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PROJECT FINAL REPORT

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4.1 Final publishable summary report

Executive summary

The three year research project "DYNAMIX – DYNAmic policy MIXes for absolute decoupling of environmental impact of EU resource use from economic growth" developed dynamic policy mixes that support absolute decoupling of the EU's resource use and associated environmental impacts from economic activities.

In order to develop and improve suitable mixes, the DYNAMIX team proceeded as follows: In a very first step a "common approach" was developed to enable a common understanding of key concepts, terminology and the project's methodological approach in order to ensure coherence throughout the project. Then the "reasons for inefficiency" were examined more closely. The team found five types of inefficiencies (i.e. the waste of by-products and unsustainable resource exploitation) and six of types of drivers of inefficiency (behavioural, technological, institutional, socio-economic, technological and bio-physical drivers), which are in detail highly specific to the problem. Many of the drivers are linked to our dominantly consumerist lifestyles, where technological fixes will not support absolute decoupling, as efficiency gains are usually lost through rebound effects. Therefore in the following the underlying paradigms, which affect resource use and how new paradigms can be translated into policy making were considered. In addition, best practices from 15 case studies of past and existing policy mixes in different sectors were compared and assessed regarding their effectiveness. The research suggests that effective policy mixes: focus on a specific resource or sector; achieve transformation because they match the type and level of 'lock-in' in the sector; have clear targets and address all phases of the policy cycle, including built-in monitoring, review and response mechanisms; to name a few of the results.

Building on this knowledge three policy mixes in fields particularly important for resource use were developed.

1) A metals and materials policy mix, with the aim to reduce the consumption of virgin metals by 80% in the EU in 2050 – without major increases in the use of other resources or environmental impacts;
2) A land use policy mix, aimed at reducing impacts of agricultural production and consumption;
3) An overarching policy mix, aimed at supporting decoupling of EU consumption from resource use and environmental impacts through creating supportive framework conditions for producers and consumers to make more sustainable choices, were developed.

The mixes included a broad variety of instruments, which were chosen for their effectiveness as found in the previous work of DYNAMIX, also taking into account the input from stakeholders.

In the next step the three policy mixes were assessed in an ex-ante impact assessment. Quantitatively the instruments (and as much as possible the policy mixes) were assessed regarding their environmental, economic, social and legal impacts. Furthermore, the public acceptability was assessed. Quantitatively the instruments (and as much as possible the policy mixes) were assessed regarding their environmental and economic impacts, with up to three different macroeconomic models, one "computable general equilibrium model" and two "dynamic stochastic general equilibrium models". The wealth of information resulting from these assessments were in the following synthesised from the project team, pointing to necessary revisions for the policy mixes and evaluating the effectiveness and synergies between the policy instruments. In addition, the results were translated into tangible policy

advice, i.e. as to which instruments should be mixed, or which should not, also including a time perspective.
The entire project was accompanied through intense stakeholder involvement and all results were disseminated to key stakeholder groups, in particular EU and national level policy makers and academia.

A summary description of project context and objectives

1. Context
Global consumption of material resources has seen marked increases in the last century, in particular since the 1950s. The use of resources, and in particular the production of bulk materials (e.g. steel, aluminium, cement and polymers), is responsible for a significant share of the energy demand and greenhouse gas (GHG) emissions of human society. Transforming these materials into consumption goods, infrastructure, and housing also generates significant additional environmental impacts: degradation of a large share of ecosystems and ever increasing ecological footprint of human activities. Global megatrends risk exacerbating the situation in the future and further challenge the likelihood and feasibility of transitioning to more sustainable resource use pathways. Rising global population and affluence levels, ever more widespread adoption of westernized life-styles and production and consumption patterns will contribute to future increases in resource consumption, which is expected to reach approximately 140 billion tons of minerals, ores, fossil energy carriers and biomass by 2050, more than doubling from the 68 billion tons reported for 2009 (Fischer-Kowalski et al. 2011). Such resource use and associated environmental impacts contribute to (further) transgressing existing planetary boundaries (Steffen et al. 2015).
Although humanity is not likely to run out of material resources in the foreseeable future, the production rate of renewable materials is limited and the economic cost of producing non-renewable materials is likely to increase with time, particularly if material use continues to increase (Allwood et al. 2011). Increasing the efficiency in the use of material resources, therefore, is important to generate as much economic value and/or well-being and serve as many functions as possible with a given resource base. In addition, increasing resource use efficiency can counteract future supply risks for certain materials, e.g. for rare earth metals, because the mineral reserves and/or mines are located at very few places in the world.

Hence, increasing efficiency in the use of material resources is important to steward our resource base and enable present and future generations to benefit from using resources sustainably, thus increasing the resilience of social-ecological systems and achieving a more sustainable economy in the long term. The use of material resources can be made more efficient through increased recycling, but also through increased material efficiency. The latter can include material-efficient production processes, material-lean products and systems, products with a long service life due to high quality and repairability, changes in consumption patterns from products to services, from owning to sharing, etc.

