirect", "virtual" or "hidden" resource flows in the literature.

(and impacts) of a nuclear accident or quantify the risks of negative impacts of GMOs on the gene pool of non-modified species. If policy targets for phasing out potentially high risk technologies are set, additional indicators are required to monitor success or failure of those policies.

3.4 Suggested basket of indicators

The following table provides an overview over the suggested basket of indicators on Level 1. As described above, the basket is split into a resource use-oriented and an environmental impact-oriented part on the one hand, and indicators on domestic resource use and global resource demand on the other hand. For both modules the project team suggested a set of eight indicators to cover the main categories of resource use: materials, energy and climate, water and land. The basket of indicators thus comprises four indicators per resource category: two indicators reflecting the underlying environmental pressures (e.g. for material use: Domestic Material Consumption and Raw Material Consumption), the other indicator reflecting the resulting environmental impacts (e.g. for material use: the territorial part of the Life-Cycle Resource Indicator and the full Life-Cycle Resource Indicator including impacts embodied in traded products). It should be noted that the project team has strived to propose a basket of indicators that is both concise and comprehensive.

Table 8: The basket of resource use relevant indicators

	Resource use-oriented		Environmental impact-oriented	
	Domestic resource use *(resources directly used for domestic production and consumption)*	***Global resource demand*** *(domestic resource use plus resource use embodied in trade)*	***Environmental impacts related to domestic resource use***	***Environmental impacts related to global resource demand***
Material use	Domestic material use Domestic Material Consumption	Global material demand Raw Material Consumption	*Territorial part of* Life-Cycle Resource Indicator (*of Environmentally-weighted Material Consumption)**	Life-Cycle Resource Indicator (*Environmentally-weighted Material Consumption)**
Energy use and climate	Domestic energy use Gross Inland Energy Consumption	Global energy demand Energy Footprint	Domestic GHG emissions Territorial GHG Emissions	Global GHG emissions Carbon Footprint
Water use	Domestic water use Water consumption *(Water abstraction)**	Global water demand Water Footprint	Domestic water exploit. Water Exploitation Index	Global water exploit. Global Water Consumption Index
Land use	Domestic land use Domestic Land Demand	Global land demand Actual Land Demand (Land Footprint)	Domestic LU intensity Human Appropriation of Net Primary Production	Global LU intensity *eHANPP, LEAC and other indicators on ecosystem quality*

Note: * ... short-term proxy indicator for the medium-term desired indicator

Most of the indicators in the column 'domestic resource use' are existing indicators. Several of them, such as Domestic Material Consumption, Water abstraction or Territorial GHG emissions are compiled through statistical routines. Other indicators are being developed by environmental agencies (such as the land use accounts by EEA, from which Domestic Land Demand is derived) or by academic groups (such as Environmentally-weighted Material Consumption or Human Appropriation of Net Primary Production). From the group of indicators on global resource demand, some are currently being tested with pilots (for example, Raw Material Consumption, Actual Land Demand, Water Footprint or Carbon Footprint). The Global Water Consumption Index was introduced in this study.

It has to be noted that JRC's life cycle resource indicators overlap with other indicators. The impacts of water, energy and land use are all covered in the JRC indicators. This issue was raised at the Second Progress Meeting, however it was seen as unavoidable by the participants as all the indicators are closely linked. Besides, each of the selected indicators has a particular focus, which is policy relevant. There is no way to develop a single indicator to cover all the different aspects of resource efficiency; therefore the Life-Cycle Resource Indicator is not a substitute to other indicators of the basket but rather a useful complement.

Note that the cell with environmental impact-oriented indicators for the category of land use in the global perspective could not be filled with a concrete suggestion for an indicator. This reflects the fact the indicators measuring ecosystem quality and the links between land use and biodiversity are still under development by various organisations and research groups. Therefore, only the most promising candidates are listed as a group here (including embodied HANPP (eHANPP) and the Land and Ecosystem Accounts (LEAC) developed by the EEA).

Note also that the RACER evaluation is biased towards established indicators that can be used immediately. For example, the DMC indicator received generally higher scores in the RACER evaluation across all criteria, as the methodology is already internationally harmonised and well accepted and reliable data sets in time series exist. Still, the project team suggests RMC as a key indicator for the perspective of global demand, as RMC includes the up-stream (or indirect) material flows of internationally traded products and is thus more robust than DMC against the outsourcing of environmental pressures to other world regions. This information on the higher robustness is available from criterion "R.5 Burden shifting" in the RACER evaluation, where RMC scores higher than DMC. This aspect is also evident in the specific evaluation under "Territory vs. Life-cycle perspective".

For each of the indicators suggested for the basket, the following two tables summarise the strengths and the reasons, why the team has suggested selecting the respective indicator for the basket. Also, the main weaknesses and areas for improvement are listed.

Table 9: Strengths and weaknesses of resource use-oriented indicators in the basket

	Resource use-oriented indicators	
Resource type	***Domestic resource use***	***Global resource demand***
Material use	*Name:* **Domestic Material Consumption (DMC)** *Definition:* DMC = domestic extraction (DE) + imports – exports *Unit of measurement:* tonnes *Data:* for all EU-27 countries; 2000-2007 *Methodology:* Eurostat/OECD handbooks available *Decomposition:* by material groups; by sectors (through linking with input-output tables) *Strengths:* • Readily available in terms of methodological harmonisation and underlying data sources • Available in historical time series and thus allowing analysing past trends • Easy to compile, transparent and comparable to economic accounts and indicators • Covers all material resources used within an economy in a systemic way *Weaknesses:* • DMC does not include upstream material requirements of traded goods and thus cannot adequately capture burden shifting through outsourcing of material-intensive production	*Name:* **Raw Material Consumption (RMC)** *Definition:* RMC = DE + Raw Material Equivalents (RME) of imports – RME of exports *Unit of measurement:* tonnes *Data:* Pilot data for EU-27 by end of 2011; pilot data for single MS (DE, AT, CZ) already available *Methodology:* currently being developed by Eurostat and other research groups *Decomposition:* by material groups; by sectors (through linking with input-output tables) *Strengths:* • Covers all material resources used within an economy in a systemic way • In contrast to DMC, applies a truly consumption-oriented approach enabling to identify material requirements along the production chain – including those which are satisfied via imports from other countries. As such it enables assessing outsourcing of environmental burden *Weaknesses:* • More difficult to compile than DMC, as additional calculations and modelling are required • Methods and data for calculating RMC are not harmonised and standardised yet; however, pilot projects have or are being finalised both on the MS and the EU-27 level
Energy use and climate	*Name:* **Gross Inland Energy Consumption (GIEC)** *Definition:* GIEC = primary energy produced domestically + net imports + variations of stocks + recovered products - bunkers *Unit of measurement:* tonnes of oil equivalents *Data:* Available from Eurostat in long time series *Methodology:* established and internationally harmonised *Decomposition:* by fuel type *Strengths:* • Data reported on a regular basis from official sources • Widely accepted indicator that has been used for target setting before • Congregates many drivers for one of the most important environmental pressures, i.e. energy consumption *Weaknesses:* • Does not include upstream primary energy requirements of traded goods (including energy/electricity imports) and thus does not fully capture burden shifting • Aggregates a range of energy sources with highly varying environmental impacts, hampering unambiguous interpretation with regard to environmental impacts	*Name:* **Energy Footprint (EnF)** *Definition:* EnF = domestic primary energy production + primary energy embodied in imported products minus primary energy embodied in exported products *Unit of measurement:* tonnes of oil equivalents *Data:* Not yet available *Methodology:* currently being developed by academic groups *Decomposition:* by fuel type, by product type *Strengths:* • Major parts of the necessary data to calculate indicator are reported on a regular basis from official sources • Congregates many drivers for one of the most important environmental pressures: energy consumption • In contrast to GIEC, EnF fully captures burden shifting through inclusion of the indirect energy requirements of imported and exported products *Weaknesses:* • Requires additional calculations and modelling to assess energy equivalents of imports and exports • No defined and agreed methodology and, hence, data for the indicator do not exist yet. However, the approach is closely related to the Energy Flow Accounting framework and thus can be developed with reasonable efforts.

	Resource use-oriented indicators	
Resource type	***Domestic resource use***	***Global resource demand***
Water use	*Name:* **Water consumption (WC); proxy: Water abstraction (WA)** *Definition:* Blue water consumption (Blue water extraction) *Unit of measurement:* cubic metres (m^3) *Data:* Available by EEA/Eurostat for various years *Methodology:* currently being refined by Eurostat *Decomposition:* by water source (groundwater, surface water) *Strengths:* • Subject of Joint Questionnaire of Eurostat and OECD • Comparable data for all European countries *Weaknesses:* • Available data are patchy and partly of low quality • Only blue water is covered, green and grey water is omitted • Data only available for the national level, not the level of water basins, which would be more reasonable • Data are currently only available for water abstraction, not water consumption	*Name:* **Water Footprint (WF)** *Definition:* Volume of blue and green water needed for the production of the goods and services consumed by the inhabitants of a country *Unit of measurement:* cubic metres (m^3) *Data:* Available for one year by Water Footprint Network *Methodology:* WFN manual available *Decomposition:* by blue/green water; by product groups *Strengths:* • Elaborated accounting concept, which is steadily further developed by the Water Footprint Network community • High level of disaggregation of data, especially in the agricultural sector *Weaknesses:* • Crude methodology for accounting WF In industrial sectors, based on an LCA -type approach • So far, data only available as average for 1995-2005
Land use	*Name:* **Domestic Land Demand (DLD)** *Definition:* Land directly under human use, including agricultural, forestry and built-up land *Unit of measurement:* square kilometres (km^2) *Data:* Available from EEAs CORINE system for 1990, 2000 and 2006 *Methodology:* EEA methodological standards *Decomposition:* by land categories *Strengths:* • Clear measure of share of total area under human use • Considers land use for biomass extraction as well as built-up. • Data for compilation of DLD are available from CORINE. • DLD is credible, transparent, and robust *Weaknesses:* • Aggregates different types of uses (along with their differences in environmental impact). • The methodology for compiling DLD is not standardised yet. • DLD does not include land requirements of traded goods and thus does not capture burden shifting through international trade	*Name:* **Actual Land Demand (ALD) (Land Footprint)** *Definition:* Land area associated with a country's final consumption, including land embodied in imports and exports. *Unit of measurement:* square kilometres (km^2) *Data:* Only pilot data for selected countries available *Methodology:* Available from academic groups *Decomposition:* by land categories *Strengths:* • ALD is rather easy to compile, transparent, robust, comparable to economic accounts and indicators • ALD applies a consumption-oriented approach enabling to identify global burden shifting • Has been applied in pilot studies for biomass *Weaknesses:* • Data on built-up land difficult to obtain on the global level • Regarding agricultural and forestry land: cannot account for impacts on land other than harvest. • The methodology for compiling ALD is quite straight forward, however, it's not standardised yet.

Table 10: Strengths and weaknesses of environmental impact-oriented indicators in the basket

	Environmental impact-oriented indicators	
Resource	*Related to domestic resource use*	*Related to global resource demand*
Material use	*Name:* **Territorial part of Life-cycle resource indicator (LCRI); proxy: Territorial part of Environmentally weighted Material Consumption (EMC)** *Definition:* This indicator reflects the environmental impacts related to domestic resource extraction and domestic emissions. *Unit of measurement:* different units of environmental impacts; aggregated: unknown (LCRI), dimensionless index (EMC) *Data:* LCRI: Available for EU-27 aggregated and Germany; 2004-2006; EMC: Available for EU countries, 1990-2000 *Methodology:* LCRI: Currently being developed by JRC/Ispra; EMC: Developed by CML/University of Leiden *Decomposition:* by products groups contributing to impacts; by impact categories *Strengths:* • Illustrates the environmental impacts caused by material extraction and emissions within the EU territory • Directly linked to a large number of environmental impacts *Weaknesses:* • Does not take into account the environmental impacts caused in other countries in world regions due to imported and exported products	*Name:* **Life-cycle resource indicator (LCRI) ; proxy: Environmentally weighted Material Consumption (EMC)** *Definition:* This indicator shows the environmental life-cycle impacts associated with the consumption of goods in a country taking into account imported and exported goods. *Unit of measurement:* different units of environmental impacts; aggregated: unknown (LCRI), dimensionless index (EMC) *Data:* LCRI: Available for EU-27 aggregated and Germany; 2004-2006; EMC: Available for EU countries, 1990-2000 *Methodology:* LCRI: Currently being developed by JRC/Ispra; EMC: Developed by CML/University of Leiden *Decomposition:* by products groups contributing to impacts; by impact categories *Strengths:* • The LCRI starts from statistics of production of goods, thus easier to link to LCA impact factors; has potential to be developed into robust impact indicator • The LCRI (and the EMC) are directly linked to a large number of environmental impacts • The LCRI (and the EMC) take a life-cycle perspective and thus fully capture burden shifting • The LCRI not only covers impacts of materials, but also of water and land use, and emissions *Weaknesses:* • Currently, only 15 product groups are covered on imports and exports by the LCRI • The LCRI (and the EMC) lack in data quality (LCA factors), availability and credibility and thus has potentially low acceptance within stakeholders • The results depend on the weighting of different impact categories and thus is not objective

	Environmental impact-oriented indicators	
Resource	***Related to domestic resource use***	***Related to global resource demand***
Energy use and climate	*Name:* **Territorial GHG emissions (TerrGHG)** *Definition:* All GHG emissions under the Kyoto Protocol from anthropogenic sources. Issus related to land use change can be included. *Unit of measurement:* tonnes of CO_2 equivalents *Data:* Available for all EU countries in Kyoto Protocol *Methodology:* Standardised in UNFCCC framework *Decomposition:* by type of GHG emission; by economic activities *Strengths:* • GHG emissions are directly linked with climate change – one of the most pressing environmental problems • Accounts of territorial GHG emissions and LULUCF are readily available in terms of methodological harmonisation and underlying data sources → very good data basis • Indicator is available in historical time series and thus allows for analysing past trends • Indicator is transparent, robust and directly linkable to economic accounts and indicators *Weaknesses:* • Indicator does not include upstream GHG emissions of traded goods and thus cannot capture burden shifting • Indicator is not accepted by an increasing number of countries (in particular, non-OECD countries) and parts of the civil society impeding the ongoing post-Kyoto negotiations	*Name:* **Carbon Footprint (CF)** *Definition:* Covers all GHG emissions released globally in order to satisfy the final demand of a country, thus includes embodied emissions of traded goods. *Unit of measurement:* tonnes of CO_2 equivalents *Data:* Available for around 100 countries from different academic groups *Methodology:* Not standardised yet; multi-regional input-output modelling favoured approach *Decomposition:* by type of GHG emission; by economic activities; by geographical region, where emissions occur *Strengths:* • GHG emissions are directly linked with climate change – one of the most pressing environmental problems • In contrast to the Territorial GHG emissions, CF applies a consumption-oriented approach enabling to capture GHG emissions along the production chain. As such it enables to trace back the outsourcing of environmental burdens. • CF would be potentially accepted by those parties at the post-Kyoto negotiations which are obstructing any progress at the moment *Weaknesses:* • Methods and data for calculating CF are not harmonised and standardised yet • Data quality, easiness and transparency lag behind the mere territorial GHG indicator, due to the complexity of the methodology, big data requirements and limited availability of highly disaggregated harmonised economic data for a large number of countries.
Water use	*Name:* **Water Exploitation Index (WEI)** *Definition:* Annual abstraction of fresh water (blue water) divided by the long-term average freshwater resources *Unit of measurement:* index (in %) *Data:* Available by EEA for EU-27 countries and selected years *Methodology:* Available from EEA *Decomposition:* only by countries (future potential: by regions) *Strengths:* • Describes how total water abstraction puts pressure on domestic water resources • Identifies countries which have high abstraction in relation to their resources and therefore are prone to suffer problems of water stress • Data available at Eurostat and regularly calculated by EEA *Weaknesses:* • Data on national level does not take account of regional / water shed differences • Indicator focuses on water abstraction not on water consumption • Data patchy and often of low quality • No consideration of water stress posed on other countries through water imports	*Name:* **Global Water Consumption Index (WCI)** *Definition:* Annual direct and indirect consumption in a water shed of blue and green water divided by the long-term average freshwater resources in the water shed *Unit of measurement:* index (in %) *Data:* not yet available *Methodology:* not yet developed *Decomposition:* in the future: by blue/green water; by geographical region, where water uptake takes place *Strengths:* • Includes blue and green water • Includes direct and indirect consumption, thus considers effects of international trade • Assesses water consumption, not only water abstraction • Water shed level, not only national level • Includes global perspective *Weaknesses:* • Indicator very difficult to calculate with high data requirements • Considerable effort in setting up accounting principles and creating data • Possibly not available in the next 5 years

	Environmental impact-oriented indicators	
Resource	***Related to domestic resource use***	***Related to global resource demand***
Land use	*Name:* **Human Appropriation of Net Primary Production (HANPP)** *Definition:* HANPP is the difference between the amount of energy that would be available in an ecosystem in the absence of human activities and the amount which actually remains in the ecosystem after human interference. *Unit of measurement:* index (in %) *Data:* Available for selected countries; no consistent time series; globally only for year 2000 *Methodology:* developed by academic groups; largely standardised *Decomposition:* by land use categories *Strengths:* • Aggregate output and structural change indicator covering different forms of land use (agriculture, forestry, built-up, natural areas) • Includes harvest and land conversion as two of the major human interventions into ecosystem energy flows. *Weaknesses:* • Not an input-side land use indicator (requires supplementary data on nutrient balances and land degradation) • Not fully unambiguous as impacts of land use as well as ecosystem quality do not necessarily correlate with HANPP • Does not take into account traded goods and the according land use related burden shifting.	*Name:* **eHANPP, LEAC and other land use indicators** *Comment:* Further development of HANPP (including HANPP embodied in traded products) or the development of alternative land use indicators is needed in order to attain more suitable environmental impact-oriented indicators for land use. *Data:* pilot data available for eHANPP and LEAC *Methodology:* still under development by various groups *Decomposition:* to be defined in the future *Strengths:* • Should better orientate towards the environmental impacts of land use. • Should be able to account for the (impacts of) land use associated with traded goods. *Weaknesses:* • Such indicators are currently at the conceptual stages of development or in pilot testing phases. Unclear, to what extent they will be available for use in the near future.

3.5 Evaluation of the basket of indicators

In this chapter, the results of the evaluation of the basket of indicators as a whole is presented. The purpose of this exercise is to illustrate strong and weak areas across the indicators in the basket and identify the key areas, where the quality of the indicators in the basket needs to be improved. As the suggested basket contains a total of 16 indicators (see above), the two modules of resource use-oriented and environmental impact-oriented indicators are evaluated separately.

The scoring in green/yellow/red has been undertaken based on an unweighted average of the eight underlying indicators in each module of the basket. Thus, if five of the eight indicators have received a green evaluation, whereas the remaining three were evaluated with a medium score (orange), the overall score of the basket in this criterion is green.

Following the same procedure as in the evaluation of the single indicators (see Annex B), the scoring of each of the five major RACER categories is also calculated as an unweighted average of the underlying sub-criteria.

3.5.1 RACER evaluation of the resource use-oriented module

Abbreviations used in the evaluation:

- Domestic Material Consumption: DMC
- Raw Material Consumption: RMC
- Gross inland energy consumption: GIEC
- Energy Footprint (EnF)
- Water consumption (abstraction): WC/WA
- Water Footprint: WF
- Domestic Land Demand: DLD
- Actual Land Demand: ALD

R: Relevant	
R.1: Policy support for resource policies	The basket of indicators received high scores for policy support for EU resource policies: most indicators suggested for the basket completely fulfilled this criterion through covering different aspects of EU resource policies. The suggested indicators on material use (DMC and RMC) directly link to most aspects of resource use and resource efficiency addressed in the Flagship Initiative or the Resource Strategy. In particular, this refers to the monitoring of increases or reductions in total use of natural resources as well as specific policies related to certain groups of materials, such as CAP, CFP, policies on transport and spatial planning as well as climate change policies. The indicators suggested for monitoring EU's energy consumption (GIEC and EnF) closely link to the Commission's Communication on Energy 2020. Water use is mentioned as one of the key resource use categories in the Flagship Initiative. Water efficiency in Europe is also encouraged by the Water Framework Directive (2000/60/EC) and the Sixth Environment Action Programme for the EU (2001-2010). The water indicators suggested for the basket (WC/WA and WF) closely link up with these EU policies. Only the land-related indicators scored with a medium score. Although land use is mentioned in the Flagship Initiative, it is not very prominent (apart from stating that the EU is facing increasing trade-offs between different forms of land use, e.g. land used to produce food, land use for energy or land supporting biodiversity or absorption of carbon from the atmosphere). The Thematic Strategy for Soil Protection does highlight soil sealing and the removal of organic matter, but is no so focused on land demand as such.
R.2: Policy support for other policies	Most indicators received a full score regarding this criterion, as most of them can be used or are already being used in other areas of EU policy making. For example, the material use indicators link to policies such as the Raw Material Initiative or the Action Plan on Sustainable Consumption and Production and Sustainable Industrial Policy. The energy indicator GIEC is already being applied in policy strategies such as Energy 2020 and closely links to EU climate policies. As water availability is strongly influenced by climate change, comparing the water indicators with the (changing) availabilities of freshwater resources can also pinpoint to the impacts of climate change. Especially in the context of the Biofuels Directive as well as with regard to questions of land grabbing, land demand has found also some resonance at the EU policy level and the land-related indicators can support monitoring those issues related to land demand and competition over land resources.

