DYNAMIX

Decoupling growth from resource use and environmental impacts

How will we know if absolute decoupling has been achieved?

Common Approach for DYNAMIX

Deliverable D.1.2 (Final Draft)

European Commission

SEVENTH FRAMEWORK PROGRAMME

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AUTHOR

Katharina Umpfenbach, Ecologic Institute

With contributions by:

Martha Bicket, Martin Hirschnitz-Garbers, Patrick ten Brinck, Roger Salmons, Adrian Tan, and Robin Vanner

With thanks to:

Gerald Berger, Andrea Bigano, Maciej Bukowski, Paul Ekins, Tomas Ekvall, Doreen Fedrigo-Fazio, Pawel Kazmierczyk, Myrim Linster, Leonardo Mazza, Aldo Ravazzi Douvan, Daniela Russi, and Umberto Pisano

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DYNAMIX PROJECT PARNTERS

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0 Executive Summary

The objective of the DYNAMIX project is to identify policy mixes to absolute decoupling of economic growth from resource use and its associated environmental impacts. While the project's work packages will apply a number of different methods, all use a set of shared key concepts and assumptions. The Common Approach serves to clarify these and ensure consistent application throughout the project. In particular, the document includes discussions of and working definitions for the following concepts:

- resources;
- relative and absolute decoupling;
- resource efficiency;
- paradigms and paradigm shift;
- policy mix, and
- eco-efficiency.

More importantly, the document presents a framework for assessing the effectiveness, the sustainability and the cost-efficiency of EU policy mixes aimed at achieving absolute decoupling. Rendering a vision for a resource-efficient EU more concrete, DYNAMIX proposes five pragmatic key targets for 2050 as a benchmark against which to assess the effectiveness of policy interventions. The targets are chosen so as to cover the most critical environmental impacts and resource scarcities, while avoiding overlap between targets. They reflect the available evidence on planetary boundaries, are grounded in a global equity perspective, and are neutral with respect to the choice of abatement measures. Our aim is to contribute to the ongoing debate at EU level about appropriate targets, indicators and ambition levels.

Proposed DYNAMIX key targets for 2050:

- **consumption of virgin metals:** *-80 % compared to 2010 measured by RMC in the EU* representing scarcity of metals and environmental impacts caused by extraction, refinement, processing and disposal of metals;
- **greenhouse gas emissions;** *2 tonnes CO_2-equivalent per capita and year (measured as footprint to reflect embedded emissions and as EU-internal emissions)* representing climate change impacts of greenhouse gas emissions through energy use as well as agricultural and industrial processes;
- **consumption of arable land:** *zero net demand of non-EU arable land* representing, as a rough approximation, impacts of biomass production on soil quality, water quality and biodiversity;

- **nutrients input:** *reducing nitrogen and phosphorus surpluses in the EU at the level best available technique can achieve* representing impacts of agricultural production on marine and freshwater quality as well as soil quality;
- **freshwater use:** *no region should experience water scarcity* representing impacts of resource use on freshwater availability.

The Common Approach stems from two main roots: a semantic analysis of literature and policy documents, and intense discussion, both within the consortium and with stakeholders. The project team discussed a first draft at an internal workshop held in Gothenburg in December 2012. The revised version was presented to stakeholders from policy, science, business and civil society and to the project's Advisory Boards at DYNAMIX's first Policy Platform in March 2013. The document will be regularly amended to reflect new insights.

The document consists of two parts. Section 1 contains the Common Approach, a concise summary of how we will proceed in the project and why. Section 2 explains in more detail how the Common Approach has been derived by placing it within the current scientific and political debate.

1 Common Approach

1.1 Spatial and temporal scope

DYNAMIX focuses on the EU in 2050

DYNAMIX develops policy mixes addressing the impacts of EU resource use within the EU and globally, to be implemented at EU level or within Member States.

Given the EU's intense trade relations with the rest of the world, consumption and production patterns in the EU substantially impact and are impacted by other world regions in manifold ways. First and foremost, both raw materials and goods imported into the EU may have generated significant impacts in the exporting countries they came from. These impacts may occur at the stage of resource extraction, production of goods or during transport. EU-wide and Member States' legislation can substantially influence the impacts associated with EU consumption. Thus, to the extent data availability allows, all impacts and resource flows that result from final consumption of materials, goods and services in the EU will be considered within DYNAMIX.

On the other hand, non-EU countries' own environmental legislation also determines the extent to which resources or products exported to the EU burden the environment in the exporting country. For example, weak recycling regulation in a country exporting to the EU might increase the amount of waste associated with this country's export goods. Another aspect to consider is that low ambition of regulation in non-EU countries might make it harder to pass stringent regulation within the EU due to competitiveness concerns of European industries and businesses.

Yet, given the high complexity in the project, policy developments and other relevant trends occurring outside the EU (and not related to EU consumption) will be acknowledged where possible, but will not be considered in detail within DYNAMIX. Thus, while they will be included in the assumptions framing the external context scenarios, where they will inform the background, they will not be an integral part of the analysis. Similarly, socio-economic impacts of the proposed policy mixes will only be assessed for EU countries.

The temporal scope of DYNAMIX when assessing the effectiveness, cost-efficiency and sustainability of the proposed policy mixes is the medium term (2030) and the long term (2050). By 2050 at the latest, the proposed policy mixes should have achieved absolute decoupling of EU economic growth from resource use and its associated impacts, notwithstanding the fact that some policies will continue to affect certain pressures beyond 2050, e.g. landfill emissions or greenhouse gas concentrations. 2010 will be used as a common base year for ex-ante assessments in Work Packages 5 and 6.

1.2 Understanding of resources

In order to address unwanted burden shifting, DYNAMIX is based on a broad understanding of resources

The focus on absolute decoupling places the assessment at a very aggregate level. In order to investigate whether economy-wide decoupling occurs, we have to consider a multitude of biotic and abiotic resources having an impact on various elements of the global ecosystem across the entire life-cycle, from extraction to disposal, and within a number of economic sectors and consumption fields. Even though some consumption fields and sectors clearly involve higher resource use and associated impacts than others – food, mobility and housing have been identified as the sectors with the most significant impacts (Tukker et al. 2006) – virtually any human activity, good or service directly or indirectly depends on resource use. A meaningful assessment of whether absolute decoupling is achieved at the level of an entire economy thus needs to take into account all types of resources in order not to neglect trade-offs between the use of different resources. Even though a policy strategy to reduce overall resource use and its impacts will have to encompass sector- or resource-specific measures, such a stand-alone strategy would risk shifting problems to other sectors or regions, or trading one type of environmental impact for another. Here, one crucial side-effect is the indirect rebound effect that occurs when income saved through efficiency gains is spent on other resource-consuming goods and services.

Definition: Resources

In line with the EU Thematic Strategy on the sustainable use of natural resources and the Roadmap for a resource-efficient Europe, DYNAMIX widely defines resources as encompassing:

- **abiotic resources**, including minerals, metals, and fossil fuels (inputs),
- **biotic resources**, including timber, fish, agricultural products and all other types of biomass as well as land, water and soil (inputs),
- **environmental media** and the **ecosystem services** linked to them: land, water, air, soil, biodiversity (impacted by outputs such as waste or emissions).

DYNAMIX thus covers all natural resources that are used or modified to create economic value (even if the resources are not physically part of the final good) and all environmental media and processes that can be affected by the production, use and disposal of economic goods and services.

For these reasons, there are no specific sectors, resources or impacts that we exclude from the assessment. This does not preclude sector-specific analysis in the case studies (WP 3) and potentially also in one of the promising policy mixes

identified (WP4) and to be assessed ex-ante (WP 5 and WP 6), feeding into policy briefs by sector or policy field (WP 8). But in all of these steps, we will strive to detect how the policy mix impacts the use of other resources not directly targeted by the policy mix.

1.3 Decoupling and planetary boundaries

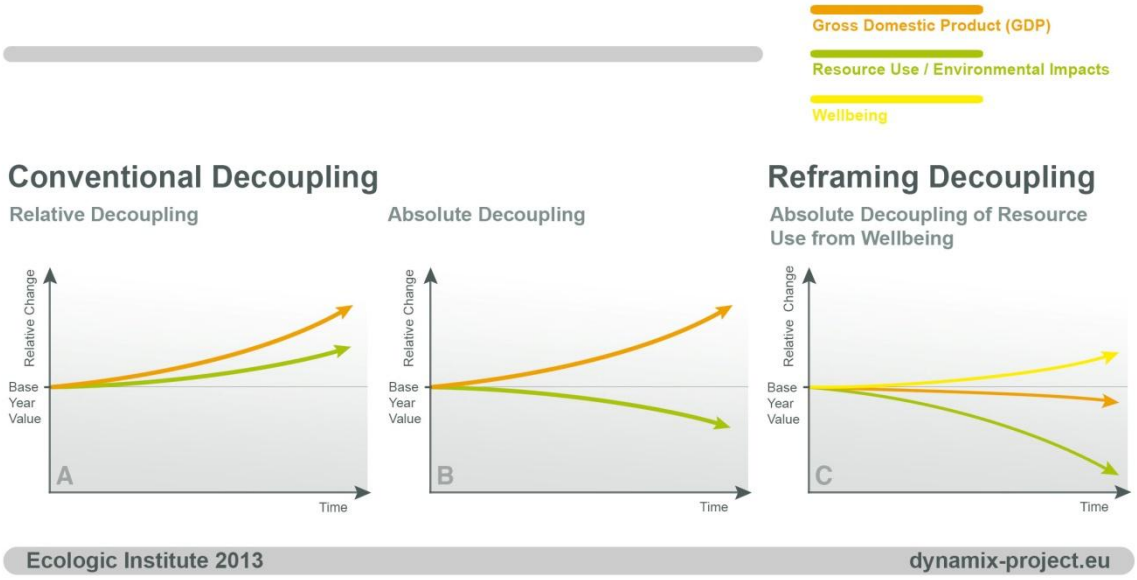
One of DYNAMIX's central questions is: How will we know if absolute decoupling has been achieved? And will absolute decoupling be sufficient to ensure that EU resource consumption stays within ecologically acceptable limits?