According to the Ecological Footprint indicator, Europe uses 20 % of the world's resources, while it hosts only 7 % of the world's population. Increasing resource efficiency has therefore been a major goal of EU policy making, and it is anchored in a number of political strategies: the Europe

2020 Strategy for smart, sustainable and inclusive growth, the EU Sustainable Development Strategy and the Roadmap to a Resource Efficient Europe have been cornerstones of European policy making. In recent years further policy initiatives that aim to provide more concrete policy goals, have been pushed forward, among them the Circular Economy Package (first tabled in July 2014 by Environment Janez Potocnik under the Barroso II Commission

and then scrapped and published in a revised by the Juncker Commission in December 2015), which includes revised legislative proposals on waste, among other topics.

Despite these advances, the resource use of the European Union remains unsustainably high and further strides forward in resource policy need to be made. But not only policy instruments are debated, also the approach to policy making for resource efficiency needs to be improved. A single material is typically used in many different applications and sectors. Economic interlocking of streams of resources, semi-finished and finished goods make resource policy a policy field involving a multitude of interdependent actors in value chains that cross national boundaries and on markets that are often global. Taking into account the specific conditions of each application and each actor is hardly possible. And yet, failing to do so increases the risk that policy interventions shift the use of resources to other applications or regions of the world, rather than increasing resource efficiency. Furthermore, efficiency gains obtained from improving resource use efficiency may trigger greater consumption of the same good/service or of other goods and services, eventually backfiring and causing rebound effects.

These complexities, the many functions that material resources serve, and the multitude of involved actors in multi-actor-systems call for a more systemic approach to resource policy making. Such an approach needs to allow policy makers to account for the most important aspects and causal relations between relevant trends and drivers and their effects when designing policies. Furthermore, such an approach requires a very broad systems perspective in order to capture as much as possible the system's complexities.

Against this background, the DYNAMIX project ('DYNAmic policy MIXes for absolute decoupling of environmental impacts of EU resource use from economic growth', www.dynamix-project.eu) analysed the underlying reasons for inefficiency and assessed existing policy instruments and mixes. Drawing from this work the DYNAMIX team identified policy mixes that support absolute decoupling of economic growth from resource use and its associated environmental impacts. These policy mixes were tested in qualitative and quantitative ex-ante assessments against

1. Their potential environmental effectiveness vis-à-vis the five key targets
    1) 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;
    2) 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;
    3) 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;
    4) 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;
    5) freshwater use: no region should experience water scarcity representing impacts of resource use on freshwater availability; and

2. Their potential side-effects in terms of socio-economic impacts, public acceptability and legal feasibility.

In order to identify promising policy mixes, we developed and implemented a heuristic framework guiding our analyses and assessments. The results of these works were in a final step synthesised, in order to make them accessible to policy makers and other stakeholders.

2. Objectives

The DYNAMIX project set out with three key objectives:

1) To carry out a qualitative and quantitative evaluation of existing resource policies existing inefficiencies in resource use.
2) To propose dynamic and robust policy mixes for resource efficiency and assess their efficiency, effectiveness, sustainability, and contribution to eco-innovation, incorporating novel concepts and paradigms for absolute decoupling.
3) To establish a sustainable mutual learning process with policy-makers, scientists and other stakeholders, supporting the development of pathways to resource efficiency and decoupling.

The three key objectives were supported by sub-objectives.
1) Qualitative and quantitative evaluation of existing resource policies, included the sub-objectives:

a) performing an in-depth analysis of the underlying reasons for the inefficient use of resources, including structural, systemic, technical, economic, and behavioural aspects.
b) To evaluate existing resource efficiency policies using qualitative and quantitative tools, including ex-post modelling and statistical analysis (WP3) regarding: effectiveness; cost-efficiency; sustainability; and contribution to eco-innovation.
   In addition, this evaluation took into consideration the different components of the policy mix and the combination of instruments and policies, including synergies and trade-offs.

These two above-mentioned objectives a) and b) were pursued mainly in work packages 2 and 3. In WP 2 the entire life cycle of resource (in-)efficiency from resource extraction, via production (including barriers to eco-innovation), consumption to the barriers to recycling and waste reduction were explored. Underlying reasons for inefficiencies, including structural, institutional and economic drivers were identified. Thus, it informed the evaluation of existing resource efficiency policies (sub-objective 1b), which was mainly performed in WP3. In WP3 a total of 15 case studies were selected. The selection followed a strict methodology, focussing on resources that have the most significant environmental impacts (agricultural goods and biotic materials, fossil fuels, metals and construction materials). The evaluation was based on secondary data, and where necessary on interviews assessing the effect, the effectiveness, the policy mix's efficiency and (social) sustainability.