R.3: Sensitiveness	The sensitiveness of the indicators suggested for the resource use-oriented component of the basket relate closely to the availability of data. Large time gaps between the actual year and the last year for which data are available impede that an indicator is capable of reacting to short-term policy changes. The sensitiveness of the indicators suggested for the basket varies, as data are being reported with a time lag of one (in the case of energy data), 2-3 years (in the case of material or water data) or more than 3 years (in the case of land use indicators based on the EU CORINE system).
R.4: Rebound effects	The indicators suggested for the basket capture rebound effects only to a certain extent. A complete fulfilment of this criterion was allocated to those indicators, which take a consumption-perspective, i.e. report the consumption of resources of an EU country, and which fully include all indirect resource flows associated with international trade. Therefore, e.g. the DMC indicator only received a yellow score, whereas RMC was scored with a green colour. Most indicators suggested for the global resource demand fulfil this criterion.
R.5: Past trends	The availability of time series for the past is limited to a few indicators in the resource use-oriented module of the basket. Long time series are currently only available for DMC and GIEC, whereas for most other indicators data have only been presented for a limited number of years. This holds particularly true for the global resource demand indicators, which are currently in the stage of development, such as RMC, WF or ALD.
R.6: Future trends	All indicators suggested for the basket can in principle be combined with models in order to derive future trends and scenarios. However, for only a few of them, this has already been applied. This holds in particular true for the energy-related indicators, which have been used in a number of energy models and scenarios, as well as the material flow-based indicators, which have been applied in resource efficiency scenarios.
R.7: Early warning	Only parts of the indicators can provide early-warning signals indicating possible future environmental problems. The energy consumption indicators may serve as early-warning indicators for climate change, as fossil fuel combustion is the main anthropological source of greenhouse gases and climate change occurs with years or even decades of delay. Other resource use indicators, such as the water consumption or land use indicators need to be combined with environmental threshold values, in order to serve as early warning indicators for policy makers.
A: Accepted	
A.1: Policy makers	Most of the resource use-oriented indicators in the basket are widely accepted by policy makers as informing about the different aspects of EU resource use. This criterion links closely to the relevance for EU and other policies evaluated above.
A.2: Statistics	Statistical offices on the national and EU level are the main data provider for almost all resource use-oriented indicators suggested for the basket. Therefore, acceptance by statistical institutions is generally very high. One exception is the Water Footprint indicator, which is currently being calculated by the Water Footprint Network, and the Actual Land Demand indicator, for which only a few pilot studies have been presented by academic institutions.

A.3: Business / Industry	Companies have increasing interest in measuring their resource use, driven by high prices for raw materials and increasing import dependency. While business has so far put most emphasis on issues related to energy use and GHG emissions, also efficient use of materials and water are increasingly recognised as key issues for securing future competitiveness of European industries. The issue of land appropriation so far has received the least attention in the business world.
A.4: Academia	Acceptance of the suggested indicators in the academic world is generally very high and academic institutions played a key role in further developing the methodologies and data sets of the various resource use indicators. This holds true for all four categories of resource use considered in the evaluation.
A.5: Civil society	The uptake of the suggested indicators by civil society, in particular by environmental NGOs, shows a very mixed picture. While energy- and to some extent water-related indicators have been used, e.g. in environmental campaigns, only a few civil society organisations have so far addressed issues related to Europe's material and land use.
C: Credible	
C.1: Unambiguous results	The detailed evaluation of the indicators regarding this criterion revealed that most of the resource use-oriented indicators provide unambiguous results and a clear message. However, some indicators require additional information and/or careful interpretation of the results, in order to not to derive misleading policy conclusions. For example, in the area of energy consumption, fuel switching may cause significant changes in total energy consumption even though final energy demand remains constant. The transformation efficiencies of different fuels and technologies from primary to useful energy vary widely. Additionally, relatively low gross inland consumption could be associated with high overall trade volumes (where the imports and exports roughly balance) and the associated environmental burdens.
C.2: Transparency	The criterion of transparency is being completely fulfilled for most resource use-oriented indicators suggested for the basket, as clear specifications of the underlying methodology are available. This is the case for the energy-related indicators, for which clear specifications have been developed by Eurostat; the material-flow based indicators with the methodological handbook by Eurostat/OECD; or the existing Water Footprint manuals. For some global resource damnd indicators, such as RMC and ADL, where methodologies are only now being developed, harmonised methodologies are still missing.
E: Easy	
E.1: Availability of data to calculate the indicator	The underlying data to calculate the resource use indicators is available for all domestic resource use indicators and for some of the global resource demand indicators, such as Actual Land Demand.
E.2: Availability of the calculated indicator	Regarding this criterion, there is a clear separation between the domestic resource use indicators and the global resource demand indicators in the basket. Whereas all four domestic resource use indicators are readily available, the global resource demand indicators are only available for pilot years so far.
E.3: Technical feasibility	Most of the indicators related to environmental impacts of domestic resource use can be calculated without any significant knowledge in computer programming or

	modelling, as the data from the original sources do not require major transformation. The global resource demand indicators all include those resources, which are embodied in internationally traded products. The calculation of some of those indicators thus requires knowledge in specific methodologies, such as input-output analysis or life cycle assessment.
R: Robust	
R.1: Data quality	Depending on the category of resource use, the quality of available data varies significantly. Whereas in general, data quality on the direct use of energy, materials and land is high, the quality of the data on resources embodied in international trade is generally lower. Furthermore, the quality of data on European water abstraction and consumption is generally still low. A solid water accounting framework is only now being developed by Eurostat.
R.2: Level of aggregation of data	This criterion is fulfilled by all indicators in the basket, as all indicators can be used either as an aggregated number on the economy-wide level, or be disaggregated by different sub-categories or economic sectors, in order to be closer linked to actual policy making.
R.3: Reproducibility	Full reproducibility of results is only ensured for a limited number of indicators in the basket, such as DMC and GIEC. In several cases, methodologies to calculate those indicators, which consider embodied resource flows, are only currently being developed by statistical or academic institutions. Harmonisation of methodologies in the future is therefore required for a number of indicators, including RMC, EnF, WF and ALD.
R.4: Geographical scale	Data for most indicators are available for all EU-27 countries plus a number of non-EU countries, if taken from an international data source.
R.5: Burden shifting	With the conception of fully including resource flows embodied in international trade, all global resource demand indicators in the basket completely fulfil this criterion. From the domestic resource use related indicators, DMC and GIEC can illustrate burden shifting to some extent, as they do include direct trade flows. WA and DLD are territorial indicators and can therefore not reflect burden shifting.

3.5.2 Specific evaluation of the resource use-oriented module

Issue	Questions
Target setting	So far, only the energy-related indicator in the resource use module of the basket has been used for target setting before: with the Energy 2020 strategy stating that the EU should achieve a reduction of 20% of its primary energy consumption by the year 2020. All other indicators have not yet been linked with a specific policy target, but proposal for such targets have been developed in Task 4 of this project.

Issue	Questions
Levels of economic activities	All indicators primarily report resource use trends on the economy-wide level. Some of them, such as the energy-related indicators or the indicators on water abstraction, are usually presented disaggregated by main sectors causing the environmental pressure. Other indicators, such as the material flow-based indicators, need to be linked to other analytical tools (in particular, input-output analysis), in order to derive information on the material use of economic sectors.
Territory vs. life-cycle perspective	All indicators suggested for the global resource demand take a full life-cycle perspective, i.e. include all resource flows embodied in internationally traded products. The indicators DMC and GIEC only partly reflect this perspective, as they do include the direct trade flows, but not the related up-stream flows abroad. WA and DLD are territorial indicators, which only report changes within European territories.
Level of aggregation within each indicator	All indicators can be reported as an aggregated number or disaggregated by major components. For example, the DMC indicator is mostly expressed along four main material categories (biomass, fossil fuels, metals, non-metallic minerals). This level is most appropriate for the application of policies and targets. The energy-related indicators can be separated into different categories of renewable and non-renewable fuels. A minimum level of disaggregation would be the Eurostat classification, distinguishing solid fuels, petroleum products, natural gas, nuclear heat and renewable energies. Also the water and land-related indicators can be disaggregated by main components (e.g. different types of water such as surface water vs. ground water; or different types of land use such as cropland, pastures or built-up land).
Limits/thresholds/ overexploitation	As all indicators in this component of the basket refer to the environmental pressures, the link to issues of thresholds and overexploitation is only provided in an indirect way, e.g. the link between the use of fossil fuels and climate change. For this reason, the project team suggested to complement the set of resource use-oriented indicators with a module on environmental impact-oriented indicators, which have a much stronger link to resource limits and overexploitation (see evaluation below).
Links to environmental impacts	See answer on limits/thresholds/overexploitation above.
Links to economic data	The material and energy data are directly derived from a system of integrated economic-environmental accounts and can therefore be easily integrated with economic data. Eurostat is currently working on setting up water accounts in accordance with environmental accounting principles. Satellite-based indicators on land use can also be linked to classifications of economic activities, as the EEA has demonstrated with its CORINE data system.

3.5.3 RACER evaluation of the environmental impact-oriented module

Abbreviations used in the evaluation:

- Environmentally-weighted Material Consumption: EMC
- Life-Cycle Resource Indicator: LCRI
- Territorial GHG emissions: TerrGHG
- Carbon Footprint: CF
- Human Appropriation of Net Primary Production: HANPP
- Water Exploitation Index: WEI
- Global Water Consumption Index: WCI

R: Relevant	
R.1: Policy support for resource policies	Reducing the various environmental impacts related to EU's resource use is one of the key policy objectives as formulated in several EU resource policies, most notably the Resource Strategy and the Resource Efficiency Flagship. The indicators allow monitoring the different impacts related to material, energy, water and land use. This criterion is thus completely fulfilled.
R.2: Policy support for other policies	This criterion is only partly being fulfilled, as the indicators were or are being primarily developed to illustrate the environmental impacts related to resource use. For example, the EMC indicator has not been applied to other policy areas, as it was designed as an indicator to measure the environmental impacts of material consumption. However, potentially, it could also be used to monitor developments in related policy areas, such as energy and climate policy, agricultural policy, and health policy. Another example is the HANPP indicator, which could relate to the on-going debates on biofuels as well as land grabbing; providing information on land use and harvest could therefore have some resonance at the EU policy level. Exceptions are the indicators of GHG emission, which – in the case of the Territorial emission indicator – are already being used in EU climate policies.
R.3: Sensitiveness	This criterion received very diverse scores, as the data availability varies significantly across the indicators. Some indicators, such as the Territorial GHG emissions, are very sensitive, as data is being produced with a short time-lag. For other indicators, such as HANPP, data is only available for pilot years.
R.4: Rebound effects	The indicators in the basket capture rebound effects only to a certain extent. Some of the indicators, such as the Carbon Footprint, can monitor all rebound effects related to EU consumption, including those induced in countries outside the EU. The same holds true for the EMC and the LCRI. Other, production-oriented indicators, such as the Territorial GHG emissions, cannot fully capture the rebound effects related to consumption.
R.5: Past trends	The availability of data for historical time series is still limited. Only one indicator suggested for the basket, the TerrGHG indicator, completely fulfils this criterion. Most indicators received a medium score, providing data for at least three years, but less than 10 years. For some indicators, such as the LCRI or HANPP, data only exists for less than 3 years.

R.6: Future trends	Apart from the TerrGHG indicator, which has already been widely used in climate modelling exercises, all the other indicators received a medium score, as they are in principle capable of being linked to models, but modelling has not yet been performed.
R.7: Early warning	Several of the environmental impact-oriented indicators suggested for the basket fulfil this criterion. For example, the GHG-related indicators can serve as early-warning indicators for climate change, as GHG emissions are the main anthropogenic source of climate change which occurs with decades of delay after emitting GHGs. The water-related indicators evaluate the status quo with regard to water stress in specific countries. As such, they can draw a picture of the current (or past) situation and can identify critical circumstances for the future. Other indicators, such as HANPP require further contextual information in order to provide early warning (e.g. on sustainable levels of land use intensity for a specific region).
A: Accepted	
A.1: Policy makers	Acceptance by policy makers varies across the different indicators. For example, the WEI was developed and is promoted by the EEA and is so far the most accepted indicator on water stress. The EMC and LCRI indicators are potentially well accepted by policy makers and green groups. However, they are not officially used so far and quality, appropriateness, and actuality of life-cycle data will be crucial for its future acceptance. The CF is a rather new indicator in policy and policy makers are still hesitant with the broad application of the indicator. In particular, policy makers in the EU do not want to be made liable for low technological or policy standards outside the EU, arguing that those aspects fall into the responsibility of the exporting country.
A.2: Statistics	The indicators in the environmental impact-oriented module scored very differently regarding the acceptance by statistics. Some of them, such as the TerrGHG indicator, are established as part of environmental statistics. Others, such as the CF, have not found their way into official statistics yet. Due to the novelty of the approach and the applied methodologies, there is still some reservation towards the CF, in particular, as this would imply gathering data outside the traditional EU boundaries. The material-impact indicators EMC and LCRI rely on the use of data from Life Cycle Assessment, which are gathered outside statistics. Therefore, regarding those components of the indicators, acceptance by statistics is low.
A.3: Business / Industry	Some indicators, in particular the GHG-related indicators, are already widely accepted and used by representatives from business and industry. Recently, consumers requiring environmental information released a real boom in quantifying and labelling the CF of products. Other indicators, such as EMC or LCRI, are not yet widely applied by businesses and industry. Those indicators are likely to be rejected by basic materials and energy-intensive industry, as it could lead to a result that basic industries are responsible for most of the environmental pressures, while the causes/drivers behind resource use and impacts are also industrial production and demand. Some indicators have a potential application on the industry level. For example, there is no acceptance of HANPP yet, however, interest has been signalled from within the agricultural sector (especially organic farming).

A.4: Academia	Methodologies and data sets for several of the environmental impact-oriented indicators are only currently being developed, so the scoring across the indicators was diverse. For example, HANPP has had strong resonance in a number of scientific communities (ecology, agroecology, land use, environmental studies, ecological economics, and industrial ecology). The CF has been gaining ground in academia in the past few years and methodologies to calculate the CF are investigated by various renowned academic institutions. This has led to significant advances in terms of methodology and data creation within the last ten years. Regarding the water indicators, the comparison of available and extracted resources is in general well accepted within academia. However, the fact that only "blue" water abstraction is considered in the WEI is still under discussion, as "green" water and return flows (water consumption) are not accounted for. The WCI as suggested for global resource demand is not yet elaborated.
A.5: Civil society	Most of the indicators are not (yet) widely used by civil society organisations. The material impact indicators are not applied due to the complexity of the method. Nevertheless, they have the potential to communicate environmental impacts of material use, as they can aggregate the results into one number. The CF received the highest scores of all indicators in this criterion, already being applied in campaigns of environmental and development NGOs.
C: Credible	
C.1: Unambiguous results	Several of the indicators require a careful interpretation of results; this criterion is therefore only partly fulfilled for most of them. For example, the TerrGHG indicator provides a comprehensive and unambiguous picture of a country's territorial contribution to climate change. However, a country's production-based emissions may decrease through shifting carbon intensive processes and industries abroad. This effect, called carbon leakage, cannot be captured by this indicator. The CF indicator is required to avoid those types of distortions in the interpretation of the results. Another example is HANPP, which is an indicator of the "human domination of ecosystems" with higher HANPP corresponding to greater colonisation efforts and/or higher harvest. However, the reverse is not necessarily true as lower HANPP could also be the result of intensification through which harvest and productivity are both increased. Next to knowledge of the components of HANPP, some contextual information on land use practices and (avoided) trade-offs of intensification is therefore required. The WEI can convey a clear message with easy and unambiguous interpretation. If data was available on the watershed and/or regional level, it could describe very explicitly how the total water abstraction puts pressure on local water resources. Using national data distorts the picture, as water resources can be very unevenly distributed within one country.
C.2: Transparency	Transparency is generally lower regarding the environmental impact-oriented indicators compared to the resource use-oriented indicators. The material impact indicators EMC and LCRI make heavy use of Life Cycle Inventory data, which are not freely available and fully documented. Also, regarding the LCRI, so far very little information on important aspects such as the clarification of system boundaries (LCI) and especially the weighting scheme (applied in order to receive a single score) is provided. For some methodologies, such as for the CF, no international harmonisation has been achieved so far and thus transparency is limited. An

	exception to the mainly medium scores in this criterion is the TerrGHG indicator, for which the underlying methodology is clearly defined by the UN Framework Convention on Climate Change.
E: Easy	
E.1: Availability of data to calculate the indicator	The availability of underlying data to calculate the indicators is restricted in most cases. The Life Cycle Inventory data required for the material impact indicators is only partly freely available through the European LCA platform. Other data systems needed are e.g. GaBi or the Ecoinvent database. Also for other environmental impact-oriented indicators, substantial amounts of data are required, which are not always easy to obtain. For example, the HANPP indicator requires data on climate (temperature, precipitation) and soil quality, which need to be derived from Dynamic Global Vegetation Models. Data on land use and land cover is easier to obtain from FAOstat or Eurostat.
E.2: Availability of the calculated indicator	In parallel to the criterion E.1 above, also the availability of the calculated indicator is limited. Best data are available for the TerrGHG indicator and also for the CF pilot data, which has been published in time series. A relatively good situation can be observed for the WEI, where the indicator is calculated on a regular basis by the EEA and data are available for various years. The material impact data are either old (only up to the year 2000 for the case of the EMC) or not yet developed in full time series (the LCRI indicator is only available for the period of 2004-2006 so far for the EU and Germany). HANPP is currently available at the global level for the year 2000 only.
E.3: Technical feasibility	Most of the environmental impact-oriented indicators require a substantial technical knowledge for their calculation. The material impact indicators EMC and LCRI require specific LCA software and knowledge how to use them properly. Other indicators, such as the CF, require comprehensive modelling approaches, such as multi-regional input-output models, which require significant technical expert knowledge to perform the calculations.
R: Robust	
R.1: Data quality	Data quality varies significantly across the indicators and – apart from the TerrGHG indicator, no indicator reached the highest score in this criterion. For the material impact indicators, two main components are required: Information about the physical production and consumption volumes, which is generally available in good quality, e.g. from material flow accounts; and life cycle impact factors, which are often prone to uncertainties and restrictions, e.g. regarding geographical and temporal specifications. Indicators relying on input-output analysis generally suffer from the limited availability of highly disaggregated harmonised economic data for a large number of countries. European water data (both for water reserves as well as for abstraction) are available in Eurostat's New Cronos database. However, reported data are often incomplete or of questionable quality.
R.2: Level of aggregation of data	Data for the indicators are not always available on the appropriate level. For example, water data is available on the aggregated country level and only stepwise being disaggregated with regard to the more appropriate water basin levels. One key problem related to the material impact indicators is that LCA impact factors are only available for single products, which makes it difficult to apply them for macro

	assessments. Therefore, the LCRI indicator applies the approach to select a limited number of representative products for each product group. On the other hand, HANPP can currently be spatially disaggregated up to a 10x10 km resolution and aggregated to all higher spatial levels. It can also be calculated for different agricultural products.
R.3: Reproducibility	Reproducibility of results is limited, as the methodologies for most indicators are not yet harmonised. This holds true for the material impact indicators EMC and LCRI as well as for the calculation of CF and the water scarcity indicators. Only HANPP and TerrGHG are sufficiently standardised to allow a proper reproduction of results.
R.4: Geographical scale	Data of the indicators are in several cases not yet available for all EU countries. For example, the LCRI developed by JRC, is so far only available for the EU-27 as an aggregate and for Germany as a national example. However, some indicators, such as the TerrGHG, are available on a national level for the 27 EU Member States and almost all other countries worldwide.
R.5: Burden shifting	The capacity to monitor burden shifting depends on whether or not the resources embodied in international trade are properly considered. Some of the environmental impact indicators in the short term are completely territorial (e.g. TerrGHG or HANPP). The global resource demand related indicators all take a global perspective and are thus able to monitor burden shifting.