In its most basic meaning, **decoupling** is the delinking of two trends over time. The term thus describes a *relation* between two variables and not their level nor the direction of their change. In environmental policy, however, the term generally refers to the delinking of some economic performance variable – usually GDP – from a variable measuring environmental pressures – in our case the level of resource use in the EU and the environmental impacts associated with it. In this sense, **relative decoupling** requires that the economy grows faster than resource use and/or some measure of environmental impact. Put the other way around, it means that each tonne of resource used yields a higher economic output – hence resource productivity of the economy increases while resource intensity of the economy declines. But in absolute terms, resource use is still increasing (Figure 1, A).

By contrast, **absolute decoupling** requires that resource use or environmental impacts stay stable or decline in relation to the base year level, while the economy continues to grow (Figure 1 B). This widely used understanding of absolute decoupling (Fischer-Kowalski et al. 2011; van der Voet et al. 2005; OECD 2002) which promises a win-win-situation of sustained growth combined with increasing environmental protection has recently come under question (Jackson 2009). Reflecting this debate, Madlener and Alcott (2011) have proposed to extend the term of absolute decoupling also to cases where the environmental pressure declines in absolute terms while the economy stagnates or shrinks at a slower rate than the environmental pressure (Figure 1 C).[1] By contrast, a scenario where GDP declines faster than resource use – i.e. resource efficiency decreases – would not qualify as absolute decoupling since the decoupling concept as employed in environmental policy always implies an increase in efficiency (for a short discussion of the questions related to a stable or shrinking economy see section 1.5).

[1] The graphs represent long-term trends in GDP change and thus do not include short-term fluctuations caused by the business cycle.

Figure 1: Decoupling Concepts



Definition: Decoupling

DYNAMIX defines decoupling as the delinking of economic output on the one hand and resource use and environmental impacts on the other hand. We distinguish between relative and absolute decoupling.

Resource decoupling means reducing the amount of primary resources used per unit of economic activity (including hidden flows). **Impact decoupling** reduces negative environmental impacts per unit of economic output. **Double decoupling** is achieved when economic growth is delinked from both resource use and environmental impacts.

Relative decoupling means that the growth rate of the environmentally relevant parameter (resources used and/or some measure of environmental impact) is lower than the growth rate of a relevant economic indicator (for example GDP). **Absolute decoupling**, in contrast, requires that resource use and/or some measure of environmental impact decline in absolute terms (compared to the base year chosen), while the economy continues to grow or stagnates, but societal well-being continues to increase.

1.4 Resource efficiency

Understood as achieving more socio-economic value with lower resource input, increased resource efficiency is a key lever for achieving decoupling

There are many ways to define efficiency. From a physical or technical perspective, efficiency is the relationship between inputs and outputs of a physical process or transformation, e.g. the useful electric power, mechanical work or heat (output) in relation to the input energy (OECD 2008). Efficiency could also be defined in terms of

the minimisation of waste. An efficient system is one that requires a minimum amount of resources to provide a certain functional unit.

From a sustainability point of view, the World Business Council on Sustainable Development (WBCSD) defined eco-efficiency as "the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impact and resource intensity throughout the life cycle, to a level at least in line with the Earth's estimated carrying capacity" (WBCSD 2000). Building on this, the European Commission in its communication "Thematic Strategy on the Sustainable Use of Natural Resources" (EC 2005) made it clear that resource efficiency meant both reducing the environmental impact of resource use and at the same time improving resource productivity, i.e. the value added per unit of resource input, overall across the economy. For renewable resources this meant also staying below the threshold of overexploitation.

The terms 'resource efficiency' and 'resource productivity' are often used interchangeably. However, in economics there is a difference between the concepts of efficiency and productivity. Efficiency is a measure of optimality (i.e. how close a system is to its optimum state or a particular system variable to its optimal value); while productivity is a measure of the relationship between a particular output and a particular input such as labour, materials, energy, etc. Productivity, or its inverse intensity, are only meaningful as comparative measures – i.e. comparing one firm with another, or one time period with another. It is, for example, not meaningful to talk about a sector being productive in absolute terms. In contrast, one can in theory define an efficient sector, but it is difficult to determine the optimal efficient state since the optimum depends on assumptions about consumers' preferences. Therefore, we explicitly do not use the term resource efficiency in the way the term efficiency or, more precisely, Pareto-efficiency is used in economics. Instead restrict ourselves to relative improvements in resource efficiency and understand them as encompassing:

- reductions in the amount of resources needed in an economy; and/or,
- increases of the economic value of the resources used in the economy; and/or,
- reductions in the environmental impacts of resource use; and,
- ultimately leading to absolute decoupling.

Definition: Resource efficiency

DYNAMIX defines resource efficiency as creating more socio-economic value with an equal level of resource input or an equal level of environmental impact, thus resulting in an increase in resource productivity. Resource efficiency increases can occur at all stages of a good's life cycle (extraction, production, distribution, consumption or disposal) and it can be measured on different scales, e.g. for one product group, economic sector, consumption field, or for the economy as a whole. In our understanding, resource efficiency can also

increase when needs are fulfilled with different products or services or when the paradigm of what fulfils a need shifts. Thus, increases in resource efficiency can be achieved by:

1. **Using fewer resources** to fulfil the same needs
2. **Increasing the (socio-economic) value and benefits** from the use of (the same amount of) resources
3. **Reducing the environmental impacts and damage** associated with the use of resources

We explicitly do not use the term resource efficiency in the way the term efficiency is used in economics where Pareto-efficient outcomes require that the distribution of goods and services is optimal, building on assumptions about consumers' preferences.

The agenda which the EU now takes forward under the heading "resource efficiency" is not new. It builds on previous efforts by the EU laid down the 2005 "Thematic Strategy on the Sustainable Use of Natural Resources" (European Commission 2005) as well as on extensive work by the OECD on waste management, sustainable materials management, and material flows which formed the basis for the Recommendations of the Council on Resource Productivity adopted by the OECD in 2008 (OECD 2008). The Recommendations invite OECD member countries to improve the data basis on material flows, to use policies for improving resource efficiency, e.g. R&D and economic instruments.

At international level, the G8 countries committed in the "Kobe 3R Action Plan" of 2008 to prioritise 3Rs policies strengthening "reduce-reuse-recycle" by reducing waste and managing it well, internalising external costs and working towards resource productivity targets.

After the economic crisis of 2008/2009, the resource efficiency topics have been integrated into a wider green recovery agenda which is pursued under the headlines "Green growth" (OECD 2011) and "Green economy" (UNEP 2011). The OECD proposes the following definition:

> *"Green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. To do this, it must catalyse investment and innovation which will underpin sustained growth and give rise to new economic opportunities."* *OECD 2011, p. 9*

This agenda of ecological modernisation argues that investment into environmentally-friendly technologies and infrastructures can become a source of new industrial activity, a boost in competitiveness through higher productivity, and job creation. The proposed policies are essentially the same as those proposed in the 2008

recommendations on resource productivity (internalisation of environmental damage costs, restructuring taxes, incentives for innovation and behaviour change), but with a stronger focus on redirecting investment towards green technologies as a means to restart the economic engine. In addition, an impetus on increasing competition and reducing debt links the "Green growth" agenda to the central economic concerns of the post-crisis governments.

The concept of the "Green economy" which was introduced by UNEP in 2010 and provided the conceptual frame for the Rio+20 summit in 2012 has large overlaps with the "Green Growth" agenda, particularly with respect to redirecting investment. The difference lies in the stronger emphasis on equity and well-being. UNEP defines a green economy as one that results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP 2010, p. x).

While there is value in relating environmental issues to ongoing public debates and to a wide range of stakeholders through the introduction of new, attractive concepts, the danger is that the objectives embedded in the concepts become elusive and increasingly vague. Within DYNAMIX, we aim to address this challenge by putting absolute decoupling of resource use and its impacts from economic growth at the centre of our research quest, while treating the elements contained in the concepts above such as resource productivity, efficiency improvements, eco-innovation and green investment as necessary (even if maybe not sufficient) building blocks to reaching this objective. Absolute decoupling promises to provide a clear, quantifiable objective for a multi-faceted problem. Looking more closely, operationalising the concept for scientific analysis brings its own challenges to which we now turn.

Definition: Eco-innovation

Within DYNAMIX, we define eco-innovation as any form of innovation delivering economic and environmental benefits at the same time, through reducing impacts on the environment, enhancing resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources across the whole life-cycle. Innovations can refer to:

- products (a resource-light car)
- processes (less emission-intense cement production)
- services (life-time maintenance)
- organizational or institutional change (resource-efficiency ratings of business by financial institutes)
- business innovation (chemical leasing instead of chemical sale), or
- system innovations (multi-modal mobility replacing individual car ownership).

1.5 Challenges of operationalising absolute decoupling

Given the breadth of resources and environmental impacts to be considered when assessing the proposed policy mixes, we face five main challenges in conceptualising and measuring absolute decoupling:

Data availability: To gauge the impact of any given EU production and consumption pattern, resource flows for biotic and abiotic resources, water and land throughout the value chain, as well as impacts occurring both inside and outside the EU, need to be tracked. Indicators such as TMC (total material consumption) include the hidden flows of EU imports and would thus be suitable, but are difficult to calculate and sufficient data do not exist for all EU Member States.

Decoupling resource use or environmental impacts, or both?: From an environmental perspective, the ultimate interest of resource efficiency policy should be to avoid degradation of the earth's ecosystems. The focus would thus be on decoupling environmental impacts rather than resource use. However, from a socio-economic point of view, looming resource scarcity is another central motivation for improving resource efficiency – pointing to the importance of measuring resource decoupling in its own right. The other reason for monitoring resource use is pragmatic: Data for resource flows in the economy (at least direct flows) can be tracked more easily than environmental impacts which in some cases are only indirectly linked to the economic activity or resource under scrutiny. Data analysis shows that – at least at the national level – resource throughput and detrimental environmental effects tend to correlate even though uncertainties about their relationship remain (Van der Voet et al. 2005; Bringezu and Bleischwitz 2009). DYNAMIX will thus – wherever possible – monitor both resource and impact decoupling.