The results from the assessment of case studies helped developing the policy mixes in WP 4.

2) The **second key objective**, developing 3-5 dynamic and robust policy mixes for resource efficiency to assess their efficiency, effectiveness and sustainability was complemented with five sub-objectives:

a) To apply a life-cycle approach to the modelling of the resource use of products and services and their respective impact on the environment (WP6).
b) To include behavioural aspects in the assessment of proposed policy mixes (WP5).

c) To show whether and how far the proposed policy mixes can lead to decoupling of economic growth from the unsustainable use of natural resources and environmental degradation in Europe and globally, using innovative modelling as well as qualitative assessments (WP5 and WP6).
d) To demonstrate pathways to absolute decoupling, taking into account paradigm shifts as much as possible as well as uncertainties in the assessments (WP5 and WP6).
e) To recommend policy mixes which support absolute decoupling while stimulating eco-innovation and improving the competitiveness of EU Member States (WP8)

The main key objective – developing 3-5 policy mixes – was pursued in WP4. In total three policy mixes were developed: 1) a metals policy mix aimed at reducing metals and materials use, 2) a land use policy mix aimed at reducing impacts of agricultural production and consumption and 3) an overarching policy mix for fostering sustainable production and consumption. These mixes from three different policy areas were designed to address absolute decoupling in general and, specifically, the use of virgin metals, the use of arable land and freshwater, the input of the nutrients nitrogen and phosphorus, and emissions of greenhouse gases. In these areas the most significant environmental impacts take place. The missing high impact area – fossil fuel use – was deliberately left out, as it was considered to receive sufficient research attention already.

The sub-objectives a), b) and c) were pursued in WP 5 and 6. The policy mixes were assessed qualitatively regarding their environmental, economic and social impacts as well as in terms of legal feasibility and public acceptance. Quantitatively the policy mixes were assessed regarding their environmental and socio-economic impacts, with three different macroeconomic CGE models, one "computable general equilibrium model" and two "dynamic stochastic general equilibrium models", and a suite of physical-environmental models, including LCA, material pinch analysis and carbon footprinting. These assessments took a life-cycle approach and the results showed to which extend the policy mixes lead to decoupling as well as which coupling of mixes is necessary for the policy mix to be effective. For example was one very significant result from the materials policy mix that the strong instruments from a green fiscal reform "materials tax" and "internalisation of external environmental costs" lead to significant positive economic and environmental impacts if they are coupled with increased spending for research and development. Without this coupling, the economic effects may be more negative. Thus also pathways to absolute decoupling (sub-objective d) were also elaborated in WP 5 and 6, and furthermore supported with the synthesising work of WP8.

In the final project phase the assessment results were synthesised and condensed, in order to evaluate the sometimes different assessment results and give a balanced view on the overall impacts. From this synthesis suggestions for improvement of the instruments or the mixing of the instruments were also collected from the previous assessments, thus tackling sub-objective e). Furthermore, the results were translated into tangible policy advice, i.e. as to which instruments should be mixed, or which ones should not, also including a time perspective. In following this advice the EU and its member states can achieve higher resource efficiency and increasing the economic output per unit of resource input, thus strengthening the competitiveness.

3. The third key objective "To establish a sustainable mutual learning process with policy-makers, scientists and other stakeholders, supporting the development of accelerated pathways to resource efficiency and decoupling." was completed with four sub-objectives

a) To apply an integrated stakeholder strategy to the entire DYNAMIX project, using recurring Policy Platforms to exchange knowledge and perceptions regarding resource efficiency and resource policies (WP7).
b) To integrate stakeholders in the research process, both in the ex-post evaluation and in the ex-ante assessment of policy mixes, including both the qualitative and the quantitative analysis (WP7 in interaction with WP1, WP2, WP3, WP4, WP5 and WP6).
c) To enable participating stakeholders to benefit from an ongoing learning process, creating an interactive community which will support the continuation of the Policy Platform beyond the end of the project duration, creating a long-term network of resource efficiency stakeholders (WP7).
d) To create an open and dynamic process and include knowledge and perspectives beyond the European horizon by integrating international institutions into a high-level Advisory Board (WP7).

The third key objective and its sub-objectives were successfully reached through (mainly) through the WP7 work. The results of the DYNAMIX Policy Platforms provided up-to-date and detailed information on policy challenges, assessments, and policy mixes on resource efficiency in Europe. They documented the discussions held at all events, the exchange among the different stakeholders, and the results of interactive group work. The results were then taken up in the various DYNAMIX WPs to refine project deliverables. In addition, an "Advisory Board" included 7 high-level personalities, representing international organisations (UNEP, OECE), the European Commission (DG Environment), the European Environment Agency, a national government ministry (Italian Ministry of Environment, Land & Sea), and research (including a representative of POLFREE, a project on resource efficiency also funded in FP7) to advice the project in its critical phases. Finally, WP7 organised a final conference for disseminating main project results.