3.5.4 Specific evaluation of the environmental impact-oriented module

Issue	Questions
Target setting	So far, only the climate-related indicator in the environmental impact module of the basket has been used for target setting with TerrGHG being the central indicator in the Kyoto protocol. All other indicators have not yet been linked with a specific policy target, but a proposal for such targets has been developed in Task 4 of this project.
Levels of economic activities	All indicators primarily report resource use trends on the economy-wide level. Some of them, in particular the material impact indicators, have a strong link to the product level, with impact factors being attached to the EU consumption of specific products. The land oriented indicators can be disaggregated and also be broken down to the level of different product groups. While the CF is being calculated widely on the product level (in the context of Carbon Footprint labelling), an integration of micro and macro results for the CF has not yet been done. However, all GHG emission indicators can be broken down into main sectors responsible for the respective emissions.
Territory vs. life-cycle perspective	Apart from the category of materials, all domestic resource use related environmental impact indicators apply a territorial perspective. As the EU is increasingly substituting material and energy-intensive products through imports, the inclusion of the embodied resources will receive growing importance. Therefore, all four suggested indicators representing global resource demand take a life-cycle perspective.

Issue	Questions
Level of aggregation within each indicator	All indicators can be reported as an aggregated number or disaggregated by major components. The material impact indicators can be broken down into the major material and product groups contributing to the overall environmental impact. The GHG-related indicators are calculated separately for different emissions (e.g. CO_2, CH_4, NH_3, etc.) and then aggregated in the unit of CO_2 equivalents. The situation for water indicators is more difficult, as e.g. the separation between blue and green water is not yet possible for the water impact indicators.
Limits/thresholds/ overexploitation	The link to thresholds is particularly close regarding the resource use categories of water and energy/climate. The WEI quantifies the pressure total water abstraction puts on water resources. So far, the warning threshold is set at 20%, which distinguishes a non-stressed region from a stressed one. Severe water stress can occur for WEI > 40%. At this rate of water abstraction strong competition for water can occur, which can trigger frequent water crises. Regarding the climate indicators, they can monitor the achievement of the target to keep climate change below 2°C and calculating the maximum amount of GHG emissions that may be released by human activities within a specific time frame. Links to overexploitation can also be established by HANPP, although no numerical HANPP target has so far been introduced. The material impact indicators link to issues such as toxicity and eutrophication and thus to the limited capacity of the environmental system to absorb environmental stress.
Links to environmental impacts	In contrast to the resource use-oriented module of the basket, the eight indicators suggested for the environmental impact-oriented module all have close links to the various environmental impacts generated by human resource use. The indicators can cover the full range of impacts, including acidification, eutrophication, toxic impacts on humans and ecosystems, global warming, land use change and resource depletion.
Links to economic data	While the resource use-oriented indicators in the basket mostly have a strong link to economic data, this is much less the case for the environmental impact indicators. They often rely on data, which is not derived from economic-environmental accounts, for example, life cycle impact factors or data from ecosystem models. The climate indicators are the indicators with the closest link to economic activities.

3.5.5 Assessment of the complementarities of the four main categories of resource use

When setting targets for resource use the interdependencies of the different types of resources should be well understood. An individual target for a specific resource type might influence the use of other resources, e.g. increasing metal recycling will also reduce the demand for water and energy. Inversely a target set for one resource might offset any efficiencies achieved for other resources, e.g. a target for biofuel use in transport could increase the demand for biofuel crop production, agricultural land and water. Figure 6 provides examples of the links between different types of resources.

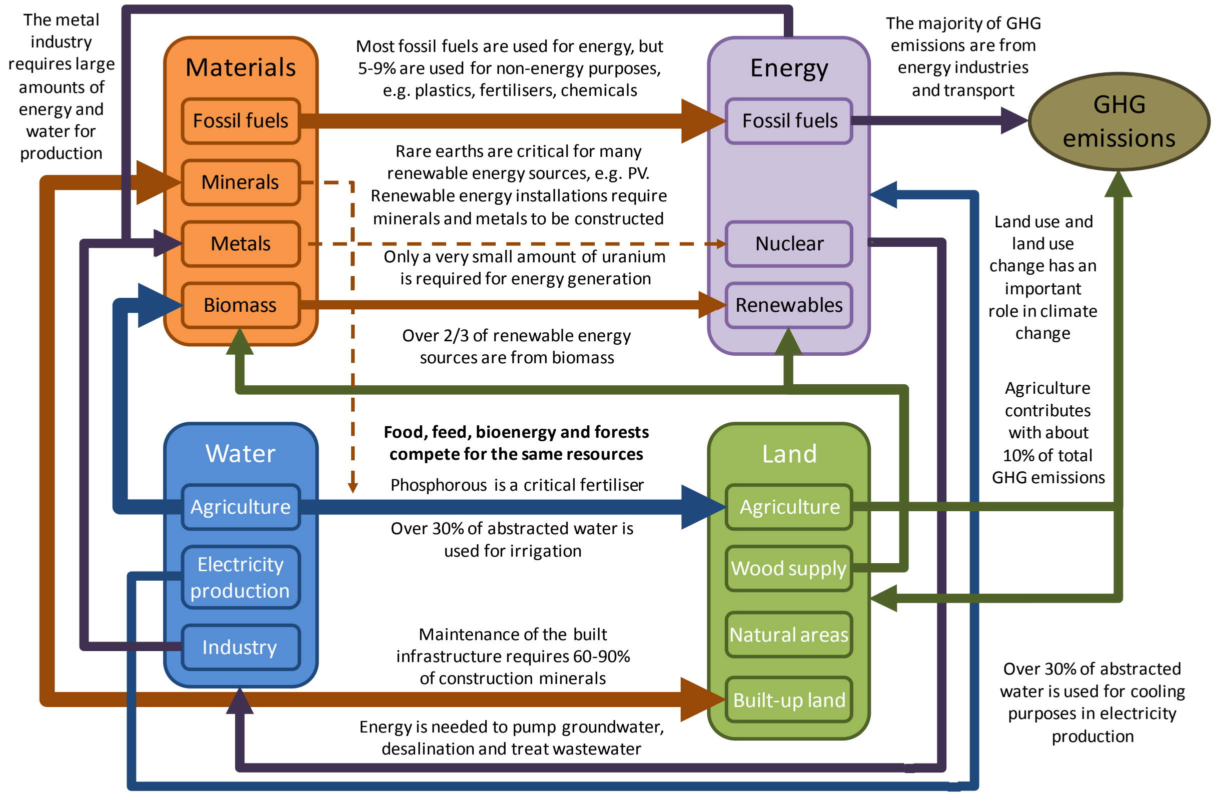


Figure 6: Examples of the interdependencies of resource use

In general the different indicators provide complementary information on the use of the main types of resources: materials, energy and climate, water and land. Figure 7 shows the approximate composition of current resource use for each of the main aggregated indicators selected for the basket.

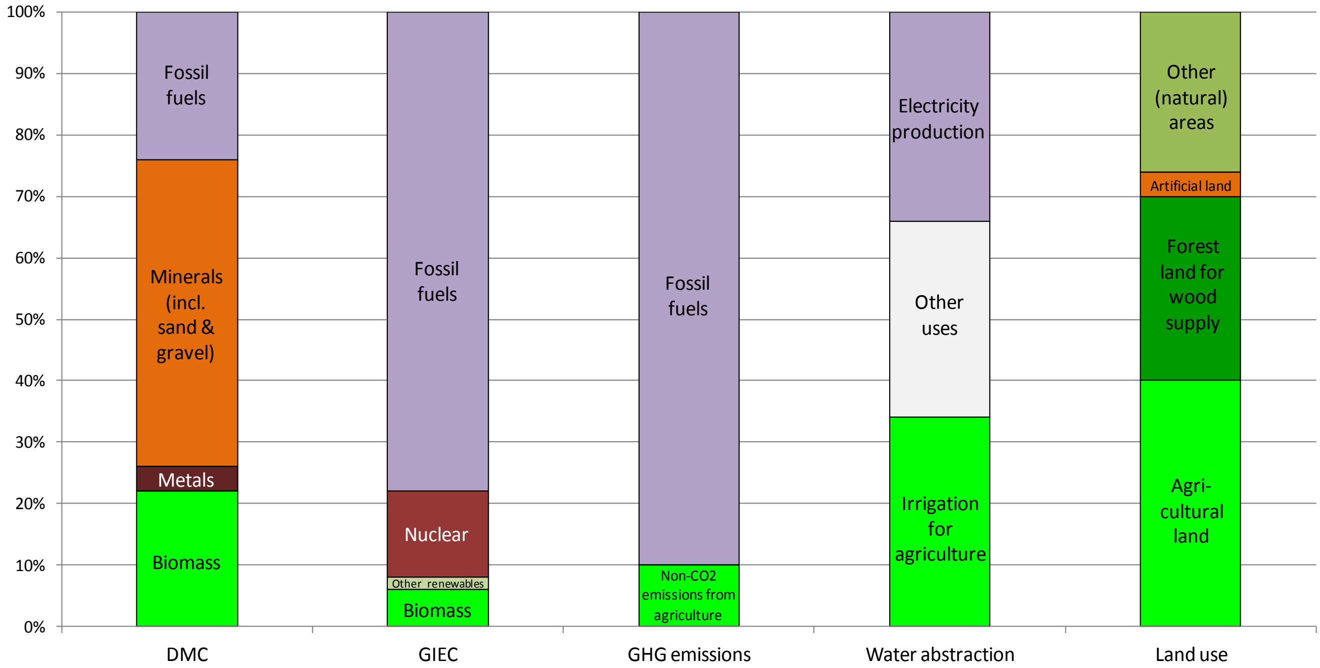


Figure 7: Approximate distribution of the main resource types for the various headline indicators

It can be seen in Figure 7 that the consumption of biomass can be tracked in all of the indicators for resource use. There is also a direct relationship between the consumption of fossil fuels in DMC, energy consumption and GHG emissions. The production of electricity is associated to both energy consumption and water abstraction. Likewise water used in agriculture can be related to agricultural land.

The consumption of metals and minerals cannot be directly associated to the indicators for energy and climate, water and land at present, but they be correlated to their use in different economic sectors, i.e. manufacturing, construction, etc. Indicators that measure water, energy and GHG emissions are disaggregated by economic sector in current datasets from Eurostat and EEA. For each of the indicators used for targets, the project team analysed the links to other indicators/targets (see Chapter 4). These links were examined in more detail in the scenario assessment (see Chapter 4).

3.6 Empirical results of the indicators included in the basket

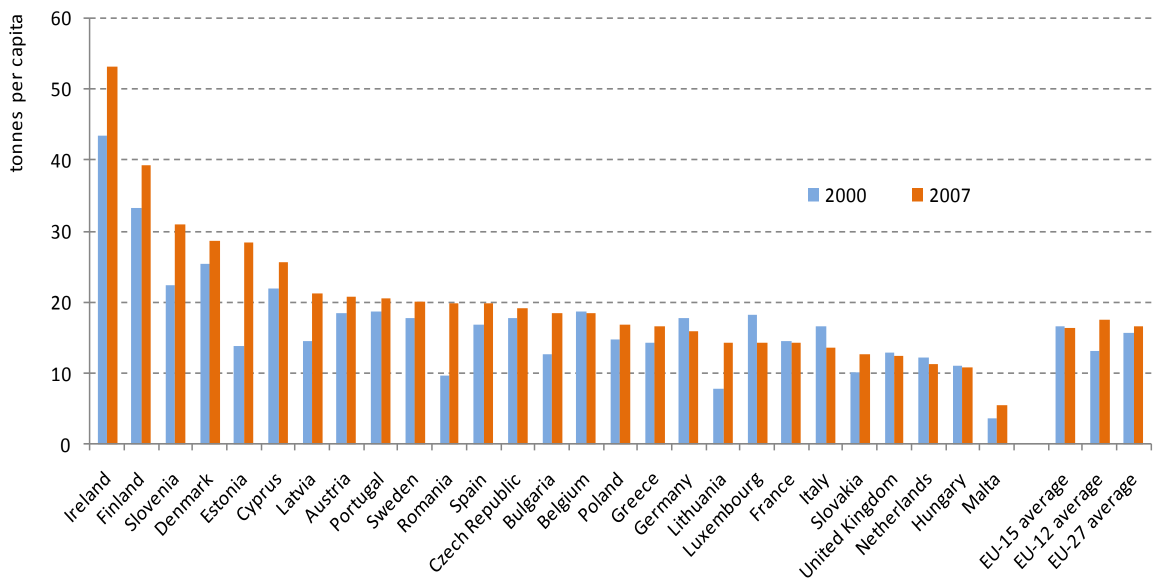
In this section, historical data for the indicators in the basket, which currently have data, are presented. A short assessment of past trends and a comparison between the different EU countries is provided for each indicator. Most comparisons are illustrated on a per capita basis. The purpose of this section is not a detailed data analysis, but rather to provide an idea of the data situation regarding the different indicators suggested for the basket.

3.6.1 Resource use-oriented indicators

Domestic Material Consumption (DMC)

Figure 1 illustrates the Domestic Material Consumption (DMC) indicator per capita for the years 2000 and 2007, as Eurostat data on material use is only available since the year 2000.

Figure 8: Domestic Material Consumption per capita (Eurostat, 2011)[29]



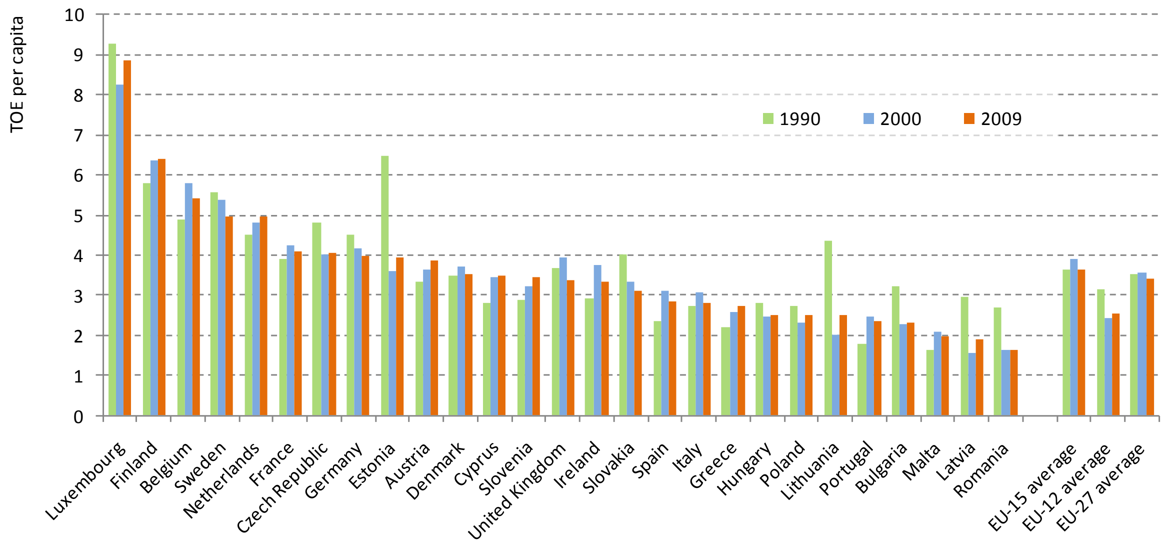
The average DMC for the EU-27 in 2007 was about 16 tonnes per capita, with no significant differences between the EU-15 and the EU-12 countries. The results show that the EU-12 experienced a steep rise in material consumption from 2000 to 2007, while the EU-15 slightly reduced their DMC. There are significant differences in the results of single EU countries. In 2007, Ireland had a DMC per capita that was almost ten times higher than the one for Malta. In general, countries with an already high DMC per capita experienced an increase in the period from 2000 to 2007, whereas a number of countries with smaller per capita values observed a decrease.

[29] Eurostat (2011) http://nui.epp.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_mfa&lang=en

Gross Inland Energy Consumption (GIEC)

The next figure illustrates the Gross Inland Energy Consumption per capita.

Figure 9: Gross Inland Energy Consumption per capita (Eurostat, 2011)[30]



In 2009, the average EU-27 energy consumption was about 3.5 tonnes of oil equivalents per capita (toe per capita). The EU-15 average did not diverge much since 1990, but the EU-12 average is significantly lower with only around 2.5 toe per capita in 2009. Most of the EU-12 countries are found among the lower range. In 2004, the toe per capita was more than four times higher in Luxembourg compared to Romania, which had the lowest result[31]. In general only small changes could be observed for the period of 1990 to 2009. Only some countries such as Estonia and Lithuania had a remarkable reduction from 1990 to 2000.

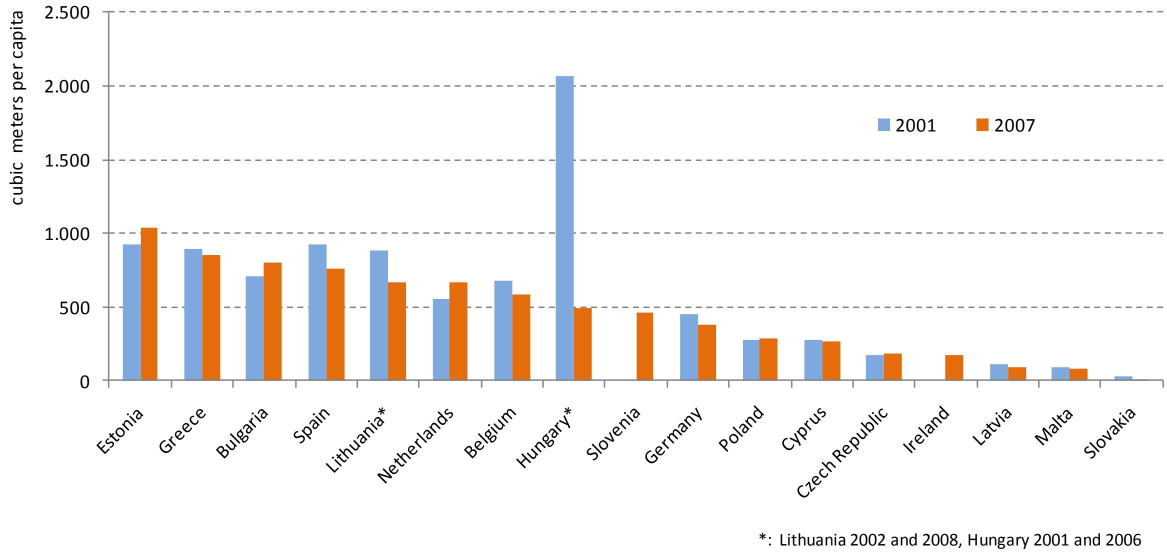
Water Abstraction (only blue water) (WA)

Figure 10 shows the water abstraction of blue water per capita for the years 2001 and 2007. In general a very diverse picture can be observed for the different countries regarding this indicator. With 1,000 cubic meters, the water abstraction per capita for Estonia in 2007. The development from 2001 to 2007 shows a very diverse picture with increases as well as decreases across Europe. The decrease for Hungary was particularly significant, from over 2,000 to about 500 cubic meters of water abstraction between 2001 and 2007.

[30] Eurostat (2011) http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_100a&lang=en

[31] A reason for this may be the significant cross border purchasing of fuel in Luxembourg due to low energy taxes.

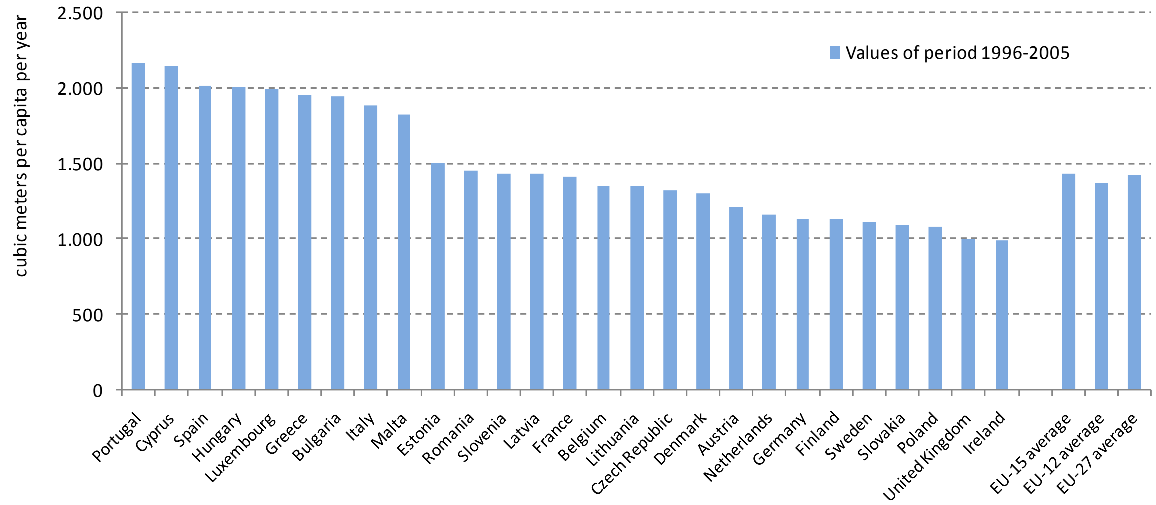
Figure 10: Water Abstraction (only blue water) per capita (Eurostat, 2011)[32]



Water Footprint (blue & green water) (WF)

The Water Footprint for blue and green water per capita for all EU countries is illustrated in the next figure.