Weighting of various impact indicators: Reducing environmental impacts of EU resource use in absolute terms (compared to base year level) should be the ultimate aim of the recommended policy mixes. Yet, in reality, policy mixes might lead to an intensification of one impact while another decreases. To allow for a final assessment, these various impacts might have to be weighed against each other. However, the weighting of impacts is hotly debated in the LCA community since it implies a value judgement and makes the assessment less transparent (Mudgal et al. 2012, p. 27). The ISO standard for LCAs does not even allow it in comparative analyses to be released to the public.

Assumption on economic growth: In general, decoupling is conceived as a delinking of resource use and its environmental impacts from economic growth, with the latter measured through changes in GDP. The 'green growth' concept assumes that resource efficiency and climate change mitigation can not only be reconciled with further growth in GDP, but are themselves – through eco-innovation and the establishment of green industries – important drivers of increased competitiveness and growth (UNEP 2011). However, the appropriateness of GDP as a measure of social progress and well-being is increasingly being questioned by various policy-

makers and scientists, including within the European (European Commission 2009). Some scientists even question whether it is feasible to reduce industrialised countries' resource use and its environmental impacts to a sustainable and fair level (taking into account poorer countries' needs) within the paradigm of perpetual economic growth (Jackson 2009; Ehrlich, Kareiva, and Daily 2012). Even though a growing GDP with stable or declining environmental impact can be theoretically conceived if technology is assumed to change at the appropriate speed and in the desired direction *and* if consumer aspirations are assumed to move towards low-impact goods and services (Ekins 2000, Hepburn and Bown 2012), it is no guarantee that this type of sustainable or 'intellectual economy' will materialise in practice (Ekins 2000, p. 318).

For DYNAMIX, this debate raises the question of whether economic growth in the EU should be seen as a necessary given or if policy mixes that involve a stagnating or shrinking GDP could be included in the final recommendations. An assessment framework that doesn't include GDP in measuring effectiveness raises the question of how to assess changes in well-being caused by the policy mix. Despite intense research activities over the last years, a widely recognised quantifiable indicator on well-being has not yet emerged (Science Communication Unit 2012). An in-depth analysis of the indicators proposed so far is out of the scope of this project, but we propose to address this issue in a pragmatic manner by applying a basket of quantitative and qualitative indicators alongside GDP (see section on Sustainability below).

There are difficult questions and concerns linked to the idea of a stable or shrinking economy, e. g with respect to the effects on employment, the servicing of public and private debt, the economy's long-term stability and potentially even the society's ability to innovate (Hepburn and Brown 2012). Most of these questions are outside the scope of DYNAMIX and its quantitative assessment tools. Nonetheless, given that these discussions are ongoing, we will not exclude them a priori, but will address them within the qualitative assessment to be carried out in WP5.

Will absolute decoupling be sufficient to reach sustainable resource use?: When proposing this FP7 research project, the European Commission called for „help to identify the most appropriate [policy mix] leading to truly sustainable use and management of natural resources and contributing to societal advances in the European Union and globally". One may question whether absolute impact and resource decoupling alone will ensure achieving the abovementioned aim. This is especially true if global justice is taken into account, requiring equitable distribution of the use of the earth's resources among all human beings. As a minimum, absolute decoupling would result in stabilising environmental impacts at the level of the chosen base year. The concept does not give any direction on how much resource consumption in the EU needs to decrease, nor any vision as to what global targets should be strived for.

1.6 Proposed approach focusing on five pragmatic key targets

When measuring effectiveness of the proposed policy mixes, DYNAMIX envisions an EU economy that respects planetary boundaries by 2050

Taking these challenges into account, DYNAMIX proposes the following approach: The Common Approach defines a vision for Europe's resource use in 2050 based on the idea of a "**safe operating space for humanity**" proposed by Rockström and colleagues in 2009 and reflected in the vision formulated in the EU Roadmap to a Resource Efficient Europe:

> *"By 2050 the EU's economy has grown in a way that respects resource constraints and planetary boundaries, thus contributing to global economic transformation. Our economy is competitive, inclusive and provides a high standard of living with much lower environmental impacts. All resources are sustainably managed, from raw materials to energy, water, air, land and soil. Climate change milestones have been reached, while biodiversity and the ecosystem services it underpins have been protected, valued and substantially restored." (European Commission 2011, 3)*

DYNAMIX proposes to render this vision more concrete by defining a limited number of key resource use and impact related targets for 2050. The key targets are chosen so that

a) In approximation, they cover the most critical environmental impacts of resource use, while avoiding overlap between the different targets. Most critical impacts are those linked to potential catastrophic environmental change on continental or global level.
b) reflect looming scarcity of vital resources;
c) progress towards them can be measured based on available data with the quantitative assessment tools used in DYNAMIX (at least in approximation);
d) The targets do not predetermine any specific measure such as recycling or diet change, but rather address the input side and most crucial impacts;
e) The targets reflect absolute reductions rather than changes in intensity or productivity.[2]

The targets are expressed as the EU's fair share of global environmental space based on the EU's estimated share of global population in 2050.[3] They are thus grounded in a global justice perspective. One drawback of this approach is that the targets' effectiveness hinges on the accurateness of population projections. However, this

[2] To formulate targets in terms of increased resource productivity has been proposed by the European Resource Efficiency Platform (EREP 2013). However, an increase in resource productivity does not necessarily result in lower resource use or reduced environmental impacts (Tan et al. 2013, p. 19f.)

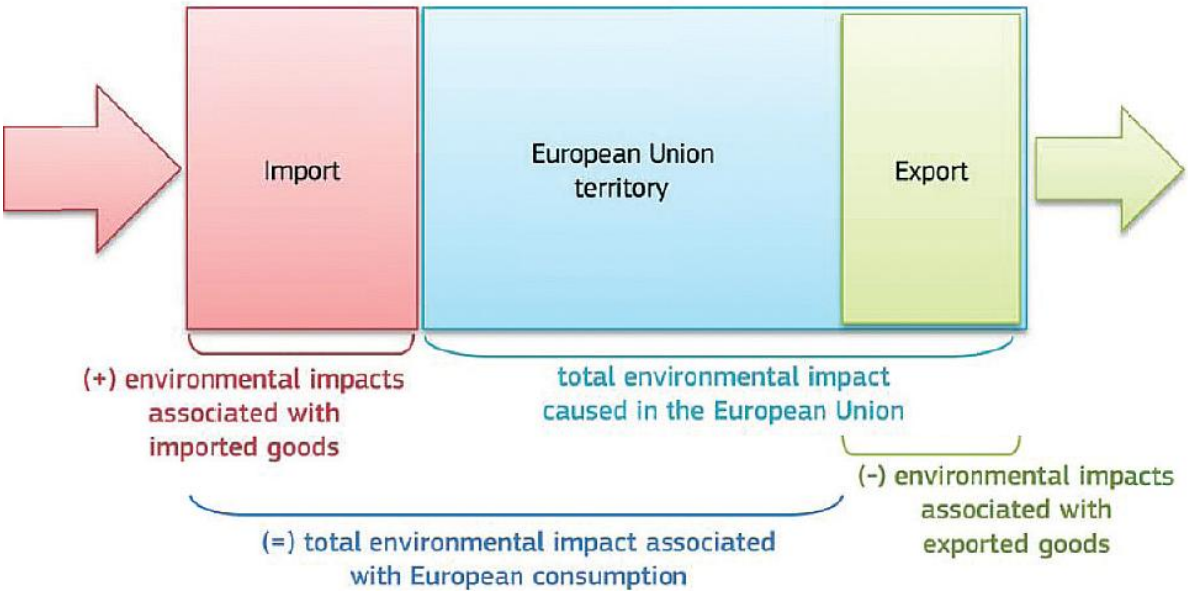
[3] By 2050 the EU will have a different number of members, but for pragmatic reasons we assume continuity of 27 Member States.

uncertainty appears to be manageable given that the quantitative assessments and the targets themselves are built on various estimates which are often much more uncertain than population projections. They will need to be considered as order-of-magnitude values rather than exact calculations.

When choosing a target indicator, one central question is whether to use a consumption-/footprint-based perspective, which traces resource use and environmental impacts of all goods consumed in the EU back along the supply chain, or a production-/territory-based perspective, which only includes the impacts of production on EU territory (Figure 2**Fehler! Verweisquelle konnte nicht gefunden werden.**). For reasons of data availability, governments still mostly use territory-based indicators. This includes the provisional lead indicator of the EU's Resource Efficiency Roadmap, 'resource productivity', measured as the ratio of GDP to Domestic Material Consumption (DMC). However, it is widely recognised that both perspectives are relevant. Not accounting for hidden or indirect flows and impacts incurred by imported products masks regional burden-shifting that can occur when polluting production is geographically displaced, while demand for the goods remains high or increases. On the other hand, efficient domestic production processes will reduce the environmental footprint of export goods from the EU. And, more importantly, the efficient production technologies developed in the EU in response to high standards might themselves become export goods and can thus contribute to the global diffusion of eco-innovations. The development of renewable energy technologies in the EU is a good example of such a process.

DYNAMIX will thus include both perspectives (consumption- and production-based), depending on the sector or good under consideration and depending on the methodological tools used.

Figure 2: Consumption versus production-based perspective



Source: Science Communication Unit (2013), p. 9.

Inspired by the themes covered in the Roadmap's dashboard indicators, DYNAMIX proposes the following key targets for 2050:[4]

- **consumption of virgin metals:** *-80 % compared to 2010 measured by RMC in the EU* representing scarcity of metals and environmental impacts caused by extraction, refinement, processing and disposal of metals;
- **greenhouse gas emissions;** *2 tonnes CO_2-equivalent per capita and year (measured as footprint to reflect embedded emissions and as EU-internal emissions)* representing climate change impacts of greenhouse gas emissions through energy use as well as agricultural and industrial processes;
- **consumption of arable land:** *zero net demand of non-EU arable land* representing, as a rough approximation, impacts of biomass production on soil quality, water quality and biodiversity;
- **nutrients input:** *reducing nitrogen and phosphorus surpluses in the EU at the level best available technique can achieve* representing impacts of agricultural production on marine and freshwater quality as well as soil quality;
- **freshwater use:** *no region should experience water scarcity* representing impacts of resource use on freshwater availability.