A description of the main S&T results/foregrounds

1. Introduction

The following sections present the main S & T results of DYNAMIX, reflecting the theoretical work finding a "common approach" regarding key concepts, terminology and the project's methodological approach (section 2). The results on "reasons for inefficiencies" (section 3) and on "existing policies and policy mixes" (section 4) were directly fed into "scenarios and new policy mixes", which are presented in section 5. In the next step the policy instruments and mixes were assessed quantitatively and qualitatively, the scientific results are presented in section 6 and 7.

The lessons learned on "In-built stakeholder involvement and dissemination" and how these lessons fed into the other project steps is presented in section 8. The final exercise, the "Synthesis for policy guidance and recommendations" is described in section 9.

2. Contributing to a clearer definition of key terms in resource efficiency (WP1)

While the project's work packages applied a number of different methods, all used a set of shared key concepts and assumptions. The Common Approach aimed to clarify these and ensure consistent application throughout the project. It stems from two main roots: a semantic analysis of literature and policy documents, and intense discussion, both within the consortium and with stakeholders. The results were documented in a key deliverable, which

served as a guiding document throughout the project (Umpfenbach, K. (2015): How will we know if absolute decoupling has been achieved and will it be enough? - Common Approach for DYNAMIX, Deliverable D.1.3., Berlin: Ecologic Institute; henceforth "Common Approach"). The "Common Approach" was revised throughout the project to integrate additional insights from the subsequent research progress within the project as well as external feedback.

In particular, the "Common Approach" includes discussions and working definitions for the following concepts: resources, relative and absolute decoupling, resource efficiency, eco-innovations, policy mix, eco-efficiency and paradigms and paradigm shift. The definitions proposed for key terms used in DYNAMIX rest on a semantic analysis of how these terms are understood in the relevant scientific literature, in policy documents as well as by stakeholders, including business associations and NGOs.

Concerning the classification of **resources**, within DYNAMIX we used the categories of Eurostat's Economy-wide Material Flow Accounts to ensure compatibility with the available data set, but extended the concept of natural resources to also include natural sinks, ecosystems, land, freshwater, air and soil. DYNAMIX thus covered all natural resources (biotic and abiotic) 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.

The approach for **decoupling** in DYNAMIX can be understood as the delinking of economic output from resource use and environmental impacts, distinguishing it also between **relative** and **absolute** decoupling. The first 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.