Figure 11: Water Footprint (blue & green water) per capita (Water Footprint Network, 2011)[33]



The EU-27 average Water Footprint is about 1,400 cubic meters per capita per year. The EU-15 and EU-12 averages do not diverge much. The results for the different EU countries range from over 2,000 for Portugal to about 1,000 for Ireland. The curve of the Water Footprint is much more homogeneous compared to the data on water abstraction, illustrating that the consumption patterns across Europe demand a comparable amount of (domestic and foreign) water. Numbers are higher than those for the WA, because also green water (i.e. water transpiration by plants) is considered in those calculations.

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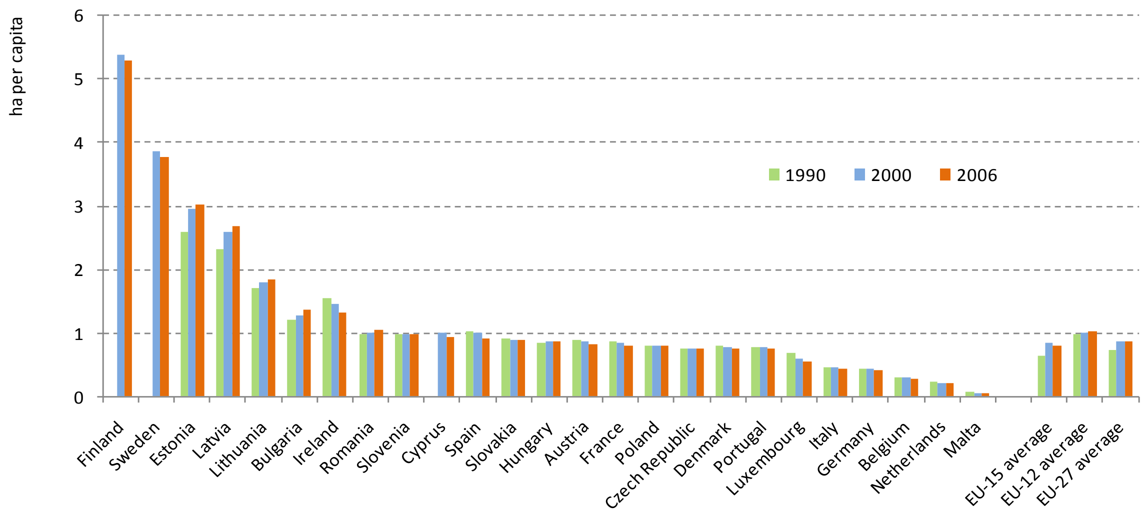
[32] Eurostat (2011) http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_watqsum&lang=en

[33] Water Footprint Network (2011) www.waterfootprint.org/downloads/Report50-Appendix-VIII&IX.zip

Domestic Land Demand

The following figure illustrates the domestic land demand per capita for all EU countries and the years 1990, 2000 and 2006. It is based on the CORINE land cover data provided by the EEA.

Figure 12: Domestic Land Demand per capita (EEA & ETC LUSI, 2011)[34]



The Domestic Land Demand of the EU-12 average is slightly higher and the EU-15 average. Large differences can be observed between different EU countries. Finland has the highest domestic land demand per capita with over 5 ha. This result is over 90 times higher than the domestic land demand of Malta with only 0.06 ha. These two countries pronounce that this indicator is closely correlated to the land available within the country. Most of the countries do not show a pronounced development from 1990 to 2006.

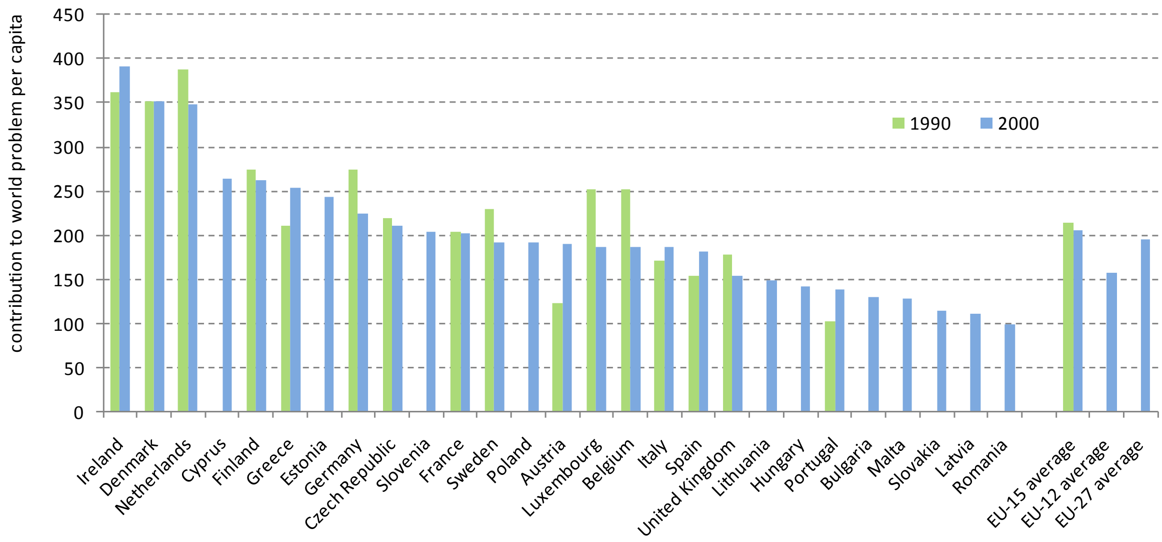
3.6.2 Environmental impact-oriented indicators

Environmentally-weighted Material Consumption (EMC)

Figure 13 illustrates the environmentally weighted material consumption per capita for the years 1990 and 2000. The EU average ranks about 200. This value describes the contribution to the world problem per capita. The average for the EU-15 is slightly higher and the one for the EU-12 ranks above 150. The results for the different countries are spread from 350 for Ireland to 100 for Romania. A very diverse picture can be observed for the development from 1990 to 2000. Some countries have decreasing values others increasing ones. For Denmark and France no change is observable.

[34] EEA & ETC LUSI (2011) www.eea.europa.eu/data-and-maps/figures/land-cover-2006-and-changes

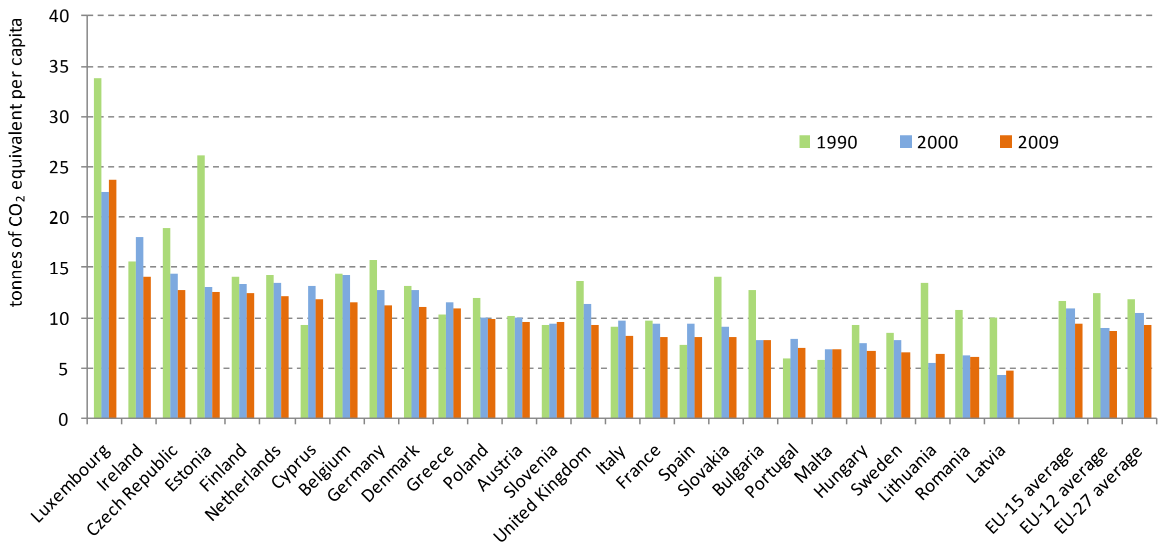
Figure 13: Environmentally-weighted Material Consumption per capita (Universiteit Leiden, 2011)[35]



Territorial GHG Emissions (UNFCCC/Kyoto) (TerrGHG)

The CO_2 equivalents in tonnes per capita for all EU countries and the years 1990, 2000 and 2009 are illustrated in this figure. The EU-27 average ranks about 9 tonnes per capita. The averages for the EU-15 and EU-12 do not diverge much. The different countries rank from 24 tons for Luxembourg to 5 tonnes for Latvia, which is almost 5 times smaller. For the development from 1990 to 2009 a general tendency of declining values can be observed. Only some countries show a rising tendency.

Figure 14: Territorial GHG Emissions per capita (Eurostat, 2011)[36]

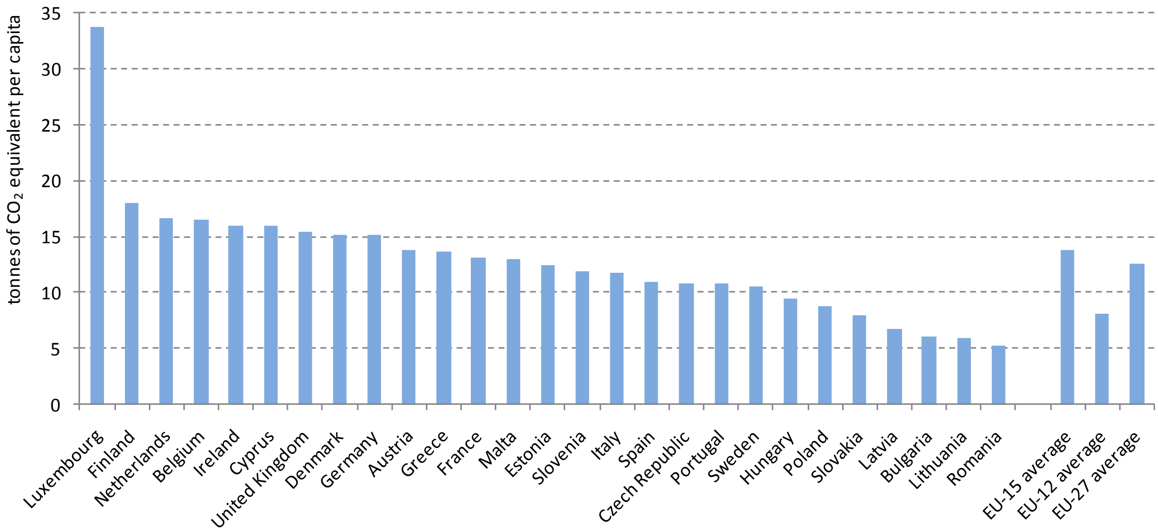


[35] Universiteit Leiden (2011) www.leidenuniv.nl/cml/ssp/projects/dematerialisation/index.html

[36] Eurostat (2011) http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tsdcc210&plugin=1

Carbon Footprint (incl. GHG emissions embodied in trade) (CF)

Figure 15: Carbon Footprint per capita, 2001 (Hertwich & Peters, 2009)[37]



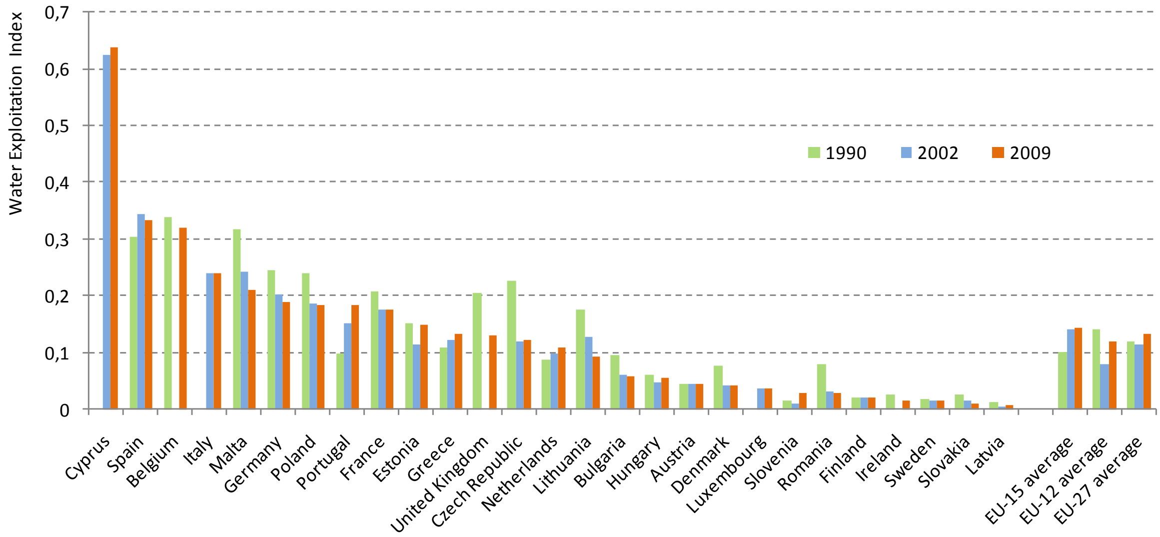
This figure shows the carbon footprint per capita. The EU-27 average ranks about 13 tonnes of CO_2 equivalent per capita. The EU-15 and EU-12 averages show different levels. The EU-15 average ranks at a value of almost 14 whereas the EU-12 average only has a value of 8 tonnes per capita. This reflects that most EU-15 countries rank among the countries with the highest results. Luxembourg has the highest value with 34 tons per capita which is almost twice the value of Finland, which ranks on the second place, and 6.5 times higher than Romania, which has the lowest result. Comparable time series data are not available yet, as data bases and methodologies require harmonisation before.

Water Exploitation Index (WEI; territorial)

The indicator illustrated in Figure 16 above shows the ratio of water exploitation to the amount of water available. The EU-27 average ranks among 13%. The average for the EU-12 and EU-15 have the results of 12% and 14% therefore only diverge little from the EU-27 average. A closer look at the different countries shows very different results for this indicator. Cyprus stands out with a value of over 60%. The other countries rank from above 30% like Spain to 1% of Latvia. In general a decrease can be observed in the time period from 1990 to 2009. Only some countries show an increase for this period.

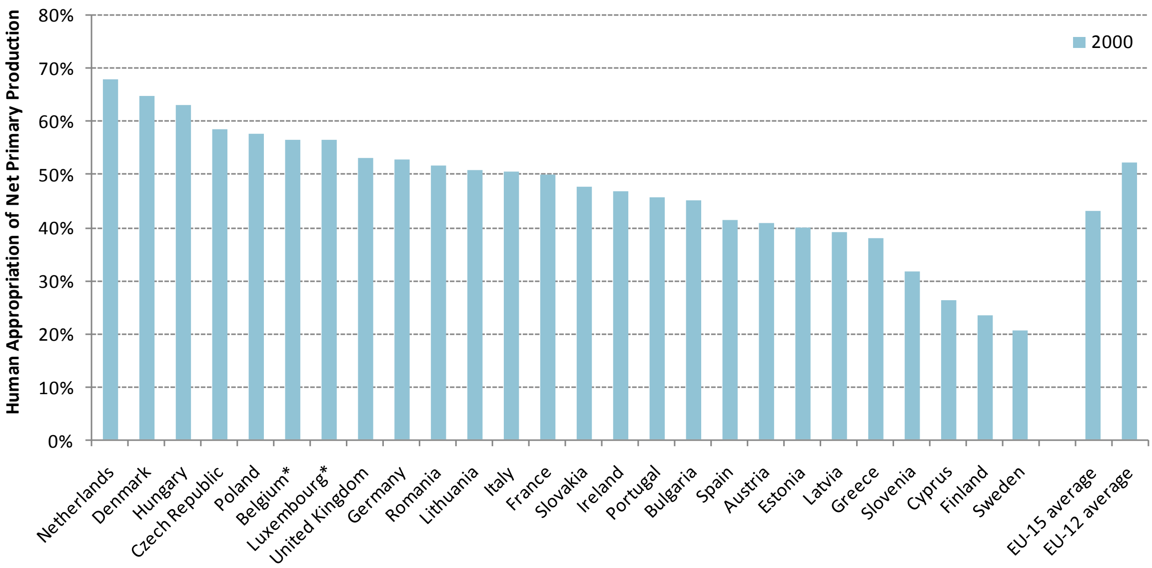
[37] Hertwich, E. G. and G. P. Peters (2009) Carbon footprint of nations: A global, trade-linked analysis. Environmental Science & Technology 43(16): 6414-6420. http://pubs.acs.org/doi/pdfplus/10.1021/es803496a

Figure 16: Water Exploitation Index (EEA, 2011)[38]



Human Appropriation of Net Primary Production (HANPP)

Figure 17: Human Appropriation of Net Primary Production (Haberl et al., 2007)[39]



This figure shows the Human Appropriation of Net Primary Production (HANPP) for the EU-27 (except for Malta). The EU-15 and EU-12 averages show differences of about 9 percentage points. The EU-15 average ranks at a value of 43% whereas the EU-12 average has a value of more than 52%. The differences between single countries are as high as 47 percentage points between the country with the highest HANPP (Netherlands) and the one with the lowest HANPP

[38] European Environment Agency (2011) www.eea.europa.eu/data-and-maps/figures/water-exploitation-index-wei-4/wei-underpinning-data-xls/at_download/file

[39] Helmut Haberl, Karl-Heinz Erb, Fridolin Krausmann, Veronika Gaube, Alberte Bondeau, Christoph Plutzar, Simone Gingrich, Wolfgang Lucht, and Marina Fischer-Kowalski. (2007) Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. Proceedings of the National Academy of Sciences of the United States of America 104 (31):12942-12947. www.pnas.org/content/104/31/12942

(Sweden). This reflects the differences in the agricultural systems of the European countries which in turn seems to be highly dependent on natural conditions (climate, soils, water availability) and population density.

3.7 Key findings from the evaluation of the proposed basket of indicators

The suggested basket of indicators provides comprehensive information on Europe's use of natural resource and its various environmental impacts. The basket of indicators developed in Task 3 allows monitoring the absolute amounts of resource use in different categories (materials, energy/climate, water and land) as well as the various environmental impacts related to EU's resource use, including impacts on climate, ecosystems and human health. It thus provides a framework for assessing environmental pressures and impacts in a consistent manner.

For all resource use categories, indicators are available already in the short term. Although the availability of data varies across the resource use categories, at least pilot data sets are currently available for all resource use-oriented and environmental impact-oriented indicators suggested for the basket. The European Commission could and should therefore start setting up a comprehensive monitoring system of EU's resource use in the context of the Flagship Initiative on "Resource Efficient Europe".

Resources are needed to further harmonise methodologies and improve the data situation. There is a clear lack of methodological harmonisation regarding many of the indicators with a global perspective, in particular related to the consideration of resources embodied in internationally-traded products. Furthermore, efforts are required to improve the data situation. At the current stage, for many of desired future indicators, only pilot studies with data for selected years are available. Those data sets are not robust enough to allow a proper monitoring of the domestic and global environmental effects related to EU's resource use.

In addition to the headline indicators suggested for the basket, the EU should implement a Level 2 of indicators, which are more closely linked to specific resources or economic sectors. The project team developed a 2-level structure for the basket: Level 1 comprising comprehensive headline indicators and Level 2 with more specific indicators. While the headline indicators provide an easy to communicate message about the overall direction of resource use in the EU, the Level 2 indicators are needed to monitor focused strategies to reduce EU's resource use and its negative environmental impacts. Examples for those specific policy areas include waste management, recycling, renewable energies, water management in agriculture, industry and households and spatial and urban planning.