The targets are not equally well established in the science and policy community. While the greenhouse gas mitigation target is (at least indirectly) sanctioned by the UN climate negotiations and EU Council conclusions, the reduction targets for metals builds on proposals by Bringezu (2009) and UNEP's International Resource Panel (2011) that have not prominently figured in political debate so far. It focuses on metals rather than all abiotic materials to capture the most critical environmental impacts of material use that are not covered by any of the other targets (by contrast to energy consumption or land take, the predominant impacts of construction materials use and nutrient inputs, the main impact of minerals used as fertilizers) and it reflects economically relevant scarcities. It is obvious that the build-up of a green economy will require high amounts of metals (e.g. to build wind turbines), the assumption is however that by 2050 this build-up will have been completed and nearly full metal recycling will be achieved.

The water target is formulated in qualitative terms owing to the fact that a quantity-based approach at aggregate level does not account for substantial regional differences in water availability that exist in the EU and globally. In an effort to focus the analysis on the most critical environmental impacts, the land use target relates to the consumption of total arable land, the extension of which is a major driver for the loss of natural habitats, increased soil erosion and water pollution. This quantity-based target conceals different intensities of land use and management techniques, and is therefore accompanied by a target focusing on the human interference with the

[4] For a detailed explanation on how the targets have been derived refer to Section 2.4.

phosphorus and nitrogen cycle – a driver for eutrophication in lakes, rivers and marine ecosystems.

In addition to representing different levels of scientific and political consensus, data availability also varies between the five targets. While global accounting for greenhouse gas emissions and emission modelling is relatively well developed, data on freshwater use and land use, particularly when associated with imports to the EU, remain more fragmented.

As a consequence, the targets will be treated differently when assessing the effectiveness of the proposed policy mixes within DYNAMIX. To be considered effective, all policy mixes will have to meet the greenhouse gas abatement target since it has been officially recognized by EU leaders. In addition, all policy mixes will need to show how far they will get us towards absolute decoupling, i.e. a reduction below the base year value, for all five targets. At least one of the four policy mixes assessed ex-ante will be designed to meet all of the five key targets. This will allow us to show the extra effort necessary to achieve the vision. For the other policy mixes, the 2050 vision will serve as a benchmark that allows us to assess how close to the vision each of the policy mixes will take the EU.

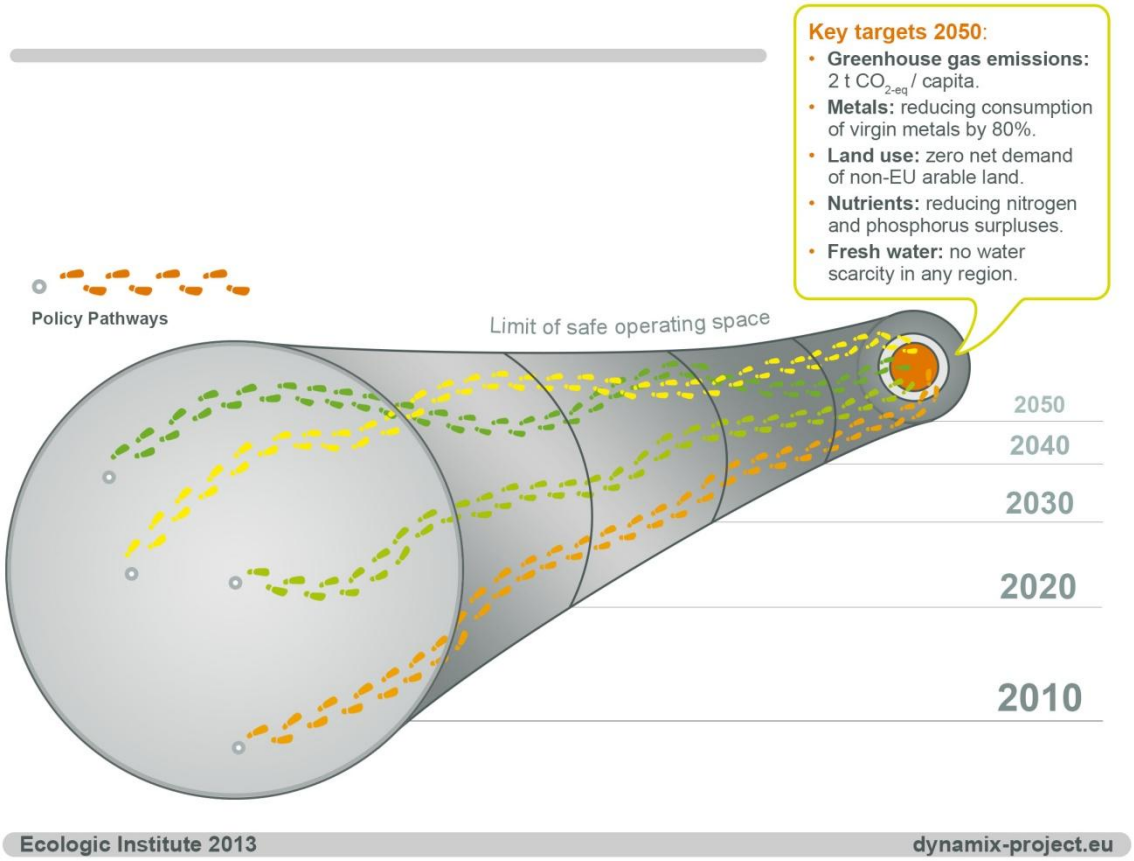
The policy mixes will be developed as different pathways to secure the well-being of EU citizens (potentially but not necessarily including GDP growth) in this resource-restricted world. Again as an approximation, well-being will be assessed by monitoring a selection of key socio-economic indicators (see discussion of sustainability below).

The approach has the following advantages:

- The targets outline the magnitude of the global challenges and provide a clear benchmark for measuring effectiveness.
- Resource efficiency – which can be achieved at many stages in the life cycle of any product and at various levels within the economy – will necessarily be part of the solution to achieving the proposed targets, but it will not serve as a benchmark for effectiveness as it is a relative concept.
- By focusing on a limited number of key targets covering the most critical planetary boundaries, complexity is slightly reduced and there is no need for introducing weighting factors. Where policy mixes perform differently with respect to the five key targets, the evidence can be presented to policy-makers to enable them to take informed, value-based judgements.
- The targets could be operationalised as restrictions in the economic models – at least as approximations.

On the negative side, this approach will potentially reduce, but not fully solve the challenge of data availability. Moreover, the general equilibrium models we employ within the project have certain limitations with respect to representing drastic structural changes in the far future because they are designed to model incremental changes within existing structures. The qualitative assessment will thus play a prominent role in addressing the questions which cannot be represented in the quantitative models.

Figure 3: DYNAMIX 2050 targets



When effectiveness is measured in ex-post analyses for specific, more restricted fields of analysis, e.g. in the case studies, the abovementioned concept of effectiveness cannot and will not be applied. In this case, effectiveness of any policy instrument or policy mix will be measured against the benchmark of absolute resource decoupling and absolute impact decoupling – including impacts of EU consumption outside the EU and hidden flows as far as data availability allows. The relevant resource and/or environmental degradation indicators will have to be chosen based on the objective set in the policy itself.

Policy assessment criteria: Effectiveness

On the economy-level: Based on the idea of a "safe operating space for humanity" proposed by Rockström and colleagues in 2009, DYNAMIX defines five key targets that address the most crucial resource streams and environmental impacts as benchmarks against which to assess the effectiveness of policy pathways. Any policy pathway that meets these targets and at the same

time secures well-being is considered as fully effective.

On the case study level: Effectiveness of policy mixes will be measured against the benchmark of absolute resource decoupling and absolute impact decoupling – including impacts outside the EU as far as data availability allows. The relevant resource and/or environmental degradation indicator will have to be chosen based on the objective set in the policy itself.

1.7 Sustainability as an assessment criterion

DYNAMIX examines the socio-economic effects and non-intended environmental trade-offs

DYNAMIX understands sustainability as including three dimensions: environmental protection, social equity and a thriving economy. In practice, the criterion will consist of a set of socio-economic and environmental indicators allowing to detect potential synergies and trade-offs between the objective of absolute resource decoupling and other economic, social and environmental goals. Socio-economic impacts will at least include impacts on economic growth, job creation, distribution of incomes, burden sharing between social groups and human health.

When assessing policy mixes targeting specific resources or sectors (mainly in the case studies), the sustainability criterion will be used to examine potential environmental trade-offs or co-benefits of the policy mix for all resources not directly targeted by the policy (and thus not covered under the effectiveness target). This could be done by quantitatively and/or qualitatively screening all imaginable side-effects of the policy mixes – followed by a second step of singling out, and where possible quantifying, significant trade-offs and co-benefits.

When assessing sustainability of policy mixes targeting resource use at economy-level (mainly in the ex-ante assessment), the proposed understanding of effectiveness based on key 2050 targets is conceived in a way to ensure that the EU stays within planetary boundaries. However, a separate screening of potential environmental trade-offs and co-benefits should nonetheless be carried out to avoid significant impacts that are not addressed by the key targets (e.g. marine issues, toxicity, severe local impacts).

Policy assessment criteria: Sustainability

DYNAMIX understands sustainability as including three dimensions: environmental protection, social equity and a thriving economy. Sustainability of the policies and policy mixes will be assessed by evaluating impacts on economic growth, job creation, distribution of incomes and burden sharing

between social groups, and other ecosystems or consumption levels of resources not directly targeted by the policy mix (and thus not covered under the effectiveness criterion). This assessment criterion is crucial to detect synergies and trade-offs between the objective of resource efficiency and other economic, social and environmental goals.

Policy assessment criteria: Cost-efficiency

Efficiency of the policies and policy mixes will be assessed comparing the achieved level of resource and impact decoupling with the monetary (or other) resources applied to achieve the outcome.

1.8 Understanding of policy instruments and policy mixes

DYNAMIX proposes effective policy mixes instead of single policy instruments.