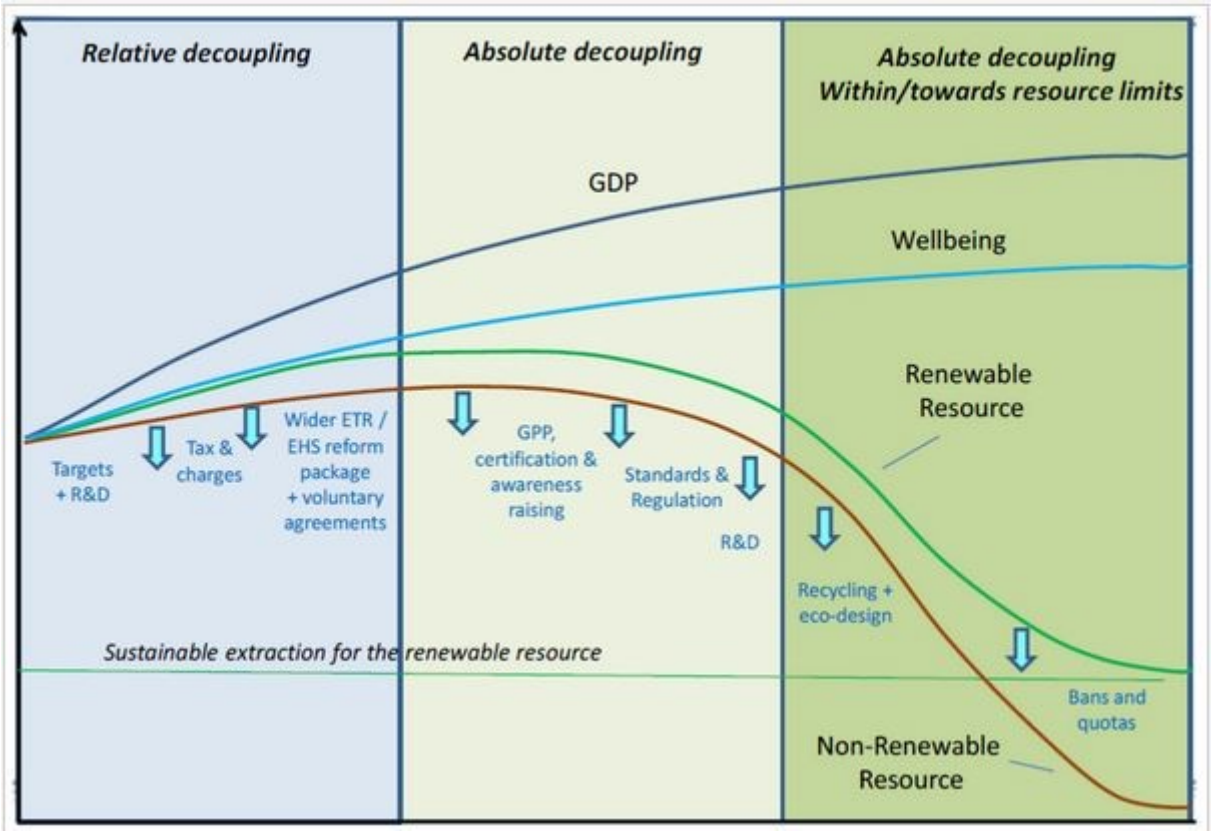

Fig. 1: Understanding of decoupling in DYNAMIX. Source: IEEP, 2014 (Deliverable D3.2).

Understood as creating more socio-economic value through an equal level of environmental impact or resource input, increased **resource efficiency** is a key lever for achieving decoupling, 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. Additionally, resource efficiency can also increase when needs are fulfilled with different products or services or when the paradigm of what fulfils a need shifts.

The resource efficiency topics have been integrated into a wider green recovery agenda since the economic crisis of 2008/2009. This agenda of ecological modernisation, named as "Green Growth" or "Green Economy", 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. Considering its relevance in supporting decoupling, within DYNAMIX, we defined **eco-innovations** 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. This 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).

DYNAMIX assumed that the magnitude and complexity of the absolute decoupling to occur requires a policy mix consisting of several mutually reinforcing instrument types. In

DYNAMIX, a **policy mix** was 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. To improve acceptability, robustness to changes, and effectiveness, the policy mix can be designed in a dynamic fashion, i.e. as a combination of instruments deployed in sequence.

With regards to the assessment of the effectiveness, cost-efficiency and sustainability of the proposed policy mixes, the **temporal scope** of DYNAMIX was the medium term (2030) and the long term (2050). It was the original goal of the policy mix that by 2050 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 was used as a common base year for ex-ante assessments in Work Packages 5 and 6.

In order to clarify the concepts used for the policy assessment criteria in DYNAMIX, we defined **effectiveness** on the economy-level and on the case study level. Based on the idea of a "safe operating space for humanity" (Rockström et al., 2009), DYNAMIX defined five key targets that addressed the most crucial resource streams and environmental impacts as benchmarks against which to assess the effectiveness of policy pathways **on the economy-level**. Any of those that met these targets and at the same time secured well-being was considered as fully effective.

The key targets for 2050 proposed by DYNAMIX, inspired by the themes covered in the Roadmap's dashboard indicators, were:

- consumption of virgin metals: -80% compared to 2010,
- greenhouse gas emissions: 2 tonnes CO2-equivalent per capita and year,
- consumption of arable land: zero net demand of non-EU arable land,
- nutrients input: reducing nitrogen and phosphorus surpluses in the EU,
- freshwater use: no region should experience water scarcity.

Effectiveness **on the case study level** was measured against the benchmark of absolute resource decoupling and absolute impact decoupling – including impacts outside the EU as far as data availability allowed. The relevant resource and/or environmental degradation indicator was chosen based on the objective set in the policy itself. The **cost-efficiency** was measured comparing the achieved level of resource and impact decoupling with the monetary (or other) resources applied to achieve the outcomes.

Sustainability of the policy mixes was also considered. It was understood in DYNAMIX to include three dimensions: environmental protection, social equity and a thriving economy. The concept was 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). Due to the project's capacity limits, the assessment of socio-economic impacts of EU policies was primarily focused on impacts in the EU.

Finally, DYNAMIX assumed that effective policies for absolute decoupling have to address the underlying worldviews of actors and contribute to **paradigm shifts**. In DYNAMIX, we understood the **paradigms** of an individual or group as the set of sometimes unconscious values, beliefs and ideologies in which they are immersed. Paradigms can be distinguished between scientific or socio-cultural paradigms and manifest themselves externally via discourses and are reinforced within society via the creation of social-technical systems. A

paradigm shift occurs when an older paradigm is partially or totally replaced by an incompatible new one.

3. Reasons for resource inefficiency (WP2)

Objective

The goal of work package 2 was to identify and assess some of the key drivers of inefficient resource use in the EU. The study examined a broad range of individual resources (e.g. materials, land, water, energy, and ecosystems), analysing their macro-economic flows and assessing inefficiencies in their use throughout their life cycles. The study also took a closer look at production and consumption in three key sectors: food, buildings and transport.