Chapter 4: Evaluation of target setting

This chapter proposes a set of resource efficiency targets for the headline indicators included in the basket of indicators (see Chapter 3: Evaluation of indicators). It begins with a discussion of approaches to setting resource related targets. Targets that have already been proposed by the European Commission or Member States are considered as a starting point to establishing links between the different types of resources and indicators. The results of an initial analysis of plausibility of the proposed targets is presented together with a discussion on what is the most appropriate level to set the target (e.g. EU, Member State, sector, region, etc.). Finally the chapter introduces a new approach to target setting.

4.1 The approach to target setting

The issue of setting targets on resource use is a very sensitive one. In order to provide a comprehensive and viable set of targets, a proposal for targets should build on existing targets and should use leading Member States as best practice examples[40]. For some indicators EU Member States (MS) or other countries have already implemented targets. A proposal from the European Commission (EC) can build on these in the sense of using them as best practice examples. On the other hand, any target proposed from the EC should relate to the targets on the MS level and should not counteract them. This task therefore builds on the review of existing targets compiled in Task 2.

The actual process of setting targets can be considered as a process of balancing different interests and perspectives. It is not a straightforward scientific procedure, but rather a normative and political one. However, science can provide background information and causal links which is a necessary basis for an informed political discussion. The proposed targets in this study are meant as indicative and directional targets in order to start the discussion of setting targets, rather than definite end results.

In order to address the different perspectives on target setting the project team developed an evaluation scheme (see Annex C in the Annex Report) to describe and discuss all aspects related to the specific target. The evaluation includes the following aspects:

- Threats if no target was set, differentiated along environmental, economic and social effects. The threats are classified as either trespassing a strong threshold and staying below the target is needed to avoid irreversible change. Or the threat symbolizes a minor danger where staying below the target ensures preserving a desired quality.
- Description of possible effects resulting from respecting the target, including a rough approximation of the expected resource use in 2020 (or 2050) as well as pros and cons of this particular target (e.g. effects on subcategories, sectors,

[40] For a list of existing targets see Annex B of the Annex Report

cross linkages between subcategories, conflicts resulting from competing uses, chances arising)

- Discussion of each specific target with regard to the four perspectives on sustainable use of resources:
  - the perspective of limitations to the resource base,
  - the perspective of limitations to absorption capacities of the earth's ecosystems,
  - the perspective of efficient and equitable resource supply for people (quality of life, well-being),
  - the perspective of efficient and equitable resource supply for economies (efficiency).
- Application of the target to the EU and MS level which discusses at what level the target should be set and how a disaggregation or aggregation to other levels can be done.
- Possible variations of the target, e.g. targets on absolute quantities, targets on preferable per capita values, targets on productivities or other intensive measures etc.
- Links to other indicators/targets
- Related Level 2 indicators or by which measures can the implementation of the headline indicator be put forward.
- Existing targets in the EU, the EU Member States or other countries.

Finally, targets can range from highly general, overall objectives down to a specific measure that directly guides the practical implementation. It is important to start with general objectives, which provide the framework for later measurements and which guarantee the full coverage of all resources. However, in the discussion of targets the project team had to address several measures that link to the overall target and that provide examples of possible measures to be taken.

4.2 Overview of existing targets in the EU and EU Member States

Table 11 shows a summary of existing targets and targets for related fields that are already implemented in the EU, EU Member States or other countries. (See Annex C in the Annex Report for a detailed table). The table shows that well formulated targets exist for GHG emissions and for energy efficiency. For other indicators, resource use is not yet targeted or only done so in individual countries.

Table 11: Summary of existing targets

Material use
DMC Domestic Material Consumption
Qualitative description of targets: "stabilisation" (+/- 0%) or "decrease"
EMC Environmentally-weighted Material Consumption
no targets yet
Energy / GHG emissions
GIEC Gross Inland Energy Consumption
Reduce primary energy consumption by 20% (compared to projections) by 2020 (building on targets set in the EU Energy Strategy). [many targets on energy efficiency, DK: fossil free until 2050]
GHG Territorial (production-based) GHG emissions
EU 2020 Energy Strategy: reduce GHG emissions by 20% compared to 1990 by 2020 European Council: decrease GHG emissions by 80-95%; achieve 2°C goal
Water use
WA Water Abstraction
no targets yet
WEI Water Exploitation Index
EEA: Water abstraction per annual available water resource below 20%
Land use
ALD Actual Land Demand
no targets yet
HANPP Human Appropriation of Net Primary Production
no targets yet

4.3 Proposed set of targets

Starting from the existing targets in the EU or in Member States, i.e. mainly starting from targets on GHG emissions and energy use, the project team generated targets for the domestic resource use oriented headline indicators.

For the other indicators, the project team developed proposals for targets based on expert knowledge and knowledge about links across resources and resource use. In a second step, the proposed set of targets were cross checked for plausibility by applying some rough calculations of the interdependencies between resources (see section 4.4). **Table 12 provides the proposal**

for targets of the four main resource types for 2020[41] and 2050. Expressed in average annual growth rates, the targets for DMC would require -2% per year until 2020 or -3% per year until 2050. For GIEC the annual growth rates are -1% until 2020 and -2% until 2050.

Table 12: Proposed set of targets in relation to 2005 as base year[42]

Material use	**DMC**	2020: -30% 2050: -70%	**EMC**	2020: > -30% 2050: > -70%
Energy use / climate	**GIEC**	2020: -20% 2050: -50%	**GHG**	2020: -20% 2050: -95%
Water use	**WA**	[indicator development]	**WEI**	2020: <20% 2050: <10%
Land use	**ALD**	2020, 2050: zero net-demand of foreign land	**HANPP**	2020: stabilisation at 50% 2050: reduction to 40%

Legend: DMC = Domestic Material Consumption
EMC = Environmentally Weighted Material Consumption
GIEC = Gross Inland Energy Consumption
GHG = Territorial (production-based) Green House Gas Emissions
WA = Water Abstraction
WEI = Water Exploitation Index
ALD = Actual Land Demand
HANPP = Human Appropriation of Net Primary Production

Setting targets can be considered as a process of balancing different interests and perspectives. The proposed set of targets was a result of several discussions among the project team members, where the different aspects were repeatedly considered. This was not a straight forward scientific procedure. After all, a decision about targets is more normative and political than scientific (see section 2.4).

The project team proposed targets using the existing scientific knowledge to the extent it could provide evidence, but otherwise based the targets on the project team's own judgement of how a resource efficient society could be achieved. The proposed targets in this study are meant to be indicative and directional targets to start the discussion before a political decision is made, rather than definite end results.

41 Proposing targets for the year 2020 is not unproblematic. The time to implement measures that change resource use patterns in such a way that these ambitious targets will be reached is short (some may argue that it is too short!). Knowing this, the project team in agreement with the Commission chose 2020 as a reference year for short-term targets - most importantly because other relevant EU policies such as the Europe 2020 Strategy or the Climate and Energy Package formulated targets for 2020.

42 This decision was influenced by the fact that most resource use data for the EU-27 (see section 3.6) are available only from 2000 onwards. Although the EU GHG emission and energy consumption targets use different baselines (1990 and a modelled scenario, respectively) for the sake of simplicity and harmonisation, the project team chose 2005 as the reference year for all proposed targets.

4.4 Analysis of the links between and the plausibility of targets across indicators

The headline indicators and thus targets formulated for those are closely linked (see Figure 18). The direct link between fossil fuel use and GHG emissions (mostly CO2 emissions) is most obvious. Likewise, a direct link is given for land use categories such as agricultural use or forests and the resulting extraction of renewable / biomass materials. Forests or forest area on the other hand link to GHG emissions due to its function as carbon sinks[43] and thus compensates for emissions. Agricultural production (and thus biomass extraction) and water resources are linked via irrigation. Water is also an important resource in industrial production in the form of cooling water or solvent in chemical processes. Links between resources and their use where considered in the process of target setting.

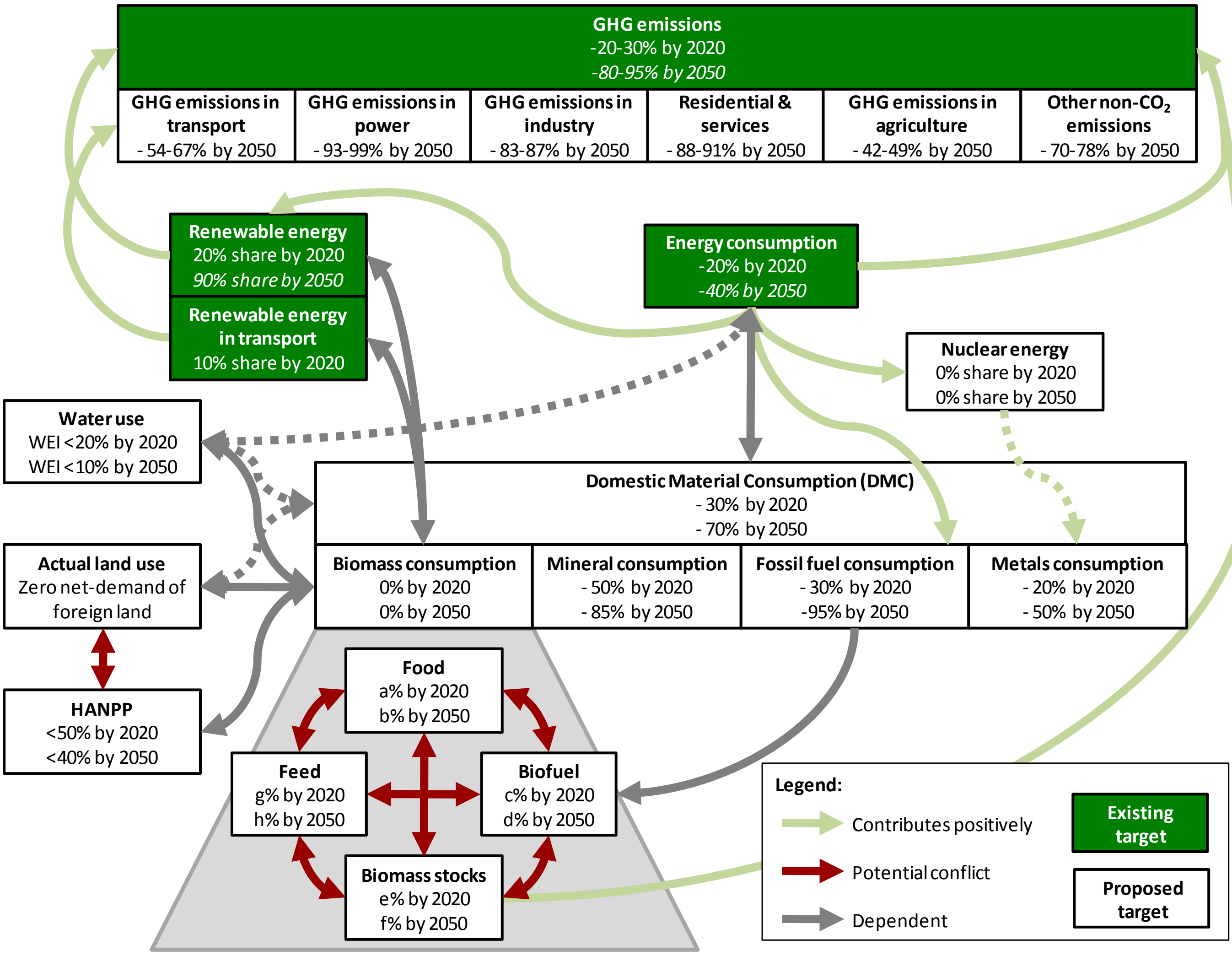


Figure 18: Links between resource use targets

Starting from existing targets on GHG emissions and energy use, the following sections presents the initial set of targets proposed by the project team. The proposed targets are discussed on the

[43] Besides other vital ecosystem services

aggregate level, but relevant sub-categories are also considered. A preliminary plausibility check was conducted for all targets.

4.4.1 Climate: GHG emissions

Targets on GHG emissions exist already[44]: they aim at reducing emissions by 20% (30%, if the conditions are right) until 2020 and 80-95% until 2050 (as compared to the year 1990). This was used as a starting point for developing targets for the other indicators. In the project team's initial proposal, a reduction of 95% of GHG emissions for 2050 was used.

Energy use / climate	**GHG**	2020: -20% 2050: -95%

4.4.2 Energy Use: Gross Inland Energy Consumption (GIEC)

In the context of energy use, three key parameters were identified to ensure a sustainable energy use in the future. These are:

1. Reducing GHG emissions and thus the consumption of fossil fuels,
2. Reducing total energy use (GIEC), and
3. Shift to a preferable energy mix.

The above mentioned reduction of GHG emissions can be converted to a reduction of fossil fuels (using the current mix of coal/oil/gas). For total energy use (GIEC) the project team assumed a reduction of 20% by 2020 as indicated in the Energy 2020 Strategy. For 2050 a reduction of GIEC by 50% was assumed[45] (just above the projections of other studies[46,47,48]).

For the preferable energy mix, the project team further built on increasing the share of renewable energy sources to 20% by 2020 (see Energy 2020 Strategy) or 90% until 2050 (the EU Energy Efficiency Plan 2011 expects nearly 100% by renewable energies). Boosting the use of renewable energy source to the main source of energy supply will lead to a tripling of the total amount of renewable energies (in energy units) until 2020 (as compared to 2005 levels) and an increase of demand for renewable energies by a factor 7 until 2050. Applying these assumptions provides wide scope for the use of nuclear energy. Different scenarios are conceivable, such as a nuclear free Europe. Targets proposed for energy use measured in GIEC:

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[44] European Commission (2010) Energy 2020. A strategy for competitive, sustainable and secure energy. COM(2010) 639 final.

[45] The EC Roadmap for moving to a competitive low carbon economy in 2050 suggests that in 2050, the EU's total primary energy consumption could be about 30% below 2005 levels.

[46] The Danish Society of Engineers (2009) Future Climate. Engineering Solutions. Includes climate plans for Germany, Finland, Ireland, Denmark, Sweden and the UK.

[47] Greenpeace and European Energy Council (2010) Energy [R]evolution. Towards a fully renewable energy supply in the EU 27.

48 WWF, Ecofys and OMA (2011) The Energy Report. 100% Renewable Energy by 2050.

Energy use / climate	**GIEC**	2020: -20% 2050: -50%

The increase of total amounts of renewable energies is the key strategy. Renewable energies can be derived from different sources. In 2005, 67% of renewable energy was derived from biomass use, hydro power made up for 23%, geothermal 5%, wind 5%, and solar amounted to 1% of renewable energy. An integrated approach to developing and deploying renewable energies in the context of resource efficiency is of vital importance. It can be expected that a significant amount of renewable energies has to be supplied by biomass and thus stands in direct competition with biomass used for food. The increase of bioenergy could have unintended negative consequences for land use change and thereby even aggravate the impacts on the environment.[49] Another example is that certain renewable energy and low carbon technologies (e.g. off-shore wind power, solar PV, electric batteries, etc.) will increase the demand for construction materials and some critical minerals.

4.4.3 Material Use: Domestic Material Consumption (DMC)

European levels of material use are significantly higher than global averages (around 9 tonnes per capita[50]) whereas so called developing countries use fewer materials. According to the International Resource Panel, increasing global material use "represents an unsustainable future" [51]. Thus, a global stabilisation of material use requires industrialized countries to reduce their demand in order to allow developing countries to grow.

On the aggregate level the project team proposed the following targets for a reduction of material use:

Material use	**DMC**	2020: -30% 2050: -70%

However, material use covers very different and diverse materials. A target on material use consequently cannot be applied equally to the four sub-categories (biomass, fossil fuels, metals, non-metallic minerals) but has to acknowledge the very different characteristics. The plausibility of the overall target for DMC were cross-checked with bottom-up developed requirements on the level of the four material sub-categories.

[49] EEA Scientific Committee, www.eea.europa.eu/highlights/suspend-10-percent-biofuels-target-says-eeas-scientific-advisory-body

[50] Fischer-Kowalski, Marina, Krausmann, Fridolin, Giljum, Stefan, Lutter, Stephan, Mayer, Andreas, Bringezu, Stefan, Moriguchi, Yuichi, Schütz, Helmut, Schandl, Heinz, Weisz, Helga (2011) Methodology and Indicators of Economy-wide Material Flow Accounting. State of the Art and Reliability Across Sources. Journal of Industrial Ecology, in press.

[51] UNEP (2011) Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A.

Fossil fuels

Fossil fuels are non-renewable materials that are used as energy carriers. Fossil fuels are directly and most significantly related to CO_2 emissions that are emitted when burning coal, oil, gas, etc. Building on the target on GHG emissions and energy use as described above , the required reduction of DMC fossil fuels[52] can be calculated as **-30% until 2020, and -95% until 2050**. Europe in 2050 would appear as mostly fossil fuel free and thus potentially independent of foreign supply of energy sources.

Biomass

Biomass comprises of materials derived from living or recently living organisms (e.g. crops and crop residues, grazed biomass, wood). Biomass materials can be considered renewable materials as long as the extraction does not exceed regeneration in a given year and productive soils are not degraded.

Due to favourable biogeographic conditions (climate, soils) and a high availability of productive land per capita, the EU has the potential of being self-sustaining with regard to food and other uses of biomass. Looking at biomass trade, the EU appears as mostly self-sufficient already. Net-imports of biomass amount to only 3% of total biomass use (although both imports and exports of biomass are considerable). Hence, a **stabilisation of DMC biomass** at current levels, i.e. stabilisation of biomass consumption (in terms of DMC) until 2020 and 2050, seem feasible.

Biomass serves five main purposes for societies:

- Feeding humans
- Feeding livestock
- Providing energy (e.g. biofuels, wood fuel)
- Use for construction purposes
- Building biomass stocks (in vegetation and soils), which are important carbon sinks (besides providing other vital ecosystem services)

Assuming a constant biomass extraction, these five use categories compete with each other. From the previous section, it was clear that the demand for renewable energy will increase in the future. Assuming that part of the increasing demand has to be satisfied by biomass resources, this means that (some of) the other categories have to decrease. Biomass stocks in forests serve as major carbon sinks and therefore forest area[53] should not decline, but rather increase. Biomass used for construction purposes is not expected to decrease but likely to increase. Given a (slowly) growing population, the overall supply of nutritional biomass cannot decrease, but changes in composition are possible. The production of animal products for human nutrition requires a high input of biomass from cropland and grassland. A shift from animal based food towards a higher

[52] The underlying calculation is based on the current energy mix (coal/oil/gas) which is questionable for the future but valid for a first estimation.

[53] Forests also provide a variety of other vital ecosystem services

share of plant based food in European diets has the potential to considerably reduce the biomass demand for human nutrition and free biomass resources for energy use.[54]

Metals

Metals are non-renewable resources, concentrated in deposits, and comprise a great number of very different metals and ores some of which have toxic properties in small amounts. Some metals are abundantly available in the earth crust; others are considered scarce; some are used in societal products in large amounts (e.g. iron ore) others only in tiny fractions ("spice metals"). Metals are mostly accumulated in stocks and thus have the potential of being recycled and reused.[55]

The two main thresholds in relation to metals arise from the limited natural stocks and the EU's dependence on foreign supply. The overall development should therefore seek for independence of foreign supply and the reduction of depletion of natural stocks in general (domestically and globally) in order to avoid restricting future generations.

It is difficult to propose a reduction of metal ore consumption. First, the high diversity within metals and ores requires objectives to be set on a more detailed level. Second, considering total DMC, metals make up for the smallest sub-group in EU material use (only 4% of total DMC). Thus, any target for metals has only little significance to the overall DMC target compared to the other material categories. However, for metals in particular, DMC only shows part of the picture. The EU relies intensively on imports of metal products (83% of DMI in 2007). For metals the consideration of upstream resource requirements in the process of extraction and processing is therefore crucial. DMC does not include these, whereas RMC (Raw Material Consumption) does. As soon as data for RMC will be available on a broader scale, a more detailed analysis of metal use can be conducted. It may then become more relevant to specify a specific target for metal RMC.

Metals are typically accumulated in societal stocks. Hence, increasing use of societal or anthropogenic stocks through recycling and reuse can provide relief to natural stocks. In order to foster a more efficient and extensive use of societal stocks, development of technologies are required as well as improvements in product design to unfold unused potentials.

Key parameters in reducing metal use are considered:

- Exhausting recycling potentials by technological innovation and improved product design
- Reduction of growing demand for metals by changes in consumption patterns
- Shifting towards increasing lifetimes of consumer goods
- Particularly addressing societal use of minerals with highest environmental impacts on ecosystems and human health

[54] Institute for Social Ecology and Potsdam Institute for Climate Impact Research (2009) Eating the Planet: Feeding and fuelling the world sustainably, fairly and humanely – a scoping study. Commissioned by: Compassion in World Farming.
[55] UNEP International Resource Panel (2011) Recycling Rates of Metals. A Status Report.