Policy instruments can be grouped in different categories depending on the way they intervene in the economy. For DYNAMIX we propose the following typology:

Table 1: Policy instrument typology for DYNAMIX

Regulatory instruments	Regulation, bans, standards, limits
Planning instruments	Regional planning, land-use, urban planning
Market-based instruments or economic instruments	Revenue-generating instruments (taxes, charges) Subsidies (direct payments, tax allowances) Property rights (licenses, tradable permits) Others (user benefits, environmental liability, payments for ecosystem services)
Public investments	Infrastructure investments, procurement, R&D spending
Cooperation-based instruments	Voluntary commitments, negotiations, networks
Information-based instruments	Information campaigns, education, advisory services and capacity building, labelling, environmental reporting, environmental monitoring, access to information and justice rights

Each type of policy instrument has its specific strengths and weaknesses in specific contexts. The instruments can be categorized on a continuum between “hard” and “soft” instruments and by type of interaction between government and private actors e.g. relying on reward or penalty, support or motivation (GTZ, CSCP, and Wuppertal Institut 2006).

DYNAMIX assumes that the magnitude and complexity of the absolute decoupling to occur requires a policy mix consisting of several mutually reinforcing instrument types. A policy mix can be defined as the combination of policy instruments, which interact to influence the quantity and quality of a selected policy objective. The policy mix concept relies on the idea that the combination of policy instruments interacting with each other yields a higher performance towards a given objective or set of objectives than single instruments in isolation. Performance towards any given policy objective is also influenced by policies from that policy sphere as well as by policies from other domains, such as, e.g. environmental regulations influencing R&D activities; hence the boundary of a policy mix (e.g. direct and indirect instruments) needs to be clearly identified and communicated in its analysis. Also, each instrument in the mix should be indispensable, i.e. the mix's effectiveness should depend on each of the instruments being fully implemented so as to ensure that the recommendations focus on the essential elements. Moreover, the policy mix should be coherent, geared towards a clear, common (set of) objective(s), and instruments should not contradict each other.

When designing a policy mix with a time horizon of 40 years into the future, one is confronted with a high level of uncertainty concerning future political, socio-economic and technological developments. Also, any proposed policy mix will be challenged by some (if not many) societal groups. To address those two challenges, DYNAMIX is proposing policy mixes that are:

- dynamic over time, i.e. instruments can be designed in sequence rather than as one static instrument bundle, whereby the sequence can depend on the level of progress towards absolute decoupling (see Figure 4);
- adaptive to new information or developments, e.g. by including review clauses, or several follow-up instruments depending on the development of certain variables;
- informed by a detailed analysis of existing paradigms (that in some cases need to be overcome) and promising new paradigms;
- informed by stakeholder input.

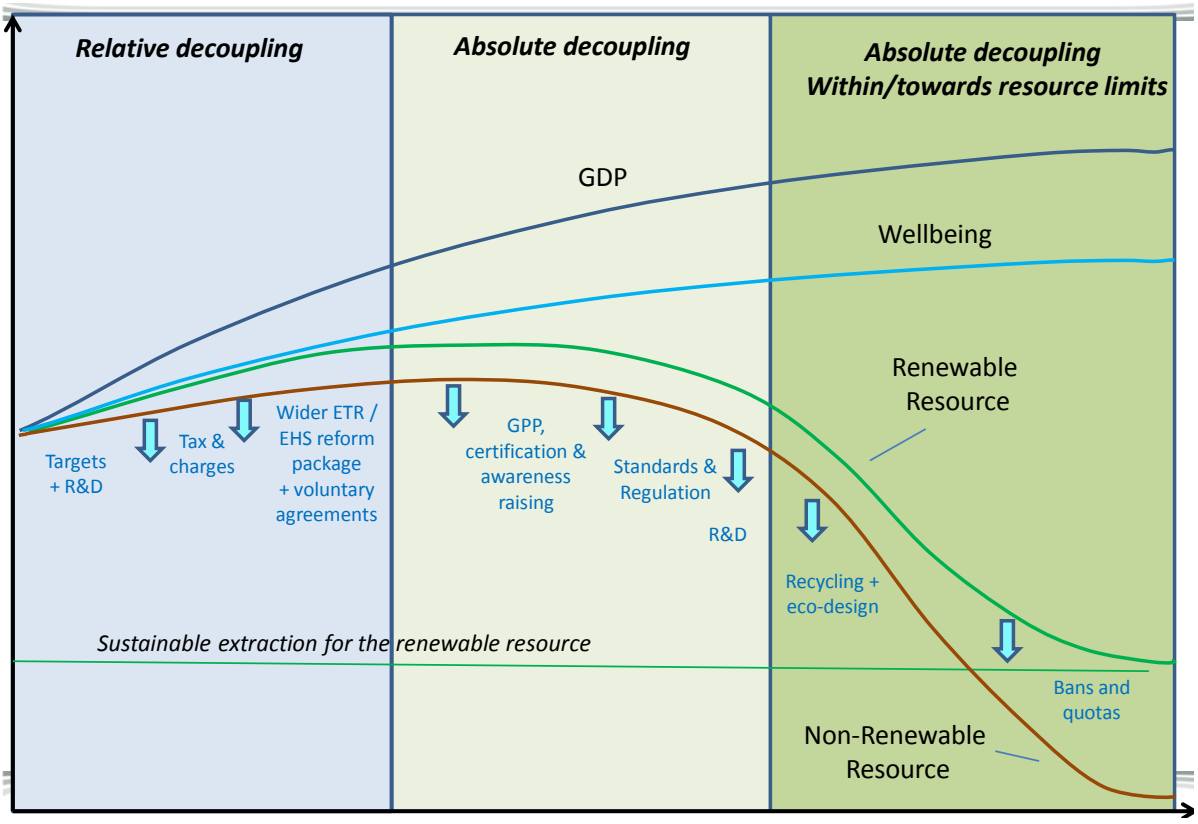
In the context of DYNAMIX, a policy mix can address different elements influencing the policy objective – sectors and activities – and target either or both input (extraction, resource use) and output (pollution) related impacts. As much as possible, the focus of policy mixes will be specific resources or types of resources and the production or consumption of a specific goods or products.

Definition: Policy mix

A policy mix is defined as a combination of policy instruments that yields a higher performance towards a given policy objective or set of objectives than single policy instruments in isolation. Typically, the policy mix will include several different instrument types, reinforcing each other in a coherent way based on (a

set of) common policy objective(s).

Figure 4: Dynamic policy mixes depending on progress towards absolute decoupling



Source: IEEP

1.9 Paradigms and paradigm shifts

DYNAMIX assumes that effective policies for absolute decoupling will have to address the underlying worldviews of actors and contribute to paradigm shifts

Within DYNAMIX, we assume that both policies and the societal landscape in which they are embedded (and which determines to a large part if new policies are acceptable and can be implemented effectively) are shaped by underlying paradigms. One central characteristic of paradigms is that they are often implicit in actors' perception of the world. They are embodied in assumptions and interpretations of measurable phenomena and most actors might not even be aware of the paradigm guiding their judgement, making them all the more powerful. Our working hypothesis is that the dramatic changes required to bring about absolute decoupling will require paradigm shifts and that policies can – at least in part – contribute to these.

We differentiate between *scientific paradigms*, which encapsulate those paradigms held by scientists and professionals in both the natural and social sciences; and *socio-cultural paradigms* which represent the remaining non-technical ideologies, beliefs, and values of society. Unlike scientific paradigms, which tend to be clear-cut

and incommensurable with one another, it is quite common for there to be a number of socio-cultural paradigms within society, apparently contradicting one another. Socio-cultural paradigms have the capacity to create their own stability when collectively held; with observable behaviour reinforcing the prevailing world view held by those around you. Scientific paradigms can be further divided into *natural science paradigms* and *social science paradigms*, grouping types of paradigm in terms of the actors associated with them (e.g. social scientists, natural scientists, laypeople).

One's paradigm can bias the way one engages externally in collective discussion about phenomena, problems and solutions. This collective external manifestation of a given paradigm is known as the *discourse*. According to Drysek (2007), discourses establish meanings, identify agents, confirm relations between actors and other entities, set the boundaries for what is legitimate knowledge, and generate what is accepted as common sense. In essence, an individual's discourse is the interface between its (inner) paradigm and the outside world. Importantly for DYNAMIX, discourses represent the main interface between scientific paradigms and socio-cultural paradigms, and therefore often highlight areas of significantly different perspectives and worldviews.

Paradigm shifts – a concept originally developed to apply to the natural sciences – are understood as resulting from the emergence of new evidence that does not appear to fit within the current dominant paradigm which then enters a state of crisis. A paradigm shift is said to have occurred when "an older paradigm is replaced in whole or in part by an incompatible new one" (Kuhn 1970, p.92).

There are few examples of socio-cultural paradigm shifts taking place without a corresponding shift in scientific paradigm. For instance, a long-term shift in the societal perception of and policy with regard to smoking follow an enhanced scientific basis for arguments against smoking. However, these social changes occurred sometime after the scientific evidence which means that other factors might have also been at play, including the role that physical addiction might play among key institutional players, as well more fundamental changes in how society perceives risks and longevity. Further, with regard to the relationship between policy and socio-cultural shifts, it may be more difficult to infer an obvious direction in the causal chain.

Definition: Paradigm

In DYNAMIX, we understand an individual or group of people's paradigm as the worldview – the set of sometimes unconscious values, beliefs and ideologies – in which they are immersed. They use their paradigm to navigate any new evidence, challenges or choices with which they find themselves confronted. Paradigms manifest themselves externally via discourses and are reinforced within society via the creation of social technical systems. In DYNAMIX, we differentiate between *scientific paradigms*, which encapsulate those paradigms held by scientists and professionals in both the natural and social sciences; and *socio-cultural paradigms* which represent

the remaining non-technical ideologies, beliefs, and values of society.

2 Basis and background of the Common Approach

2.1 Natural Resources

In its broadest sense, the term ‘resources’ encompasses a whole set of inputs to the economic system that allow to create value, ranging from human resources to financial resources. When we use the term ‘resources’ within the DYNAMIX project, we exclusively refer to natural resources, unless otherwise stated.