Methods

In conducting this work, DYNAMIX took a multi-step approach to identifying and evaluating key areas of inefficient resource use and the drivers behind them. An initial review of the global and macro-economic flow of resources, conducted largely via a literature review and Material Flow Analysis (MFA), provided a first indication of the key inefficiencies associated with use of various resources.

A more detailed literature review, coupled with a meta-analysis of the literature, allowed us to map key drivers and causes associated with resource inefficiencies in general and with specific key areas of inefficiency. Each area was then assessed with respect to its potential contribution to decoupling and the relative feasibility and effectiveness of addressing it via policy.

The analysis focused primarily on resource use in the EU, while also considering global resource use driven by EU production or consumption. Following a preliminary screening of the literature, we decided to examine resource use from two key complementary perspectives – a resource type perspective, and a production and consumption perspective. In the resource type perspective, all key resources were treated, with a particular focus on materials, energy, water, land and ecosystems. In the production and consumption perspective, particular attention was given to the food, transport and building sectors, given the significant environmental and resource-use pressures that these sectors exert in the EU (EEA 2013). In both cases, we used a life cycle approach, tracing resource use from extraction to outputs in the form of waste and emissions to the natural environment.

Results

<u>Global resource use and main areas of inefficiency</u>

Based on our literature review and resource-specific MFAs, the DYNAMIX team found significant potential to increase efficiency for all resources considered, and we were able to recognise several general and specific areas of inefficiency.

In general, many of the inefficiencies identified can be seen as ‘classical’ examples of technical inefficiencies where a comparison is made between the amount of resources needed as inputs per unit of output. This type of inefficiency typically relates to the production side of resource use, and improvements in productivity can be made via technology and use of best practices. By contrast, other inefficiencies relate primarily to use and consumption behaviours, such as choice of diets, use of products and overconsumption in general. A third general type of inefficiency relates to resources that are typically discarded as waste, despite

their potential to be reused, recycled or transformed to another useful resource, thus easing pressure on new (virgin) resources. A fourth type of inefficiency identified is the potential to substitute the use of one resource with another resource that is less harmful to the environment. A final key type of inefficient resource use identified relates to unsustainable resource extraction or use (i.e. an unsustainable rate of extraction in relation to natural stocks or rate of replenishment).

These different types of inefficiencies should not be considered individually. In effect, they are often interlinked and depend on how the problem is framed. For example, food waste is a mixture of production inefficiencies (e.g. bakers make more bread than they can sell); consumption inefficiencies (e.g. consumers buy more than they can eat); waste inefficiencies (e.g. leftovers are thrown away); and substitution inefficiencies (e.g. fresh milk does not keep as well as long life milk). One should view these inefficiencies more as different dimensions of inefficiency rather than separate categories.

We were able to identify several specific main areas of inefficiency for each of our key consumption sectors reviewed. These selections were based on the significance of resource use involved in each area, as well as its potential for efficiency gains. The following key areas of inefficiency were identified for each sector:

- Food: Nutrient and pesticide losses; unsustainable fisheries; irrigation, food losses and wastes; diets and food choices.
- Transport: Vehicle design and fuel efficiency; design and choice of materials for transport infrastructure; choice of vehicles and driving patterns; choice of transport modes; vehicle occupancy; distance travelled.
- Buildings: Building design and choice of materials; inefficiencies in heating and cooling; inefficiencies in lighting, appliances and electronics; water consumption and losses in buildings; urban sprawl; number of people per household / area per person.

Key drivers and causes of inefficient resource use

DYNAMIX found that in much of the existing literature on resource efficiency, population growth and rising incomes are identified as two of the main root causes of existing unsustainable patterns of resource use. However, rising income and population growth are mainly indirect drivers, and we focused on identifying relatively more direct factors accounting for resource inefficiencies.

Based on the literature review and meta-analysis of drivers, we were able to identify six main broad groups of factors that directly or indirectly influence inefficient resource use:

- Behavioural and informational;
- Institutional and organisational;
- Policy and regulatory;
- Economic and demographic;
- Technological and infrastructural; and
- Bio-physical.

Our review confirmed that these drivers can act at any point in a resource's or product's life cycle. We also found that several of these drivers are typically at play simultaneously and that significant linkages exist between them.