Metals represent both high value resources and significant environmental impacts. Instead of attempting to disaggregate the overall DMC target to DMC of metals, it would be better to focus on increasing their resource efficiency. Although, the general aim would be reduce the consumption of metals and their associated environmental impacts, this should not come at the expense of compromising EU's competiveness, nor should it hinder construction of the low carbon and renewable energy infrastructure that is needed in the short and medium term.

- **Non-metallic minerals**

Non-metallic minerals such as sand, gravel, limestone, clay, are mainly used for construction activities building up infrastructure (roads and buildings). This material category makes up for around half of material use.

An estimate for the EU[56] reveals that around 25% of construction minerals are used for building new infrastructure, the other 75% are used for maintaining existing stocks. At the same time, land area is limited and the constant expansion of built-up land has to be stopped in order to reduce pressure on land area (and thus on biodiversity and ecosystem services). Stabilising built-up stocks is considered a key strategy since it results in a reduction of material use, a reduction of energy use in the production and use phase, and a reduction of the use of land. The use of non-metallic minerals should range around -50% by 2020 and -85% by 2050.

Stabilizing built-up stocks will require boosting recycling and reuse of societal stocks. Recycling potentials are expected to be rather high (between 80-90%) and could significantly reduce the pressure on natural stocks. At the same time, societal patterns of mobility and transport have to be reconsidered and further developed under considerations of sustainability.

- **Consequences of DMC Reduction**

The DMC targets will result in a per capita material use of 11 t/cap/yr in 2020 and nearly 5 t/cap/yr in 2050. Other scenarios such as those presented by the International Resource Panel in the "Decoupling Report" arrive at similar results. The Resource Panel's Scenario 3 "Tough contraction and convergence" project 5 t/cap/yr for industrialized countries with high population such as the EU. Expressed in average annual growth rates, the targets for DMC would require -2% per year until 2020 or -3% per year until 2050. (For GIEC the annual growth rates are -1% until 2020 and -2% until 2050).

4.4.4 Material Use: Environmentally Weighted Material Consumption (EMC)

Targeting EMC is rather difficult because the indicator still needs further development with regards to methods and data availability. However, some general recommendation can be formulated based on the available studies on EMC.

Current resource use policies (e.g. the "Thematic Strategy on the Sustainable Use of Natural Resources" of the EC) call for a double decoupling, i.e. decoupling of resource use from economic

[56] Large Scale Planning and Design of Resource Use. A project under the Framework contract ENV.G4/FRA/2008/0112. 2011.

growth and decoupling of environmental impacts from resource use. Hence, a **target on EMC should aim for exceeding the reduction of DMC.** In the case of biomass, this means that although the use of biomass resources is stable, the EU should still strive for reducing the environmental impact from agriculture and forestry such as land degradation, top soil loss, etc.

Material use	**EMC**	2020: > -30% 2050: > -70%

4.4.5 Land Use: Domestic Land Demand

Land area is increasingly exposed to increasing demand by agriculture but also built-up land and at the same time increasing pressure due to intensification of land use. Monitoring and targeting domestic land demand addresses the first of these issues and asks for a balanced share between different land use categories. Land use categories that have the smallest effects on land cover should be preserved. This refers to wilderness areas but also forests. Conversely, expansion of agricultural land should be strongly limited (see also the recommendation of the Stockholm Resilience Centre[57] on limiting the percentage of global land cover converted to cropland to 15%).

On the global level, distributional issues have to be considered additionally. As mentioned before, Europe is characterized by favourable biogeographic conditions (climate, soils) and a high availability of productive land per capita. Thus, Europe's demand for foreign land area (in particular productive land such as agricultural land) should be balanced. This can be traced by the indicator Actual Land Demand (or comparable calculations such as GLUA[58]), which considers land requirements embodied in trade flows. In relation to the request for stabilising biomass use, and limiting the EU demand for limited land resources to a fair share, the target for zero net-demand of foreign land is considered well-balanced.

Land use	**ALD**	2020, 2050: zero net-demand of foreign land

Indicators and calculation methods still need development and harmonization, however, some first estimates exist[58, 59, 60]). Estimations for the EU15 revealed that 18% of domestic demand of agricultural products are supplied by foreign land.[61] Projections for future land demand estimate an increase of global or actual land demand by 20% to 50% until 2030.[62]

[57] Rockstrom et al. (2009) Editorial, Earth's boundaries? Nature. Vol. 461, Issue 461, pp. 447-448. See also: www.stockholmresilience.org/planetary-boundaries)

[58] Bringezu and Bleischwitz (2009) Sustainable Resource Management. Global Trends, Visions and Policies. Greenleaf Publishing.

[59] Lambin & Meyfroidt (2011) Global land use change, economic globalization, and the looming land scarcity. Proceedings of National Academy of Sciences www.pnas.org/content/early/2011/02/04/1100480108.full.pdf

[60] Erb, Karl-Heinz (2004) Actual land demand of Austria 1926–2000: a variation on Ecological Footprint assessments. Land Use Policy, Volume 21, Issue 3. Pages 247-259

[61] Bringezu and Bleischwitz (2009) Sustainable Resource Management. Global Trends, Visions and Policies. Greenleaf Publishing.

[62] Lambin & Meyfroidt (2011) Global land use change, economic globalization, and the looming land scarcity. Proceedings of National Academy of Sciences www.pnas.org/content/early/2011/02/04/1100480108.full.pdf

4.4.6 Land Use: Human Appropriation of Net Primary Production (HANPP)

HANPP, an indicator addressing land use intensity, varies across different land use categories. Cropland is typically characterized by high HANPP levels at or above 85%, whereas forests have low HANPP values below 30%. Depending on land cover patterns and the intensity of land use, domestic HANPP across European countries differs widely. The highest average HANPP (60-70%) occurs in countries with a high share of intensive agriculture, such as the Netherlands, Hungary, Denmark and the Czech Republic. Countries with less intensive land use and a high proportion of forest cover have much lower average HANPP. Average HANPP in Sweden, Finland or Slovenia, for example, is less than 30%.

Land use	**HANPP**	2020: stabilisation at 50% 2050: reduction to 40%

HANPP as share of NPP_0 is currently about 48% in Europe (40% in Western Europe and 52% in Eastern and South-Eastern Europe). While HANPP in Western Europe is mainly driven by harvest (NPP_h), in Eastern and South-Eastern Europe land conversion ($NPP_{\Delta LC}$) plays an important role[63]. The proposed target for 2020, i.e. 50%, represents stabilisation, whereas the 2050 target requires action towards decreasing land use intensity without expanding the land area used.

The overall target for the EU-27 of stabilising average HANPP at 50% or reducing it to 40% should not be applied equally to individual Member States. Countries with less favourable conditions for intensive land use (e.g. Sweden, Finland or Slovenia) should maintain low levels of HANPP. Whereas countries with productive land suitable for agricultural production (e.g. the Netherlands, Hungary, Denmark and the Czech Republic) should still engage in agriculture – and thus can have levels above the target level. However, **HANPP in regions with high suitability for intensive cropland agriculture should not exceed 75%.** Although the proposed 2020 target for HANPP corresponds to current levels, this still requires action to avoid that HANPP in regions of high intensive land use does not exceed 75%. In other words, stabilising or reducing average HANPP in Europe may require a stabilisation or increase in extensive land use types, and a sustainable intensification on the best agricultural land. This is a trend, which has been observed in Europe during the past decades.

The short discussion shows that the national level is not the most suitable level to monitor and manage average land use intensity. A spatially explicit perspective is required and a more suitable scale to apply HANPP targets could be based on regions defined by bio-geographic characteristics such as agro-ecological zones. Agro-ecological zoning (AEZ), as applied in FAO studies, defines zones on the basis of combinations of soil, landform and climatic characteristics. The particular parameters used in the definition focus attention on the climatic and edaphic[64] requirements of crops and on the management systems under which the crops are grown. Each

[63] 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.

[64] Relating to soil

zone has a similar combination of constraints and potentials for land use, and serves as a focus for the targeting of recommendations designed to improve the existing land-use situation, either through increasing production or by limiting land degradation.[65]

4.4.7 Water use

Indicators on water abstraction are still in development and some major decisions on conventions still have to be taken. Thus, a target on water abstraction cannot be formulated for the time being.

Water use	**WA** [indicator development]

The Water Exploitation Index is currently used in Europe[66]. In line with EEA recommendations, the proposed target is to reduce the WEI below 20% until 2020 and below 10% until 2050. A Water Exploitation Index between 10% and 20% is considered as *"low water stress"*), WEI between 20% and 40% is indicating *"stress on water resources"* and above 40% represents *"severe water stress"*.

Water use	**WEI**	2020: <20% 2050: <10%

The targets on WEI have to be considered as overall targets. In order to be operational they need to be linked to a particular spatial scale. Water and water bodies do not follow administrative boundaries and consequently the level of management has to be set on a more ecosystem-related level – this would preferably be at the river basin level.

4.5 Targets and the application on different levels

The set of targets proposed so far have been formulated for the EU-27 as a whole. These targets provide a general framework and are orientated for specific measures to monitor the progress of the EU and MS. In a next step, the overall objectives have to be translated to targets on a national level or other relevant regional scale and then have to be complemented by specific measures (see the previous chapter and the evaluation forms in Annex C in the Annex Report).

A breakdown of targets to the Member State level is reasonable for the resource use-oriented headline indicators, i.e. DMC, GIEC, WA, ALD. These indicators are closely linked to socio-economic activities and thus a disaggregation along political/economic entities is well grounded. The same is true for the environmental impact-oriented indicators EMC and GHG.

The definition of **targets on the MS level** then again is not an easy task and can be done under different perspectives:

[65] FAO, www.fao.org/docrep/W2962E/w2962e00.htm#P-2

66 EEA (2009) Water resources across Europe – confronting water scarcity and drought. EEA report No. 2/2009.

- Equal breakdown of EU targets to the MS level, i.e. a 30% reduction on the EU level equals a 30% reduction in all MS
- Breakdown according to population size (e.g. per capita), which represents social equality and the aim of providing all inhabitants with equal resources.
- Breakdown according to economic output, which tackles the assumption that economic development needs resources and in return the right of using a certain amount of resources in order to allow for economic development. This takes the different economic structures in MS into consideration
- Breakdown according to predominant ecosystem characteristics (see also below)
- Or a combination of the approaches above

The question of which approach or combinations of approaches to apply is a matter of political negotiation.

For HANPP and WEI the national level does not represent the appropriate reference scale (see sections 3.5 and 4.4). These two indicators are closely linked to ecosystem functioning and operational information can only be gained on a spatial scale that orients itself at the relevant ecosystem boundaries. In the case of HANPP, agro-ecological zones are considered as a highly relevant scale for targets to be set. In the case of WEI, river basins would be preferred. However, in both cases (i.e. for HANPP and WEI) the aggregate level of the EU-27 and an overall target on this level is useful because this serves as an overall framework and can complement the ecosystem-perspective with the necessary administrative level.

4.6 Focussing on multi-return strategies

The above set of specifications provides a target for each of the headline indicators included in the basket of indicators. This section introduces a different approach to setting targets. When considering targeting resource use, one could try to build on the strong functional links between resources[67] and then identify key or "multi-return" strategies that capture, with one policy intervention, all or most resources.

The strong functional ties between materials use, energy use, water use and land use grant certain synergies, but sometimes also burden shifting. If one develops a strategy of reducing materials, there may be an additional energy requirement for the investment, but then in the longer run one will also save on energy (and on transport). The same logic also works the other way round, and as a rule extends also to land use and water use. In some cases, the relations are not synergistic but complementary. For example, one needs to invest in materials in the short term to save on energy for heating and cooling in the long term. But even in this case, in the long run there would be an overall materials and energy saving (as insulation materials tend to be light and applied only once, while energy carriers for combustion are saved throughout the use phase).

[67] Steinberger, Julia K., Krausmann, Fridolin, und Eisenmenger, Nina (2010) Global patterns of material use: a socioeconomic and geophysical analysis. In: Ecological Economics 69(5), S. 1148-1158.

Following this, it is possible to identify **"Single-Return Strategies"**: strategies that target one specific effect. An example of this is Carbon Capture and Storage (CCS). CCS may substantially reduce carbon emissions, but at the same time it lowers the energy return on investment, requires substantial construction materials to be built, and potentially creates a risk of leakage in the long run.

And then there are *"Multi-Return Strategies"* where one measure can have several effects on a broad set of or even all resources. Among these Multi-Return Strategies the following have been identified:

1. **Changing the human diet** towards a lower share of animal based food. Tackling this will have several effects:
    a. Positive effects on human health (less obesity, less cardiovascular diseases, lower risk of livestock-related epidemics)
    b. Decreasing livestock and thus lowering pressure on land because less land area is needed for agricultural production (i.e. market fodder for livestock)
    c. Lowering pressures on groundwater (nitrification)
    d. Savings of energy (cooling, transportation)
    e. Decreasing GHG emissions from ruminants
    f. Savings on water use
2. **Steady stocks of built-up infrastructure and densification of settlements**, reducing urban sprawl
    a. decreasing material use, i.e. construction minerals, metals use in infrastructure,
    b. facilitating a continuous recycling of construction materials
    c. decreasing energy use for the construction of infrastructure, in transport and in the use phase (more efficient heating, shorter distances)
    d. decreasing use of land area and sealing of land
3. **Product re-design for longevity and recycling**. This is not really **one** strategy, but a bundle of strategies, to be developed for groups of products.
    a. reducing toxic materials, increasing use of bio-degradable materials
    b. increasing longevity, repair-friendliness and re-use of products
    c. increasing recyclability by design
    d. improving energy efficiency in production and use of products

In the policy context of targeting, the question is whether several targets should or could be set or if political concentration and power should focus on "Multi-Return strategies" that require less action but broader effects.

4.7 Proposal of a range of targets

Based on the above the project team proposed a range of resource use targets for 2020 (medium term perspective) and 2050 (long term perspective) corresponding to three different levels of ambition levels. It was assumed that the targets proposed in the previous task represented the most ambitious level of targets. The ambition levels for the moderate and conservative target scenarios are rough estimates based on the interdependencies of resources. The feasibility of achieving these targets with known technology, while maintaining current levels of activity is examined in the next chapter.

Table 13: Overview of the proposal for resource use targets for different ambition levels

	Ambitious	Moderate	Conservative
GHG emissions (baseline 1990)	-30% by 2020 -95% by 2050	-20% by 2020 -80% by 2050	-20% by 2020 -50% by 2050
Energy consumption (GIEC) (baseline 2005)	-20% by 2020 -40% by 2050	-15% by 2020 -30% by 2050	-10% by 2020 -20% by 2050
Material use (DMC) (baseline 2005)	-30% by 2020 -70% by 2050	-10% by 2020 -30% by 2050	-5% by 2020 -20% by 2050
Land use	Zero net demand of foreign land by 2020	Zero net take of artificial land by 2020	Limit annual net increase of artificial land to 200 km^2 by 2020
Water use **Water Exploitation Index (WEI)**	<20% WEI by 2020 <10% WEI by 2050	<25% WEI by 2020 <20% WEI by 2050	<30% WEI by 2020 <25% WEI by 2050

Chapter 5: Scenario analysis

This chapter assesses the feasibility and consequences of setting the resource use targets proposed in the previous chapter. In order to have a reference for the analysis, a baseline scenario had to be first defined. The baseline scenario is a business-as-usual (BaU) scenario, which takes into account current EU policies on resource use and climate change.

The scope of this study did not allow for any extensive modelling to be performed, therefore the project team could only construct a very crude method to analyse the scenarios. The project team built the baseline scenario around existing models for resource use and climate change. When no models could be identified the per capita resource consumption trends from historical data were used to estimate future total resource consumption. This involved many simple assumptions on each of the resources and their mutual dependencies. Corresponding to the targets proposed, the baseline scenario estimates the EU-27's material, energy, water and land use for 2020 (medium term perspective) and until 2050 (long term perspective).

The following sections document the structure and assumptions used for the baseline scenario and for scenarios where resource use targets have been set.

5.1 Baseline scenario

In order to assess the possible impacts of setting resource use targets, a reference or baseline scenario must first be defined. The baseline is a business-as-usual (BaU) scenario, which includes the present scope of the current EU policies on resource use and efficiency.

Statistical data for EU-27 was gathered for all the main resource categories. The project team sought to gather data as far back as 1990 (the reference year for the EU climate and energy targets). While the energy statistics are complete, there is only complete EU-27 data from Material Flow Accounts (MFA) covering 2000 to 2007. The water and land use statistics have considerable data gaps. Therefore, the project team only considered data from 2000 and onwards. Data gaps for specific years were filled by using data from the closest year where data was available. Data gaps for individual Member States were filled by taking the per capita consumption in a similar country (size, climate, etc.) and extrapolating it using the population statistics.

The future trend for BaU resource use until 2050 was determined by using Eurostat's population projections and results from trend analyses and models in relevant studies. Several projections already exist for energy consumption and climate change. These were used directly to define the energy consumption and GHG emissions (see the following sections).

For the resources that are clearly linked (see the previous chapter), if future projections already existed for one resource type, then the relationship between the resources was used to determine the future resource use trends. For example, projections for renewable energy from wood (solid biomass) already exist. The projections for wood fuel material consumption and forest land use would then be linked to the projections of renewable energy from solid biomass.

When no clear projections could be found for a resource, the average annual change (i.e. increase or decrease) per capita consumption over the past decade (or for as many years as there was a complete set of historical data) was used to predict the evolution of resource use (by simple linear extrapolation). In this way the evolution of population could be taken into account. If any evidence of future trends for resource use were identified (e.g. from EEA's State and Outlook reports), the calculated average annual change for future projections was adjusted accordingly.

The details of the baseline scenario definition are presented in Annex D in the Annex Report.

5.1.1 Energy and climate change

The baseline scenario takes into account the EU 2020 climate change and renewable energy targets. The EU seems to be on track for achieving both of these. However, the reduction of energy consumption (energy efficiency) target does not appear to be in sight with the current implementation of policies. Although the recent Energy Efficiency Action Plan of the European Commission stressed the need for energy efficiency measures, the latest projections for energy consumption in the EU show only a minor decrease compared to current consumption[68]. In the Impact Assessment of the "Roadmap for moving to a competitive low carbon economy in 2050"[69] the Commission's reference scenario expects EU's energy demand (in terms of Gross Inland Energy Consumption) to increase slightly towards 2020, but then decrease and stabilise around 1750 Mtoe (see Figure 19).

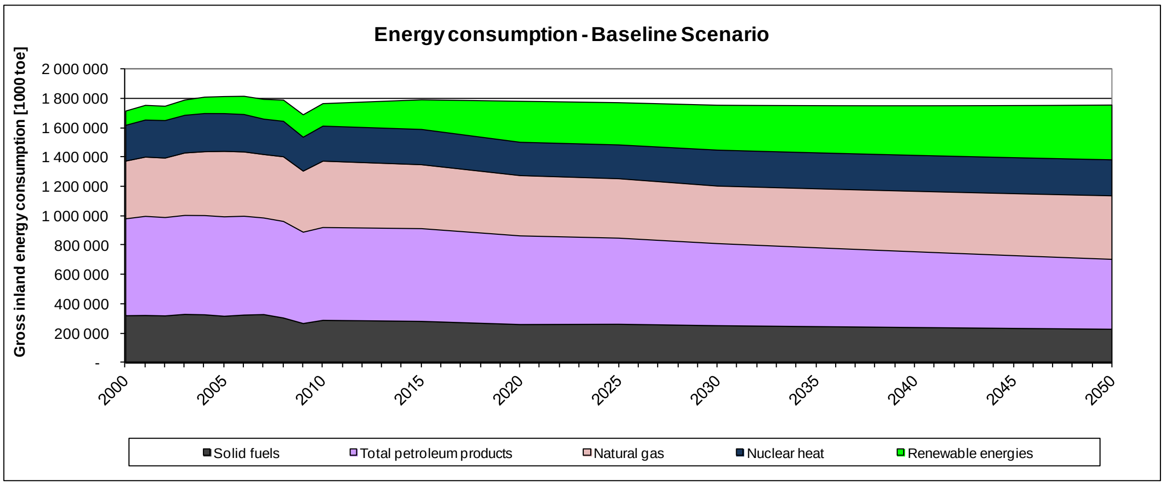

Figure 19: The baseline scenario for Gross Inland Energy Consumption in EU-27 until 2050

Building upon the Commission's energy trends to 2030, the project team assumed that the consumption of fossil fuels will gradually decrease towards 2050, nuclear energy will remain constant and renewable energy will increase to meet the demand. At present about 70% of renewable energy in the EU is provided by biomass, mostly from wood and wood waste[70, 71]. From 2030 to 2050, the project team assumed that renewable energy sources will continue to

[68] European Commission (2010) EU energy trends to 2030 — UPDATE 2009. DG Energy.