Natural resources, in turn, can also be understood in a broad sense, encompassing all elements of the natural world which have some value to humans – be it monetary or immaterial (Fischer-Kowalski et al. 2011). In the scientific and policy literature dealing with resource efficiency, however, the term is interpreted more narrowly, including only those natural resources that are deliberatively used to create economic value and can be measured in physical or monetary units:

> *“In the context of the Resource Panel, resources refer to the natural resources used by economies. They include abiotic materials (fossil fuels, metals and minerals), biomass, water, and land. In general, resources can be seen as ‘gifts’ of the natural system that can be used in the economic system, but which are not part of the economic system.” (Fischer-Kowalski et al. 2011, 5)*

Some researchers, most prominently Bringezu and Bleischwitz (2009), additionally call for inclusion of those resources that do not enter the economic system, but need to be modified or moved to extract the resources which are used (‘unused resources’). An example would be soil, excavated for infrastructure, or modified, as mining tailings.

While the public and many businesses tend to associate the term ‘resources’ mainly with materials, most scientific studies and policy documents acknowledge that natural resources also encompass natural sinks (e.g. air, water, soil, atmosphere), which absorb the output of human activity in the form of emissions and waste, as well as ecosystem services, including biodiversity, climate stability and the maintenance of ecological biochemical systems, that provide the basis for economic activities (UBA 2011; Science Communication Unit 2012; Fischer-Kowalski et al. 2011; European Commission 2011). For example, the European Commission states in its EU Thematic Strategy on the sustainable use of natural resources:

> *“[…] natural resources, 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). Whether the resources are used to make products or as sinks that absorb emissions (soil, air and water), they are crucial to the functioning of the economy and to our quality of life.” (European Commission 2005, 3)*

In order to classify types of resources, the most common typologies either differentiate between biotic and abiotic resources or renewable and non-renewable

resources. Within DYNAMIX we use the categories of Eurostat's Economy-wide Material Flow Accounts to ensure compatibility with the available data set (see Table 2), but extend the concept of natural resources to also include natural sinks, ecosystems, land, freshwater, air and soil.

Table 2: Material resource categories used by Eurostat (2012)

Biotic resources		Abiotic resources	
Biomass	Crops (excl. fodder crops)	Metal ores	Iron
	Crop residues (used), fodder crops and grazed biomass		Non-ferrous metal
	Wild fish catch, aquatic plants/animals and plants	Non-metallic minerals	Marble, granite, sand stone, porphyry, basalt, other ornamental or building stone
	Wood		Chalk and dolomite
			Slate
			Chemical and fertilizer minerals
			Salt
			Limestone and gypsum
			Clays and kaolin
			Sand and gravel
			Other
			Excavated earthen materials (including soil, only if used)
		Fossil energy materials/ carriers	Coal and other solid energy materials/ carriers
			Liquid and gaseous energy materials/ carriers

2.2 Resource Efficiency

In its 2011 survey on resource efficiency policies and approaches in 31 EEA member countries, the European Environment Agency found that "there is neither a clear definition nor a common understanding of key terminology. Terms such as 'resource efficiency', 'decoupling', 'sustainable use of resources' or 'minimising use of natural resources' often seemed to be used as synonyms" (EEA 2011, 8). A semantic analysis of German policy documents, news articles, NGO and business statements showed a similar result: Stakeholders tend to use the above mentioned terms interchangeably and they often also use the term 'resource efficiency' synonymously with 'energy efficiency' (Grünig et al. 2011).

In the scientific literature as well as in relevant policy documents, 'resource efficiency' is understood as describing "the relationship between a valuable outcome and the input of natural resources required to achieve that outcome. It is the general concept of using less resource inputs to achieve the same or improved output" (Fischer-Kowalski et al. 2011, 5). The EU Roadmap to a Resource Efficient Europe extends

the concept to refer not only to lower resource input, but also to a reduction in environmental impacts: “Resource efficient development […] allows the economy to create more with less, delivering greater value with less input, using resources in a sustainable way and minimising their impacts on the environment.” (European Commission 2011, 3). This type of efficiency that focuses on reducing harmful environmental impacts of resource use is referred to as ‘eco-efficiency’ (WBCSD 2000).

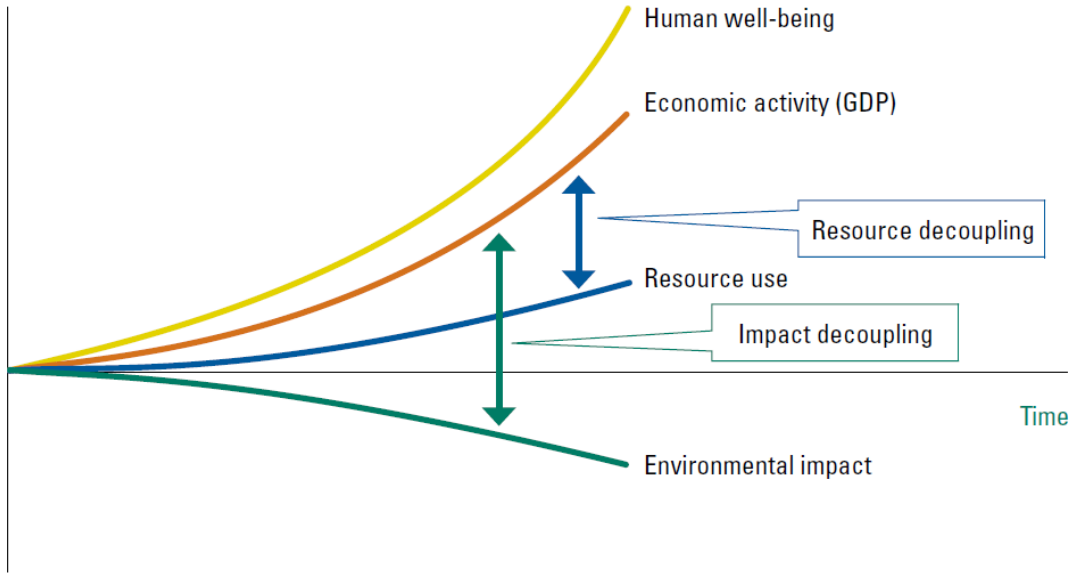
Changes in resource efficiency can be observed at different levels, from the level of single products or production processes to firms, sectors and the economy at large. Depending on the level under review, the indicators used to measure resource efficiency will vary: When measuring the resource efficiency of a process, the relation can be expressed in physical terms (less steel or less energy used), while an economic measure such as value added or GDP will be used to express change when looking at the sector- and economy-levels (Schütz and Bringezu 2008). At economy-level, resource efficiency is usually expressed as increased resource productivity (value added per unit of resource use) or reduced resource intensity (resource use per unit value added) (Fischer-Kowalski et al. 2011, 5).

An improvement in resource efficiency indicates that resources are used more effectively to generate physical output or economic value. But the efficiency improvement is only a relative measure and does not necessarily go hand in hand with a decrease of resource use in a firm, sector or within an economy in absolute terms. One reason is that efficiency gains can be partially counterbalanced by increased production and consumption of the same good or service (direct rebound effect) or of a different good or service also associated with resources use (indirect rebound effect). The other reason is that economic growth due to productivity gains and technological progress can lead to increased resource use despite efficiency improvements. For the state of the environment, however, what matters are the cumulative total flows and the impacts they generate. This is why, the focus shifted from the concept of efficiency to decoupling.

2.3 Decoupling resource use from economic growth

The term ‘decoupling’ was first introduced by the OECD in 2001 to refer to breaking the link between “environmental bads” and “economic goods” (OECD 2002). In the specific context of resource efficiency, ‘resource decoupling’ denotes “the delinking of economic growth and resource use” while ‘impact decoupling’ describes “the delinking of economic growth and negative environmental impacts”. For a situation where both types of decoupling occur at the same time, UNEP’s International Resource Panel introduced the term “double decoupling” (Fischer-Kowalski et al. 2011, 6 et seq.).

Figure 5: Decoupling Concepts



Source: UNEP 2011, p. xiii.

The scientific literature and increasingly also policy documents differentiate between 'relative decoupling' and 'absolute decoupling'. "In relative decoupling the growth rate of the environmentally relevant parameter (e.g. resources used or environmental impact) is lower than the growth rate of the relevant economic indicator (for example GDP). [...] Absolute decoupling is a shorthand description of a situation in which resource productivity grows faster than economic activity (GDP) and thus resource use is absolutely declining" (Fischer-Kowalski et al. 2011, 6). Both types of decoupling imply that resource efficiency is improved at economy-level. However, while in the case of relative decoupling, efficiency gains are overcompensated by output economic growth, in the case of absolute decoupling, resource use declines in absolute terms (relative to the base year chosen).

It is important to note that the adjective 'absolute' does not describe the relationship between output (economic growth) and input (resource use), which by definition is always relative, but rather refers to the change in resource use or impacts relative to the base year chosen, indicating their decrease over time while the economy continues to grow (European Commission 2011; Schütz and Bringezu 2008). Thus, the underlying assumption of the concept is that economic growth is a given, while the level of resource use can be changed irrespective of the rate of economic growth.

In the recently revived debate about the future role of economic growth in industrialised countries, it has been questioned whether absolute decoupling can actually be achieved if the economies of both industrialised and emerging economies continue to grow (Jackson 2009). Madlener and Alcott (2011) therefore propose to extend the decoupling concept also to cases where GDP in industrialised countries stagnates or slightly declines over time, a case we also include as a possibility

(although not as a target scenario) within DYNAMIX. It is crucial to emphasize that in any such case, resource efficiency still would have to increase. A situation of economic break-down where GDP declines faster than resource use would not qualify as absolute decoupling. The proposed concept of absolute decoupling should be understood as a delinking of well-being or quality of life from resource use and its environmental impacts.

2.4 Deriving key targets for 2050

In defining the key per capita targets for our vision for 2050, we use the UN DESA's 2011 medium variant projections for global population growth. According to this projection, world population will reach 9.3 billion people in 2050, going up to 10.1 billion in 2100 (UN DESA 2011). According to Eurostat, in the same timeframe, the population of the EU-27 is projected to grow from 501 million in 2010 to 524 million in 2050 (Eurostat 2013). In 2050, the EU-27 population will thus represent 5.6% of the global population.