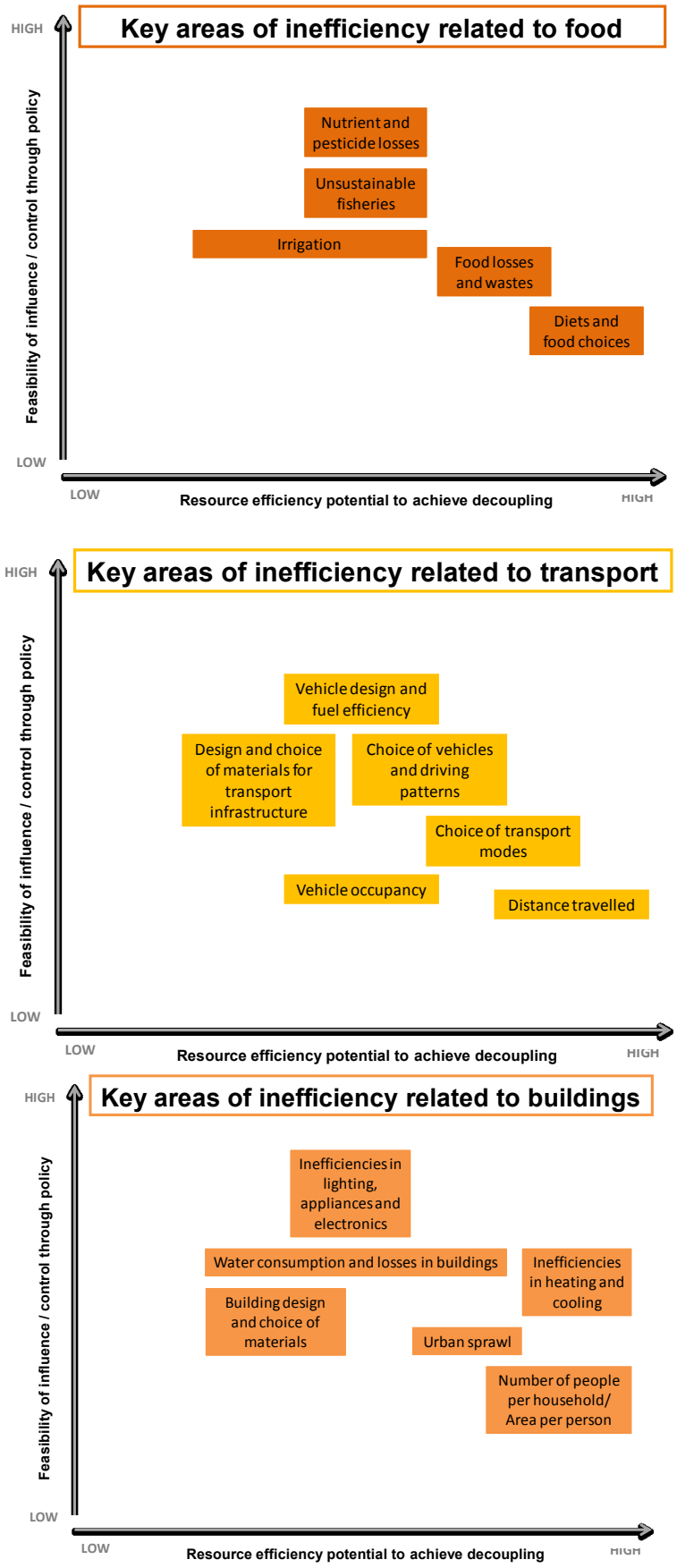

Fig. 2: Preliminary assessment of key areas of inefficiency in relation to potential for decoupling and policy intervention; Source: Tan et al. (2013) (Deliverable D2.2)

Key areas of inefficiency to address via policy

Figure 2 above provides the final impact-feasibility mappings constructed to rank and compare areas of inefficiency and determine those to address in priority via policy measures. These mappings were constructed for each consumption sector considered in the study (food, transport and buildings). According to these mappings, areas of inefficiency with the greatest potential contribution to decoupling include diets, distances travelled, inefficiencies in building heating and cooling systems and size of households and dwellings. Those inefficiencies which may most easily be addressed via policy include nutrient and pesticide losses, vehicle design and fuel efficiency and inefficiencies in lighting, appliances and electronics.

Approaches to improving resource efficiency

One of the most common strategies to improving resource efficiency is to reduce waste and losses. This can contribute to other resource efficiency strategies upstream in the life cycle of resource use such as reducing the overall demand for resources, reducing the need for resource inputs and ultimately leading to a more sustainable level of natural resource extraction. The reuse and recycling of resources can also reduce the need for virgin resources by closing material loops and reducing the demand for resources.

A set of resource efficiency strategies focus more on reducing the environmental impacts associated with resource use rather than the amounts of resources used. These are substituting specific resources with other types of resources that are less harmful to the environment (e.g. using wood instead of metal), using resources in a way that results in less environmental damage (e.g. applying fertilisers only in certain times of the year) and using resources that actually protect or improve the environment (e.g. establishing green areas to reduce heat islands in urban areas).

Figure 3 summarises the main strategies to improving resource efficiency.