[69] European Commission (2011) Roadmap for moving to a competitive low carbon economy in 2050. COM(2011) 112

[70] Eurostat

[71] European Commission (2011) Impact Assessment, Roadmap for a shift to a competitive low carbon economy in 2050.

grow with 1% annual reaching 372 Mtoe in 2050. Although other renewable energy sources will come to play, biomass will remain an important component amounting to 228 Mtoe in 2050 (predominantly crops, residues and waste)[72].

In the European Commission's "Roadmap for moving to a competitive low carbon economy in 2050"[73] the modelling showed that full implementation of current policy will result in a 39% reduction of domestic GHG emissions in 2050 (compared to 1990). If current trends continue energy production and industry will reduce their GHG emissions, but the transport sector will keep increasing its carbon emissions (see Figure 20).

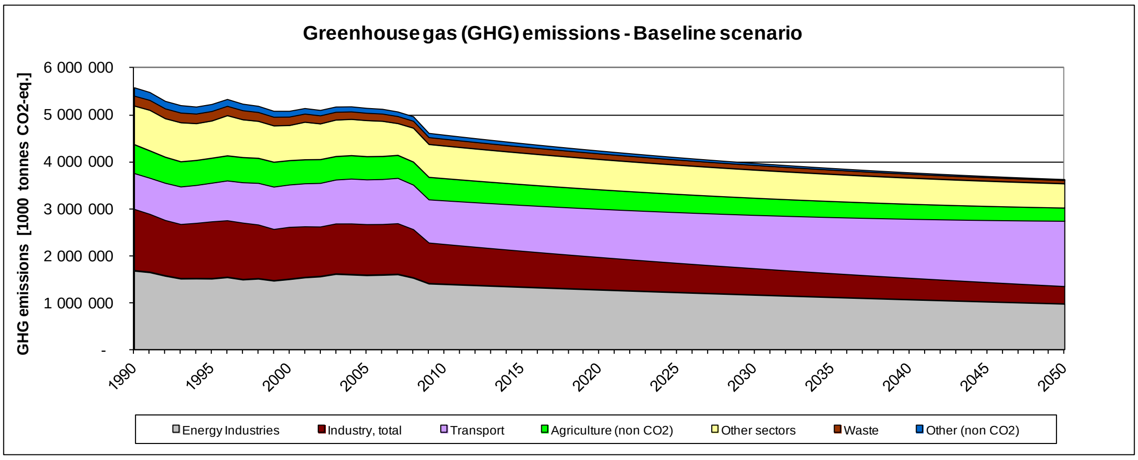

Figure 20: The baseline scenario for domestic greenhouse gas emissions in EU-27 until 2050

5.1.2 Material consumption

In the baseline scenario the overall domestic material consumption (DMC) in the EU-27 is expected to rise slightly with growing population, but otherwise remains at around the current levels (see Figure 21). The composition of DMC will however change – mainly due to current energy policy. The projection for fossil fuel DMC follows the projections for fossil fuel energy consumption. DMC of metals and minerals is expected to decrease slightly over the next decade and then stabilise. Biomass is the component of DMC that is expected to grow the most - mainly to meet the demand of renewable energy production.

[72] European Commission (2011) Impact Assessment, Roadmap for a shift to a competitive low carbon economy in 2050.
[73] European Commission (2011) Roadmap for moving to a competitive low carbon economy in 2050. COM(2011) 112

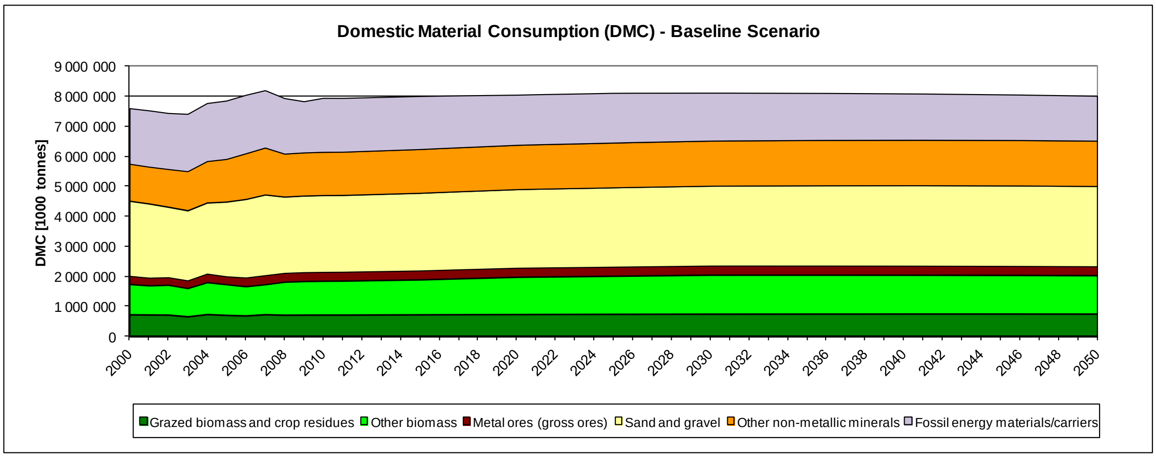

Figure 21: The baseline scenario for Domestic Material Consumption in EU-27 until 2050

Domestic extraction used (DEU) for fossils fuels is expected to decrease (due to the exhaustion of current oil fields). The baseline scenario projects overall DEU will increase slightly towards 2050 due to higher demand for biomass energy, but also the general trends for iron ores and minerals (Figure 22).

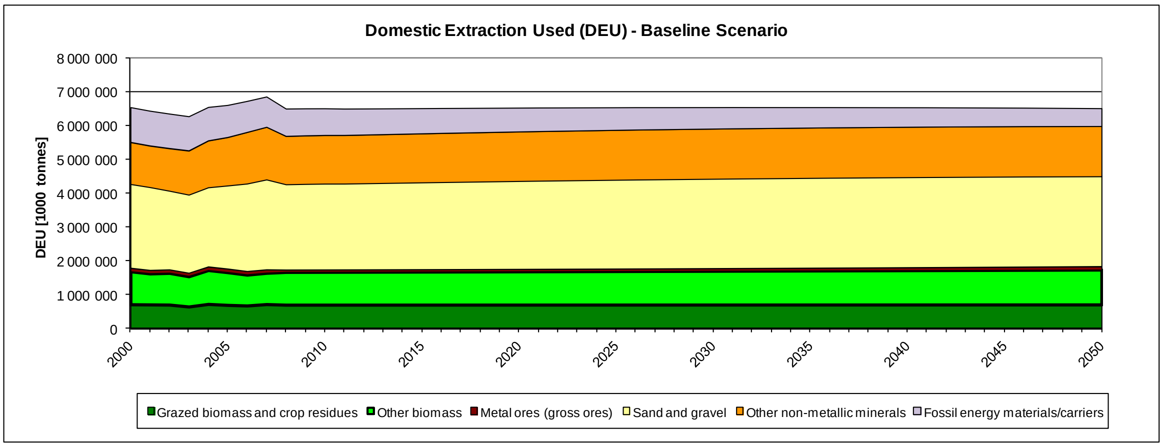

Figure 22: The baseline scenario for Domestic Extraction Used in EU-27 until 2050

The trends for material exports are expected to continue. In order to maintain GDP growth, the EU will continue increasing the export of metals, fossil fuels and biomass (Figure 23). These materials represent the main products that the EU is competitive in, i.e. machinery, transport equipment, refined petroleum products, meat and dairy products, etc.

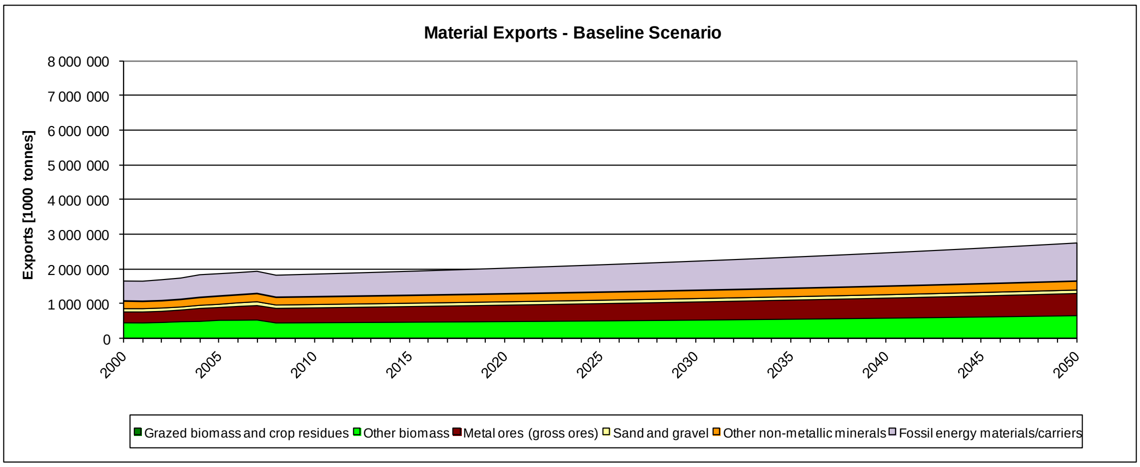

Figure 23: The baseline scenario for material exports in EU-27 until 2050

The baseline projections for material intensive exports drive the demand for material imports. The demand for imported raw metal ores, fossil fuels and fodder crops is assumed to continue to increase without any improvements in material productivity (Figure 24).

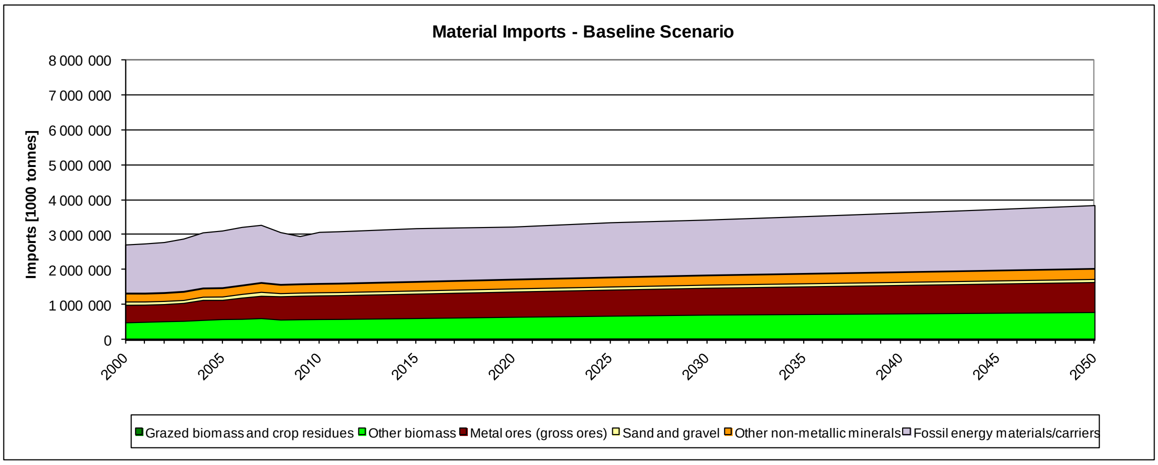

Figure 24: The baseline scenario for material imports in EU-27 until 2050

5.1.3 Land use

The baseline scenario is performed without considering any changes to the current number of Member States. Therefore the total (domestic) area of land in the EU is assumed to remain constant. Current trends show artificial areas, forests and other natural areas are increasing at the expense of agricultural land (see Figure 25).

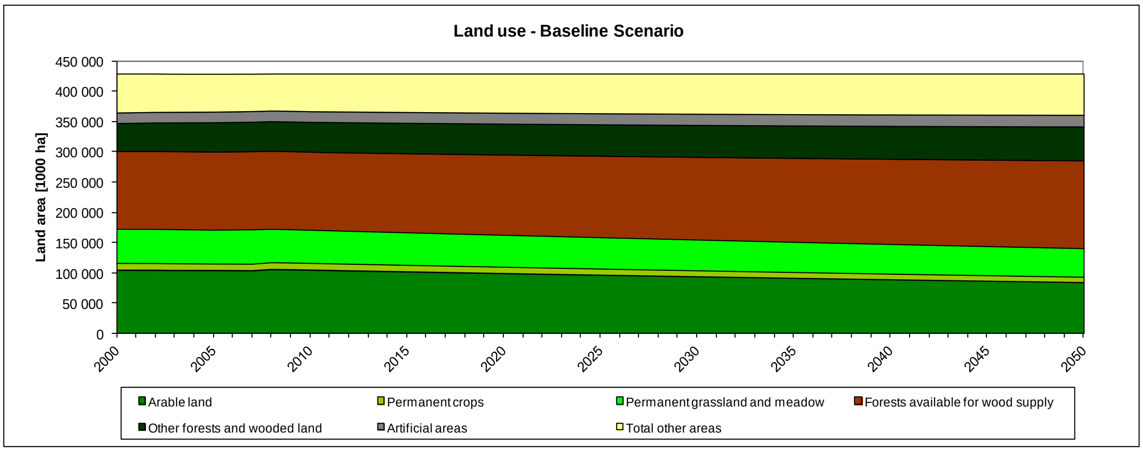

Figure 25: The baseline scenario for domestic land use in EU-27 until 2050

The decrease in domestic agricultural land together with the increase in demand for biofuel will drive the demand for global crop land. The increase in demand for biomass energy is not expected to increase the demand for wood fuel from forests outside of the EU. The EU is able to meet its own domestic demand of bioenergy from forestry[74].

5.1.4 Water use

All Member States have reduced their abstraction of water over the past decade. This trend is expected to continue with greater water efficiency in the major water using sectors. At the EU level it is not possible to determine how the Water Exploitation Index will evolve in the future as water stress is a local issue. It can be assumed that the Member States with high abstraction for agricultural use (i.e. Cyprus, Spain, Italy and Malta) will continue to experience severe water stress in the future without strengthening of current policy.

The Water Footprint (global water use in the life cycle of products consumed in the EU) is also expected to increase following the trends for increasing material imports.

5.2 Scenario with proposed resource use targets

In the previous section the baseline scenario for resource use in the EU-27 was established for 2020 and 2050. Current climate change policy is expected to reduce GHG emissions by 39% by 2050 compared to 1990. Energy consumption will decrease slightly but otherwise remain stable under this scenario. Material and global land use is projected to increase.

In this section the resource use targets for EU-27 proposed in Chapter 4: are analysed. Starting with the climate change targets the analysis assesses whether the resource use targets proposed are feasible while maintaining current levels of activity. When possible, the consequences of setting the target are discussed.

[74] EEA (2006) How much bioenergy can Europe produce without harming the environment?

5.2.1 Climate change

In its Impact Assessment of the "Roadmap for a shift to a competitive low carbon economy in 2050"[75] the Commission has already assessed the impacts of setting a GHG emissions target. Meeting the 2ºC objective requires the halving of global emissions by 2050. In order to make its proportionate contribution, Europe must reduce its GHG emissions by 75% or more by 2050 (compared to 1990).

The Impact Assessment showed that in order to achieve 80% reduction of domestic GHG emissions while maintaining or even increasing activity levels in transport, annual energy consumption should decrease by 30-35% to 1300 – 1350 Mtoe and that most of the energy is based on renewable energy sources. Depending on early investment in different (known) technology assumptions and global action, this could be cost-effective and lead to reduced fuels costs.

Industry, services and the residential sector will also have to dramatically decrease their carbon emissions through low carbon technologies, zero-energy buildings and carbon capture and storage. Carbon emissions from the transport sector will inevitably rise towards 2030, but increased vehicle efficiency, the use of cleaner energy and better use of infrastructure will significantly decrease the sector's contribution to GHG emissions. Non-CO_2 emissions (mainly from the agricultural and waste sector) will require greater yields, efficient fertiliser use, bio-gasification of manure and better treatment of waste and manure.

High investments are required, but this offers opportunities for growth and employment. There will be shifts in job sectors and 'green' labour skills would need to be revised and updated. Carbon pricing initiatives and extension to non-ETS sectors could help guide investment. This could bring benefits by reducing labour costs. As a reduction of domestic GHG emissions would encourage the diffusion of renewable energy, this would decrease fossil energy imports and increase security of energy supply. Furthermore, a reduction in GHG emissions would also reduce SO_2, NO_x and PM emissions that would benefit the environment and human health.

A less ambitious target or delays in investment and global action would increase fuel costs and supply risk, besides aggravating the effects of climate change. A more ambitious target (e.g. 95% reduction of GHG emissions by 2050 compared to 1990) is technically and economically feasible according to Greenpeace[76] and WWF[77], but would require greater infrastructure investments and a lower demand and modal shift in the transport sector.

[75] European Commission (2011) Impact Assessment. Roadmap for moving to a competitive low carbon economy in 2050. SEC(2011) 288 final

[76] Greenpeace and the European Renewable Energy Council (2010) Energy [r]evolution. Towards a fully renewable energy supply in the EU 27.

[77] WWF, Ecofys and OMA (2011) The Energy Report. 100% renewable energy by 2050.

5.2.2 Energy consumption

In order to respect individual Member States' preference for nuclear energy, the project team maintained the current share of nuclear in EU's overall energy mix. A reduction in energy consumption would also reduce the total amount of nuclear energy in 2050.

Even with a total shift of energy production to nuclear and renewable energy sources, reducing energy consumption in the EU will be key to achieving the 2050 climate change targets. As mentioned, the Commission's Impact Assessment claims that current activity levels can be maintained (and even increased for transport and residential space) with a reduction of energy consumption up to 30% in 2050 (compared to 2005). Both the Greenpeace and WWF studies assume that a 40% reduction in energy consumption is possible (also compared to 2005), but this includes greater investments in energy efficiency and possibly some reduction in activity levels for some sectors.

The proposed 2050 GHG emissions target would drastically change the EU's energy mix. The EU will shift from reliance on fossil fuels and instead satisfy its energy demand from renewable energy sources. Biomass currently provides about two thirds of EU's total renewable energy. EEA estimated that Europe has sufficient sources of domestic 'environmentally compatible' bioenergy to cover its demand. Their estimates were only made until 2030, but other more recent studies show that the technical annual production potential of bioenergy in Europe in 2050 when considering sustainability constraints could be more than 500 Mtoe[78]. If this was also economically feasible, then renewable energy could provide with enough so that phasing out nuclear energy is a possibility.

Table 14: Scenarios for biomass for renewable energy in the EU in Mtoe

Year	2005	2010	2020	2030			2050	
Scenario	REF	EEA	EEA	EEA	REF	EFF	REF	EFF
Crops	5	47	96	142	76	53	80	134
- Second generation	0				57	40	79	127
Agricultural residues	17				31	32	36	49
Forestry	40	43	41	55	51	51	42	59
Waste	25	99	99	96	63	63	60	87
Import	2				9	12	9	26
Total	**90**	**189**	**236**	**293**	**231**	212	**228**	356

REF: Bioenergy production requirements for reference case in EC Impact Assessment of the Low Carbon Economy Roadmap
EFF: Bioenergy production requirements for effective technologies decarbonisation case in EC Impact Assessment of the Low Carbon Economy Roadmap
EEA: Environmentally-compatible bioenergy potential estimated by the European Environment Agency

Crops and crop residues would provide the greatest share of bioenergy, with forestry residues as the second greatest source. Animal manure and waste can also contribute with significant amounts, but their potential for future growth is limited.

[78] Haberl et al. (2010) The global technical potential of bio-energy in 2050 considering sustainability constraints. Current Opinion in Environmental Sustainability.

There is currently a lot of ongoing discussion on how the increase demand of bioenergy will affect food and feed production as well as land use change. The production of feedstock for bioenergy is closely linked to food, feed and forestry production. It is not clear what will drive the demand in a global market. Without proper policies in place, the bioenergy would undoubtedly compete against food production and put even more pressure on global water use and land use change resulting in unintended negative environmental and social consequences. There does however seem to be evidence that there is potential to increase agricultural and forestry yields in order to meet the demand without also increasing pressure on the environment.

Bioenergy will therefore continue to be the main source of renewable energy, at least until the other renewable energy technologies establish themselves over the next two decades. Biomass energy will then decrease but remain the principal energy source well into the future. The demand for bioenergy will depend on when electrification of the transport sector will occur. At present, the shift to battery-driven vehicles is not envisioned before 2030.