Extraction of raw materials: Reducing use of virgin metals by 80 % (base 2010)

In contrast to climate mitigation targets, restrictions on global extraction of natural resources have so far only been discussed within the scientific community and not in the realm of an international agreement. It is probably fair to say that even among resource efficiency experts the debate on appropriate targets for global resource extraction is at a much earlier stage than the scientific discussion related to climate change. One reason is that no intergovernmental panel comparable to the IPCC exists that would be capable of proposing an international agreement, probably because the common good character of natural resources is less accepted than in the case of climate or biodiversity. As a consequence, data are also sparse. Consistent accounting of national resource consumption and international resource flows is still in a development phase. Another crucial difficulty in defining targets is the question of how to define the system boundaries both in relation to the type of resources included and in terms of life cycle stages covered, i.e. whether to include unused extraction (such as mining tailings) and hidden flows (resources used to produce export goods that are not physically part of the exported good).

The following table gives an overview of existing scientific proposals for restrictions on global resource extraction:

Table 3: Proposed targets for resource restriction

Author	Scope	Resources covered	Indicator	Base value (2000)		Target value (2050)	Relative change
Bringezu 2009	EU	abiotic (without erosion)	TMC_{abiot}	33.4 t/cap EU-27	100-110 Gt global total	5.6 – 6.1 t/cap	~80 %
Bringezu 2009	EU	biotic raw materials	TMC_{biot}	4.0 t/cap domestic plus imports		Domestic +25%? reduced imports	constant
UNEP 2011 Scenario 3	global	abiotic and biotic	Total extraction used (EU)	8.5-9.2 t/cap (2005)	47-59 Gt global total	6 t/cap 50Gt total	-60-80% (industr. countries)
Lettenmaier et al. 2012*	EU	abiotic and biotic	TMC			10 t/cap	~80 %

*Lettenmaier et al. 2012 are building on Bringezu 2009.

While Bringezu (2009) and Lettenmaier et al. (2012) include used and unused extraction (i.e. Total Material Consumption (TMC)), UNEP's International Resource Panel only accounts for materials actually used in economic processes to avoid problems of data reliability. Thus, per-capita targets vary depending on the metric used. Nonetheless, the estimates entail a similar order of magnitude change in relative terms: To achieve a sustainable level of resource consumption by 2050, industrialised countries would have to reduce resource extraction (triggered by their final consumption) by 60 to 80 %.

Within DYNAMIX, the 2050 key targets are intended to focus the analysis on those resources that are most critical for alleviating detrimental environmental impacts. Looking at Eurostat's three categories of abiotic resources – metal ores, non-metallic minerals and fossil energy carriers – fossils fuels are certainly key, given their impact on the climate system when burned. However, the environmental impact of greenhouse gases is covered by the greenhouse gas emission target. Therefore, an additional target for the reduction of fossil energy carriers would only create overlap and is not necessary.

Non-metallic minerals make up roughly half of total materials used within the EU, measured by weight. The construction materials sand and gravel dominate this category, representing approx. 70 % of all non-metallic minerals used (Schoer et al. 2012, 70). However, the environmental impacts of construction materials are not proportionate to their share in overall materials use. Their main impacts include CO_2 emission from transportation and cement production, land degradation and waste generation (Fischer-Kowalski et al. 2011). CO_2 emissions are covered under the greenhouse gas reduction target. Due to current technological limits for decarbonising cement production, strict greenhouse gas restrictions are likely to result in an overall decrease in the use of cement and thus sand and gravel and its corresponding

contribution to land degradation and waste generation. In its effort to focus on the most critical resources and impacts, DYNAMIX therefore does not define a key target for reduction of non-metallic minerals use. Mineral fertilizers the second biggest category of non-metallic minerals is covered by the nutrients target.

Compared to construction materials, the extraction, processing and disposal of metals can have severe pollution impacts with significant detrimental effects on the environment and human health. One example is the rapidly increasing amount of electronic waste, large shares of which are exported to developing countries where treatment takes place under unhealthy conditions. The environmental and health impacts of metals do not necessarily occur in proportion to the amounts used. For example, rare metals like platinum group metals are very resource-intensive in mining and refining and cause severe pollution (Bringezu et al. 2009). Moreover, the potential for medium to long-term scarcities in the supply of relevant metals (taking into account rising global demand) underlines the strategic importance of improving resource efficiency in the use of metals. DYNAMIX therefore proposes the key target of reducing extraction of virgin metals for EU consumption (measured by RMC) by 80 % by 2050 compared to 2010 levels.

The build-up of the green economy will require significant input of metals, for example for the expansion of renewable energy capacity. However, we assume that the net additions to the stock have been completed by 2050 and near-to-full recycling will be achieved, allowing the EU to reach the metals target.

Greenhouse gas emissions (GHG): 2 t $CO_{2\text{-eq}}$ per capita per year

The EU aims to keep the increase of global mean temperature until the end of the century below 2°C compared to pre-industrial levels, a target that has also been recognized (albeit not formally adopted) by the 15th Conference of the Parties to the United Nations Convention on Climate Change (UNFCCC) in 2009.[5] To date, the 2°C-target has not been translated into formal GHG reduction targets in the EU or globally. However, in its conclusions on the EU position for the Copenhagen Conference, the European Council of Environment Ministers underlined that "*developed countries as a group should reduce their GHG emissions below 1990 levels through domestic and complementary international efforts by 25 to 40 % by 2020 and by 80 to 95 % by 2050 […]*". In addition, the Council noted that, "*based on available elements such as current population projections, global average greenhouse gas emissions per capita should be reduced to around two tonnes CO_2 equivalent by 2050, and that, in the long term, gradual convergence of national per capita emissions between developed and*

[5] Decision 2/CP.15: Copenhagen Accord, paragraph 1: „[…] we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius, on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change."

developing countries would be necessary, taking into account national circumstances" (Council of the European Union 2009, 2–3). Compared to 2010 per capita emissions of 9.4 t $CO_{2\text{-eq}}$ (2009) (EEA 2012a), a 2 t $CO_{2\text{-eq}}$ target implies a reduction of roughly 80 % (-93 % compared to 1990).

The scientific community discusses a much broader range of potential boundary values to avoid irreversible or catastrophic change in the climate system. Rockström and colleagues (2009) propose a very restrictive boundary for the CO_2 concentration in the atmosphere of 350 ppm which - given that current concentration levels are at 387 ppm - would require removing CO_2 from the atmosphere. The boundary is defended based on findings about long-term feed-back processes, potential instability of the polar ice sheets and recent evidence of rapid change in some of the Earth's subsystems such as the Arctic sea ice. The paper by Rockström and colleagues does not, however, assess the feasibility of implementation.

Recent scenario building in preparation for the 5th Assessment Report of the International Panel on Climate Change (IPCC) has identified the RCP2.6 emission pathway as one of the most ambitious, but feasible mitigation scenarios (Van Vuuren et al. 2011). Under this scenario, CO_2 concentrations fall under 400 ppm in 2100, ensuring that global mean temperature does not rise above 2°C, but rather stabilizes between 1.5 and 2°C. For this to happen, greenhouse gas emissions must decline to 5-6 billion t $CO_{2\text{-eq}}$ in 2050 and continue down towards roughly 2 billion t $CO_{2\text{-eq}}$ by 2100. In this case, per capita emissions would need to be cut to 0.6 t $CO_{2\text{-eq}}$ in 2050 (based on the UN DESA estimate of 9.3 billion people). Technically, and from the perspective of governance, this is a very challenging scenario where all known mitigation potentials have to be used in time and to the full extent.

Slightly less ambitious mitigation pathways such, as that proposed by (Stern 2008), confirm the EU approach by proposing to reduce GHG emissions to 20 billion t CO_2-eq by 2050 and then further to 10 billion t $CO_{2\text{-eq}}$ by the end of the century, resulting in a per capita target of roughly 2 t $CO_{2\text{-eq}}$. Probabilistic assessment of a range of climate model runs shows that such a mitigation pathway would not give security to hold the 2°C target line. Instead, Meinshausen et al. (2009) determine a 15-49% chance that 2°C will be exceeded if emissions are stabilised at 20 billion t $CO_{2\text{-eq}}$ in 2050.

From the viewpoint of the precautionary principle, it is not satisfactory to risk exceeding the 2°C guardrail, especially because recent findings indicate that even with a 2°C temperature rise, severe impacts for the environment and society cannot be avoided (Richardson et al. 2009). Yet, from a policy perspective, putting in place the policies required for achieving 2 t $CO_{2\text{-eq}}$ per capita already implies a tremendous challenge in terms of feasibility and – more importantly – acceptability. Within DYNAMIX, we will thus use 2 t $CO_{2\text{-eq}}$ as our key climate policy target for 2050, building on the EU Council conclusions from 2009.

Land use: Zero net demand of non-EU arable land

Against the backdrop of a looming global land scarcity if natural forests are to be preserved (Lambin and Meyfroidt 2011), discussion about appropriate indicators and targets on global land use change has recently intensified (Rockström et al. 2009; Bringezu and Bleischwitz 2009; Lugschitz, Bruckner, and Giljum 2011; Mudgal et al. 2012). In a study commissioned by Friends of the Earth, Lugschitz and colleagues (2011) have assessed the actual land demand embodied in imports and exports of agricultural and forestry products to and from the EU. The land footprint is calculated using a multi-regional input-output model, differentiating between three types of land cover a) arable land, b) meadows and c) forest areas. The results show that the top consuming countries in terms of total direct and indirect land demand per-capita include OECD countries such as Australia, Canada and Finland, but also Latin American and African countries. The reason for this relatively unexpected result is that the methodology does not reflect differences in land use intensity. Countries with low land use intensity, e.g. with a high share of extensive grazing areas, can thus rank higher than countries with high productivity and high land use intensity such as European countries.

The level of land use intensity, however, correlates closely with impacts on biodiversity, soil and water quality. Most studies agree that the expansion of arable and built-up area for infrastructure represent the major driver for detrimental ecosystem change, resulting mainly from deforestation, use of fertilizers, soil erosion and habitat fragmentation (Foley et al. 2011; Millennium Ecosystem Assessment 2005)(Foley et al. 2011, Lambin and Geist, 2009, Millenium Ecosystem Assessment 2005). The planetary boundary for land-system change proposed by Rockström et al. (2009) therefore puts the amount of total cropland in the centre, recommending that not more than 15 % of global ice-free land surface should be converted to cropland. Distributing this restricted resource equitably across global population and regions is not a simple task given the variety in productivity even within the category “arable land”.

With respect to the EU, several studies show that current net land consumption levels, including land requirements embedded in imports and subtracting land embedded in exports, exceed the EU’s fair share (Lugschitz, Bruckner, and Giljum 2011; Bringezu et al. 2009). Despite its rich endowment in high-productivity farmland, the EU currently covers a substantial share of its demand for agricultural products by importing virtual land. According to estimates by Bringezu et al. (2009), foreign land supplies 18 % of agricultural products consumed in the EU. Taking into account also forestry products, Lugschitz et al. (2011) estimate that the share of foreign land amounts to up to 60 %. Given its resource base and stagnating population, the EU should be capable of sustaining itself without net influx of non-EU cropland. Building on the proposal by Mudgal et al. (2012) to strive for zero net-demand of foreign land – but focusing on cropland as the most crucial resource – DYNAMIX therefore proposes to reduce net consumption of non-EU arable land to zero by 2050 (and preferentially earlier). This

would be achieved if the land use associated with imports of agricultural products and biofuels into the EU equals or is lower than land use associated with exports. The EU has about 6.5 % of global arable land while hosting 5.6 % of global population, but given that the arable land in the EU is among the most productive in the world, the target can still be considered moderate with respect to global equity requirements.

While the target covers direct land use change occurring as a result of EU consumption, it does not include the effects of indirect land use change resulting from chains of displacement that are very hard to quantify (e.g. soy production displacing grazing and grazing encroaching on primary forest). The quantitative target thus needs to be accompanied by a qualitative assessment examining how conversion of natural environment driven by EU consumption can be avoided.

Nutrients input: reducing nitrogen and phosphorus surpluses in the EU at the level best available technique can achieve

Fertilizers improve the yield and thereby the productivity of agricultural land. Although this helps reduce land demand, current fertilizing practices has resulted in large scale oxygen depletion in waterways and coastal zones. Much of the man-made nitrogen and phosphorus fertilizers used washes out and causes nutrient enrichment and eutrophication (Schröder et al. 2010). Rockström et al. (2009) identified both the global nitrogen and phosphorus cycles as important for setting planetary boundaries. The global nitrogen cycle (measured as the annual amount of N_2 removed from the atmosphere for human use) is thought to already been overstepped, while the phosphorus cycle (measured as the annual amount of P flowing into the oceans) is critically close to the proposed planetary boundary.

In addition to upsetting the functioning of ecosystems, phosphorus is a finite resource with reserves diminishing at a rapid rate. Peak phosphorus is likely to occur around 2035 (Cordell, Drangert and White 2009). In 2050, it is likely that the EU will be very dependent on imports from Morocco – one of the few countries with significant resources (Cordell 2010).

Eurostat tracks the uses and balances (inputs, outputs and losses) of nitrogen and phosphorus in agriculture in the EU. As the consumption of inorganic fertilizers and the application of manure are the greatest sources of nutrient inputs (and also represent the most reliable data), these are chosen as the measure for defining this target. The level of ambition for this target should be based on the best available techniques that minimise the loss of nitrogen and phosphorous fertilizers on fields. The optimal level is determined by many factors including climate conditions, soil type and soil characteristics, and management practices such as drainage, tillage, irrigation, etc. The level of optimal use has not yet been quantified for the EU, but this may be determined through fertilizer application standards based on soil and crop types and knowledge of nutrient balances. Such an approach was used by Denmark

to decouple farm inputs of nitrogen and phosphorus fertiliser from agricultural production (OECD 2007).

A target of nutrient input would complement the target on arable land by ensuring that any productivity increases of farmland in the EU do not come at the expense of ecosystem degradation due to more intensive agricultural practices. This target also contributes to mitigating the supply risk of phosphorus; reducing energy consumption for the production of inorganic fertilizers; reducing emissions of nitrous oxide (a greenhouse gas) from soil; and, reducing nitrate pollution to freshwater resources.

Freshwater use: No region should experience water stress

Rockström et al. (2009) proposed a quantity-based planetary boundary for global freshwater use, demanding to keep global freshwater use below 4000 km^3 of consumptive use of runoff resources per year. This quantity-based approach at aggregate level masks enormous regional differences in water scarcity that exist globally and within the EU. A break-down to an EU fair share or EU per-capita targets would therefore be misleading.

The Water Exploitation Index (WEI), developed by the EEA, is currently used to track water scarcity in the EU (EEA 2012b). WEI, or withdrawal ratio in a country or a river basin, is defined as the mean annual total abstraction of freshwater divided by the long-term average freshwater resources. Although thresholds of water stress for WEI have been defined as when the WEI of a water body exceeds 20% (the abstraction of water is more than 20% of the long-term average freshwater resources) (Alcamo, Henrich and Rösch 2000), these thresholds are debated among EU Member States and experts (Faergemann 2012). The issue is that water stress depends on when (summer, winter, peak consumption), where (available water resources are distributed unevenly) and how (water returned to resources varies in terms of quantity and quality). In order to properly determine water stress, data per hydrological unit (river basin district) and on a monthly basis would be the most appropriate scale to reflect the hydrological realities and seasonality effects. However, this level of detail is rarely available and it would considerable efforts in collecting data and modelling the hydrological flows.

Despite lacking available data and method for measuring water stress, DYNAMIX proposes to strive for a status where no region in the world experiences water stress (based on the best available information). Unlike the other key targets, this goal is not directly linked to EU consumption and production alone. The contribution of EU policies to achieving this goal will have to rely on qualitative assessment.

2.5 Eco-innovation

Over the last five years, the concept of eco-innovation has been extensively discussed in scientific debate, referring overall to innovations that improve the environmental performance of activities related to production and consumption (Del

Río, Carrillo-Hermosilla, and Könnölä 2010; Kemp and Foxon 2007; OECD 2009). On the European level, the relevance of eco-innovation has been fostered by the adoption of the Environmental Technologies Action Plan (ETAP) in 2004, which mainly focused on the further development and use of environmental technologies.[6] A report published by the European Commission in 2007 on the ETAP found evidence of strong growth in environmentally related industries globally, but also identified the need to enhance actions raising demand for environmental technologies and eco-innovation and thus called for going beyond a merely technological focus in eco-innovation (Ekins 2011). In response to this call, the diversity of aspects analysed under eco-innovation increased to include processes, products, services, and organisational changes in incipient, immature or mature states (Del Río, Carrillo-Hermosilla, and Könnölä 2010).

Since 2010, the European Commission has been funding the Eco-Innovation Observatory (EIO), a three-year initiative aiming at facilitating market development of eco-innovation by providing an "integrated information source on eco-innovation for companies and innovation service providers, as well as providing a solid decision-making basis for policy development".[7] In addition, the EIO also strongly contributed to attempts for consolidation of conceptual strands of eco-innovation, inter alia by coming up with an integrative definition of eco-innovation in its methodological report from 2010. Accordingly, eco-innovation can be defined as "[…] the introduction of any new or significantly improved product (good or service), process, organisational change or marketing solution that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle" (Eco-Innovation Observatory 2010).

While this definition integrates the OECD definition of innovation[8], it goes beyond it by linking innovation to improvements in ecological state and performance. Furthermore, it also includes:

a) material flow eco-innovation, which will capture innovation across the material value chains of products and processes aiming at helping to reduce material requirements and thereby helping to transition the present widespread consumption and disposal paradigm towards a circular economy system

b) social innovations, which include novel, more effective, efficient and sustainable approaches from public sector, NGOs and businesses to solving social problems

[6] See http://ec.europa.eu/environment/ecoap/about-action-plan/objectives-methodology/index_en.htm, accessed 7 December, 2012.

[7] See http://www.eco-innovation.eu/, accessed 6 December, 2012.

[8] According to OECD Manual (OECD 2005) innovation is defined as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (OECD 2005, p.46). The OECD Manual can be accessed under http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/OSLO/EN/OSLO-EN.PDF.

and thereby primarily creating social change and value (Eco-Innovation Observatory 2010).

c) system innovations, which according to Geels (2005), refer to transitioning from one socio-technical system to another, both requiring and leading to changes in
    a. the social dimension (such as values and attitudes, but also regulations, etc.),
    b. the technical dimension (technologies, infrastructure, production processes, etc), and
    c. the relations between them.

System innovation often needs to include elements or combinations of all of the above types of eco-innovation (product-level, process-level, marketing, organizational, institutional or social). Therefore, system innovations are to be developed and implemented by a diverse set of actors, including policy makers, civil society, business and academia.

While DYNAMIX follows the EIO definition of eco-innovation, in its definition of eco-innovation it makes more explicit the link to system innovation. It does so because in the scientific debate, eco-innovation is furthermore divided into radical eco-innovation on the one hand and incremental eco-innovation on the other hand. While the former refers to substantial, more systemic changes at the level of production-systems, e.g. closed-loop systems where waste from one process may become the resource input for other processes, incremental eco-innovations encompass minor changes in production processes, e.g. improvements in energy efficiency or in filtering technology (Del Río, Carrillo-Hermosilla, and Könnölä 2010).

In line with calls from researchers expressing a clear need for radical, systemic eco-innovation in order to achieve the sustainability transitions required in the face of global change (Del Río, Carrillo-Hermosilla, and Könnölä 2010), DYNAMIX's objective to support absolute decoupling clearly calls for systemic changes, too. Therefore, the project will focus mainly on radical, more systemic eco-innovation as one important aspect of policies fostering absolute decoupling. Nonetheless, because incremental, more production process-oriented eco-innovation also contributes to reducing resource use and associated environmental impacts, DYNAMIX will also take into consideration incremental eco-innovation. Upon this basis, DYNAMIX expands the above definition of eco-innovation to explicitly mention system innovation (e.g. multi-modal mobility replacing individual car ownership).

3 References

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