5.2.3 Material consumption

- **Biomass**

The phasing out of fossil fuels from energy production will drastically reduce the DMC of fossil energy carriers. A small amount of fossil materials will however still be needed for non-energy uses, i.e. plastics and chemicals (approx. 85 – 115 Mt) [79]. On the other hand the uptake of renewable energy will be largely driven by a greater demand for biomass for energy production. This will increase dramatically until 2040 but then stabilise as the other renewable sources (e.g. wind, solar and geothermal) take off. As mentioned, biomass for energy use will be in direct competition with the demand for food, feed and forests.

Both Greenpeace and WWF believe that the increasing world demand (for 9 billion people) for food, bioenergy and even biomass material feedstock for materials can be supplied sustainably without jeopardising forested and protected land areas. This does however require a 1% annual increase in yield of global agricultural cropland[80]; a 50% reduction of current per capita meat consumption in OECD countries by 2050; and a significant increase of energy recovery from biowaste.

Bioenergy will predominantly come from energy crops (which are in competition with food and feed), but with the current technological development this will instead be based on residues from crops, animals and forests in the future. All other things being equal this would increase DMC of biomass as more crop and forest residues would be 'used' in the economy. Therefore due to the increase in demand for bioenergy, it would be difficult to reduce DMC of biomass. However, due to favourable biogeographical conditions (climate and soils) and a high availability of productive land per capita, the EU has the potential of being self-sustaining with regard to food and other uses of biomass. The improvement of yields will be key to meeting the biomass demand. In

[79] Greenpeace and the European Renewable Energy Council (2010) Energy [r]evolution. Towards a fully renewable energy supply in the EU 27.

[80] Current annual yield increase projections vary from 0.4 to 1.4%. The 1% annual yield increase does not take into consideration the effects of climate change on agricultural production.

agriculture the two approaches to increasing yields has either been through input intensification (e.g. increasing the use of water, fertilisers and plant protection) or factor intensification (e.g. applying best practices and new technology). In the case of resource efficiency, factor intensification should be promoted rather than input intensification. If not, the improvement of yields would entail higher levels of water and fertiliser use.

Another approach to meeting the demand for biomass, as mentioned in the previous chapter, is by changing human (and animal) diets. At present, the EU average human diet contains a large amount of protein and animal based products. Nutritional guidelines for a healthy diet recommend a lower intake of protein and much less animal based products. The project team roughly estimates that a 30% decrease of current consumption levels of beef and pork could reduce biomass demand by over 6%. On a per capita level this would correspond to replacing a beef steak or pork chop meal with a vegetarian option once a week. There also seems to be considerable potential to reduce food waste. A 10% reduction of food waste by 2050 is quite feasible and together with a less animal based diet this could almost reduce total biomass (including food, feed and energy) demand by 10%. Besides reducing the amount of biomass and the resulting environmental benefits, changing diets would have positive effects on human health. Assuming all other things constant, expenses for food would decrease, which could contract the economy of the food sector (but not necessarily the agricultural sector).

It is not clear whether extensive organic agricultural practices are compatible with the increase in demand for biomass. Although, organic agricultural practices reduce the pressure on the local natural environment, this may outweigh the global pressures by decrease in yields. There is evidence [81] that organic farming can match the yields in conventional farming practices in Europe, but it is actually in developing countries where the potential for increasing yields is greatest (organic or not). With diet changes to a less meat intensive diet, there is a possibility that organic agricultural practices could meet the demand for biomass in the future. Whatever the case, more sustainable agricultural practices are certainly possible with the proposed targets, even if intensive agriculture is necessary in some regions of Europe.

Metals

Metals only constitute 4% of DMC, but they contribute significantly to the EU economy and global environmental impacts. Setting ambitious targets to encourage more efficient use of metals, would both be cost-effective, environmental beneficial and limit dependence on foreign imports (particularly for the critical raw materials such as rare earths). Although, it is feasible to reduce the DMC of metals, this can only be done to a certain extent. While the baseline scenario does not expect DMC of metallic ores to increase, metals are crucial for EU's competitiveness in the global trade of machinery, transport equipment and clean technologies. In order to maintain the EU's global trade position, domestic demand and exports should not be compromised by limits in DMC, but rather in improvement of material productivity. It would therefore seem pertinent to decrease domestic material input (DMI) by increasing recycling and resource efficiency of metals. The potential of recycling, waste prevention and ecodesign has initially been

[81] Halberg, N., Knudsen, M.T., Alrøe, H.F. and Kristensen, E.S., eds. (2006) Global Development of Organic Agriculture: Challenges and Promises. CABI Publishing.

estimated to be between 50 and 130 Mt of the DMC of metallic ores[82]. This represents about 20% to 45% reductions of metal DMC compared to the year 2000. In the years leading up to 2050, these material savings might not lead to an actual reduction of DMC. DMC of metals could actually instead increase. In order to achieve the target for reductions in GHG emissions and energy consumption, metals are required for the construction and production of energy efficient infrastructure and products, and renewable energy installations such as windmills and biogas plants. Once the new energy infrastructure is in place, it would possibly be able to reduce DMC.

Construction minerals

Construction minerals (even excluding sand and gravel) constitute the majority of DMC of all non-metallic minerals. A recent study investigated the material input flows related to EU-27 transportation infrastructure and built-up areas[83]. A large share of the construction materials are needed just to maintain the existing building stock and infrastructure. The shares of the input flows needed for replacement at end-of-life are estimated at about 63-90% for the transportation network and 88% for buildings. The study concluded that the materials flows related to maintenance and renewal of existing stocks are much larger than the ones related to infrastructure expansion. The estimates of the amounts of construction and demolition (C&D) waste generated in the EU are not very reliable, but even when taking the high estimate of C&D waste (approx. 1700 Mt) the current demand for construction minerals (2300 Mt) in the EU cannot be satisfied even with 100% recycling[84]. Applying the full potential of C&D waste recycling, only 25% of current construction mineral DMC could be reduced. But again, similar to DMC of metals, the investment in energy efficiency and renewable technologies will also increase the demand for construction minerals over the next decades.

If DMC of non-metallic minerals is to be reduced further as proposed in the previous chapter, solutions for maintaining the current built stock have to be found. Significant increases in the use of biomass and metals as substitutes for construction materials do not seem to be feasible with the expected demands for bioenergy and metals. Substituting construction minerals with wood may be a sustainable approach to construction (wood is an excellent sink for carbon emissions), but this will not contribute to reducing the overall DMC. Solutions for reducing non-metallic mineral DMC will have to include stabilising (and maybe even reducing) the built stock, extensive recycling, increasing the density of urban areas and improving large scale planning. No evidence was found concerning to what extent renovation of infrastructure could be less material intensive. It is however believed that better planning of infrastructure maintenance could significantly reduce DMC of construction minerals. Just consider how much materials are dug away every time an electricity cable has to be replaced.

As it is not very clear how DMC of non-metallic minerals can be reduced, one could question whether it is appropriate to set a target based on this indicator. Compared to other materials the environmental impacts of many construction minerals (such as sand, gravel and clay) are minor

[82] BIO Intelligence Service, VITO and the Institute for Social Ecology (2011) Analysis of the key contributions to resource efficiency. Study commissioned by the European Commission, DG Environment.

[83] BIO Intelligence Service (2011) Large Scale Planning and Design of Resource Use. Study commission by the European Commission (DG ENV).

[84] It must be noted that in general, the estimates for the use of construction minerals are not very reliable.

even when considering their large quantities that are used. Furthermore, the demand for construction minerals may increase in the next decades in order to achieve the targets for energy efficiency of buildings (e.g. increased insulation) and to build new infrastructure for renewable energy plants (e.g. wind, solar, biogas, etc).

5.2.4 Land use

It is evident that without greater yields, it will not be possible to increase biomass production without land use change. Artificial land is currently increasing at the expense of agricultural land. Although artificial land only constitutes less than 5% of the total land area in the EU, increases of artificial land use drives the consumption of construction materials and has significant negative impacts on the environment (e.g. soil sealing and fragmentation of natural habitats).

A major challenge to achieving the proposed target of limiting the increase of artificial land is that the construction sector is currently very closely linked with economic growth. Many measures to boost economic activity are related to the construction of new infrastructure. This is beneficial for the economy on the long term, but often happens at the expense of agricultural or natural land areas. Limiting net take of artificial land is possible, but will require densification of existing built-up land, and/or remediation and reconversion of artificial land to natural land.

The EU is capable of being self-sufficient in biomass, but the target for land use should not compromise the competitive advantage of growing crops in the biogeographic regions that are most productive and best suited from a sustainability perspective. The proposed target for zero net demand of foreign land must be carefully considered in this respect. The necessary change to a less animal based and in season locally sourced diet could support this target.

5.2.5 Water use

The increase in demand of bioenergy will certainly also increase the need for irrigation. Water availability depends on local conditions, but climate change may also have significant effects. At an overall EU level it is difficult to assess what consequences the proposed resource use targets will have on water stress. A major issue is good water use data to actually monitor the efficient use of water. Several regions and countries in the EU do experience severe water stress, but it is generally believed that it is possible to reduce the demand for freshwater through better measuring and resource efficient practices[85]. It is therefore assumed that the water use targets can ensure that all regions have sufficient water resources available.

[85] BIO Intelligence Service (2011) Water saving potential in agriculture in Europe: findings from the existing studies and application to case studies. Study commissioned by the European Commission, DG Environment

5.3 Summary of findings from the target scenario analysis

Table 15 presents an overview of the project team's assessment of the feasibility of achieving resource use targets for 2020 and 2050. It should be noted that the modelling and analysis performed in the study is crude and makes many assumptions on the projections of resource use and their links, cost-effectiveness and the diffusion of resource efficient technologies.

There is evidence that **the EU can achieve an almost fully renewable energy based supply by 2050 and maintain the current activity levels. This would require a 40% decrease in energy consumption** compared to current levels. Bioenergy will be the main renewable energy source (at least until the other renewable energy sources have developed fully). The **EU can potentially meet 70% of its primary energy demand through domestic bioenergy production**, but this would **require significant increases in yields, diet changes and use of biowaste** as an energy source.

A reduction in domestic material consumption of fossil fuels is a consequence of the GHG emission reduction target. Until 2050, it is not clear whether reductions in metal consumption can also be achieved while maintaining current activity levels. Although recycling and other approaches to increasing material productivity do result in reduced demand for metal ore extraction, there will be a need for these materials to build new products and infrastructure suited for a low carbon economy. **Biomass material consumption could potentially be stabilised but again this is dependent on diet changes and the treatment of biowaste**.

It is **unlikely that it is possible to reduce the consumption of non-metallic minerals** (even with increased recycling) as these are needed to maintain current buildings and infrastructure and their demand might increase with greater demand for energy efficient buildings and new infrastructure for renewable energy sources.

Thanks to its climate and soils, the **EU could potentially be self sufficient in biomass production with a shift to a less animal based diet and crops that are suited for the region and seasons**. Consideration should however be given to maintain (intensive) crop production in the regions of Europe and the world that are most suited. An important learning from the EU's biofuel target is the importance of defining clear sustainability criteria for bioenergy in order not to cause unintended negative impacts on land use change, climate change and biodiversity.

Water use is expected to increase with growing demand for bioenergy in the EU, but it is assumed that **if the use of water is better monitored, the demand can be reduced through water efficient technologies and practices**.

Table 15: Overview of the assessment of the economic and technical feasibility of achieving the proposed range of targets

	Ambitious	Moderate	Conservative
GHG emissions (baseline 1990)	-30% by 2020 -95% by 2050	-20% by 2020 -80% by 2050	-20% by 2020 -50% by 2050
Energy consumption (GIEC) (baseline 2005)	-20% by 2020 -40% by 2050	-15% by 2020 -30% by 2050	-10% by 2020 -20% by 2050
Material use (DMC) (baseline 2005)	-30% by 2020 -70% by 2050	-10% by 2020 -30% by 2050	-5% by 2020 -20% by 2050
Land use	Zero net demand of foreign land by 2020	Zero net take of artificial land by 2020	Limit annual net increase of artificial land to 200 km^2 by 2020
Water use **Water Exploitation Index (WEI)**	<20% WEI by 2020 <10% WEI by 2050	<25% WEI by 2020 <20% WEI by 2050	<30% WEI by 2020 <25% WEI by 2050

Legend for feasibility:	Possibility to achieve targets with significant changes in levels of activity and significant advancement from known and future technologies	Possibility to achieve targets with slight changes in levels of activity and greater investments in known technologies	Possibility to achieve targets while maintaining current levels of activity and cost effective investments in known technologies

Chapter 6: Recommendations: Moving forward with existing indicators

This chapter provides the Commission with the project team's recommendations for setting resource use and resource efficiency targets.

6.1 The next steps for setting targets

The European Commission has made it clear in its Europe 2020 strategy which direction that the EU should be moving. Indicators and targets are important tools to guide, coordinate and encourage progress in the right direction. This study has proposed a framework of indicators that can help the Commission in its efforts towards a resource efficient, low-carbon economy. Although the study has demonstrated that many of the available indicators desperately need to be improved or developed further, this should not deter the Commission in continuing their work by discussing and considering possible resource use and resource efficiency targets. There is too much at stake to wait for a perfect set of indicators. Many of proposed indicators can already be adopted for use in resource policy development. In the case of limitations, other supporting indicators and experts should be consulted.

6.1.1 Further development and implementation of indicators

This study developed a basket of indicators to be used by the European Commission in the context of the Resource Efficiency Roadmap and other resource policy processes. On the one hand, the basket contains indicators, which are available in the short term (1 year) and could be readily applied already from 2012. On the other hand, the suggested global resource demand indicators are currently being developed and refined or newly introduced in this study. In the following, the main areas for further development are summarised and specific recommendations are provided regarding priorities in the field of indicator development and application.

6.1.1.1 Resource use embodied in trade

The domestic environmental pressures within EU borders are well represented in all of the suggested indicators of the basket. However, with increasing globalisation and international trade, the inclusion of resource use embodied in internationally traded products becomes ever more important for a directionally-safe interpretation of trends in European resource use and efficiency.

- Further develop and harmonise different methodological approaches to calculate resource use embodied in international trade of the EU-27 and EU MS and expand and refine databases allowing this calculation:
    - Support the development of global, multi-regional input-output frameworks extended by resource use data on the level of economic sectors and product groups, in particular regarding the disaggregation of resource-intensive economic sectors as well as the production of time-series.
    - Support the further development of approaches applying resource intensity coefficients on the product level derived from Life Cycle Assessments (LCA), in particular regarding the geographical and temporal specifications of such resource intensity coefficients of traded products.
    - Support the development and testing of hybrid approaches combining the mutual advantages of the two basic alternatives, i.e. using coefficient approaches where a high product detail is required (e.g. imports of different metal ores from various countries outside the EU) and input-output approaches for higher-manufactured products, which are more homogeneous regarding their material composition and very time-consuming to assess with LCA.

6.1.1.2 Indicators on environmental impacts of resource use

In the past years, several indicators have been presented, which aim at quantifying the different environmental impacts related to human resource use. Those indicators are still in the stage of development and have only been tested with data for a few years or a few countries.

- Further strengthen and test currently developed methodologies and improve the underlying data bases for their calculation:
    - Support the improvement of the LCA-based impact factors for different resources, in particular in the context of the JRC-based European Life Cycle Database (ELCD). This concerns especially the geographical specification of impacts according to countries outside Europe, where the environmental impacts take place as well as the development of time-series of impact factors, in order to reflect technological improvements.
    - Ensure that the "Resource Life Cycle Indicator" developed by JRC is further expanded in its scope, e.g. through inclusion of more than the current 15 main traded product groups and the consideration of more representative products within each of the selected product groups.

6.1.1.3 *Indicators on impacts on ecosystems and biodiversity*

The area of global resource demand, environmental impact-oriented indicators for the resource category of land use was the only area, for which no specific indicator could be suggested in the basket. Indicators covering those aspects of land cover and land use change are only currently being developed.

- Support the development of approaches to link land cover and land use change to indicators on ecosystem quality and biodiversity, such as the Land and Ecosystem Accounts (LEAC) by the EEA.
- Support the further refinement of methodologies which enable assessing the impacts of European production and consumption on ecosystems in other world regions, such as embodied HANPP (eHANPP).

6.1.1.4 *Indicators on the natural capital stock*

This project focused on indicators, which reflect the flows of resources (materials, energy, water) plus the issue of land use. Indicators illustrating the developments of natural capital stocks were beyond the scope of this study. However, they are of crucial importance for assessing issues such as overexploitation and resource scarcity. The main barrier for integrating such indicators into an indicator system as proposed in this study is the still very limited data situation concerning both non-renewable resource stocks (e.g. mineral resources) and stocks of biomass (e.g. forestry stocks, carbon stocks, stocks of natural habitats).

- Refine and harmonise methodologies to account for natural capital stocks, for example, in the context of the upcoming revision of the SEEA system of integrated environmental and economic accounts.
- Support the collection and validation of data on the Member State and EU level on both reserves of non-renewable resources (metal ores, industrial and construction minerals) and stocks related to biomass and ecosystems.

6.1.1.5 *Level 2 indicators*

This study introduced a system of two levels for monitoring European resource use and efficiency: a top level with headline indicators plus a second level with more detailed indicators within each resource category. The further refinement and testing of the level 2 indicators was beyond the scope of this study.

- Refine the understanding of the interlinkages between level 1 and level 2 indicators
  - Analyse the influence of specific level 2 indicators on the overall trend of the corresponding level 1 indicator, in order to set priorities for policy action to improve the overall trend.
  - Test the suitability of level 2 indicators for target setting accompanying the level 1 headline indicators and targets. This

includes for example targets for material efficiency or GHG intensity of specific economic sectors, targets for maximum waste generation, or targets limiting specific environmental impacts from resource use (e.g. acidification or ozone depletion).

- Support the further development of specific level 2 indicators, which are not yet available. Those indicators include:
  - Waste reduction, e.g. food waste
  - Recycling indicators
  - Water indicators such as water use by water source and water scarcity by region
  - Soil indicators

6.1.1.6 Response indicators

Response indicators illustrate the action taken by policy, business or the civil society to improve current trends in European resource use and efficiency. This study only briefly touched on the issue of response indicators and a deeper understanding of the impacts of responses on certain categories of resource use is still missing.

- Develop methodologies to better assess the impacts of (policy) responses (e.g. environmental taxes, R&D spending in eco-innovation areas, subsidies for resource-efficient technologies, etc.) on resource quantities and related environmental impacts, in order to prioritise policy and business action.
- Include resource use and resource efficiency indicators as key indicators in EU environmental assessment methodologies, which should ensure that the implications of policy decisions on resource use and resource efficiency are taken into account before the actual decisions are made.

6.1.2 Develop the knowledge base for impact assessments

Based on existing targets on climate change, renewable energy and energy consumption, this study proposed an extensive set of possible resource use related targets for EU-27 for 2020 and 2050. The use of resources are closely linked. The analysis of the target scenarios showed to what extent (non-energy related) resource use can be more sustainable in the EU. The analysis made it clear that not all of the proposed targets are suitable for policy purposes. Only the level 1 indicators was assessed for target setting in this study. Many of these indicators provide an overview for general resource efficiency trends, but often the more specific level 2 indicators are more suitable for setting targets, e.g. recycling of critical raw materials instead of DMC of sand and gravel.

- *Multi-return strategies* – investigate how improving resource efficiency for several resources at the same time can be achieved through focused policy interventions

- *Methodologies to better assess the impacts of (policy) responses* (e.g. environmental taxes, R&D spending in eco-innovation areas and subsidies for resource-efficient technologies) on resource quantities and related environmental impacts, in order to prioritise policy and business action, e.g. marginal abatement curves for resource use
- *Build-up the policy "business case"* – find socio-economic evidence to justify setting a target, when the scientific evidence on the environmental rational is missing, e.g. emphasise the benefits of securing supply and competitiveness

6.1.3 Involve external actors and stakeholders in the process of target setting

An approach to the target setting process is to arrange open multi-party debates where representatives of the main stakeholders are brought together to define concrete objectives and plan of actions. Extensive consultation allows all viewpoints to be heard on an equal level and is a good starting point for building consensus. It is therefore recommended to develop the following:

- *Communication of indicators* - rethink how the indicators could be better communicated and more easily understood by everybody. Many of the current resource related indicators use confusing language and terms, e.g. embodied water, actual land demand and virtual footprint. Consider renaming or harmonising the terminology.
- *Establish open multi-party debates* - extensive consultation allows all viewpoints to be heard on an equal level and is a good starting point for building consensus.
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