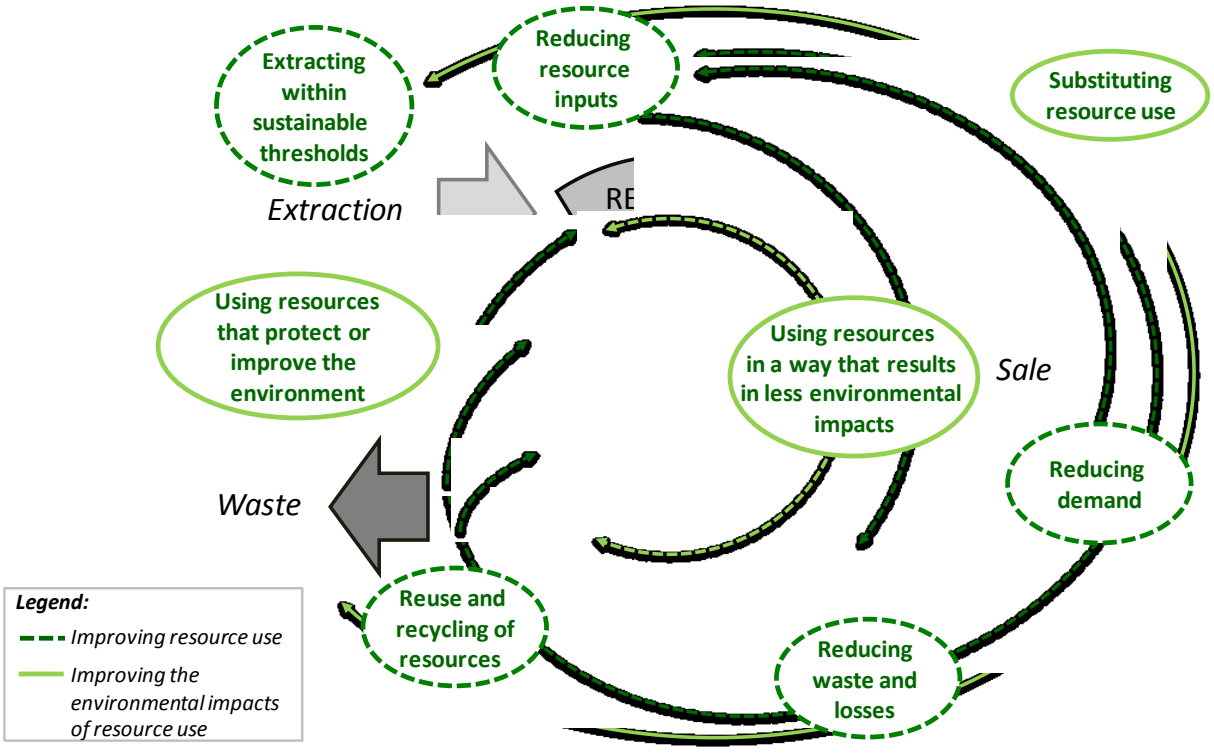

Fig. 3: The identified main strategies to improve resource efficiency; Source: Tan et al. (2013) (Deliverable D2.2)

Conclusions

Overall, the findings from the literature review and the meta-analysis contribute to an improved and more comprehensive picture of relevant drivers affecting resource inefficiency. These outcomes served as a guide for the other work packages of the DYNAMIX project, which aims were to identify policy pathways to absolute decoupling of economic growth from resource use and its environmental impacts.

4. Assessing existing policy mixes (WP3)

In order to prepare the policy mixing process in the following work of DYNAMIX, as a pre-step the effectiveness, efficiency and sustainability of exemplary existing policies and policy mixes concerning resource efficiency as well as their contribution to eco-innovation was analysed. The case study selection was guided by a strict methodology in order to ensure that relevant examples for existing resource efficiency policies were examined while at the same time covering a broad thematic scope and the full range of available instruments.

A rich selection of examples was identified and analysed in Deliverable 3.1, which covered 15 real-world policy mixes, including: fossil fuel use in Sweden and Denmark; local municipal waste in Slovakia; and land take in England and Germany. The work package found that relative decoupling is being achieved in Europe, though at different rates across countries and resource issues. Evidence of absolute decoupling is less frequent and related to specific resources and countries. Examples include Denmark's fertiliser use, the UK's use of aggregates, Ireland's plastic bag use and Japan's "sound material cycle society". In Iceland, absolute decoupling within resource limits had been achieved for some fish species.

The review of real world experience carried out under Work Package 3, and which is synthesised in Deliverable 3.2, suggested that effective policy mixes:

- Focus on a specific resource or sector.
- Achieve transformation because they match the type and level of "lock-in" in the sector.
- Are informed by a clear understanding of limits and thresholds.
- Address the global impacts of resource use, particularly imports from overseas.
- Have clear targets and address all phases of the policy cycle, including built-in monitoring, review and response mechanisms.
- Strike the right balance between effectiveness and public acceptance.
- Have predictable effects, thereby increasing efficiency.
- Include information instruments to increase awareness, but do not use them in isolation, because information alone fails to deliver the scale of change required for decoupling.

We identified no obvious trend between the absolute number of instruments in a policy mix and its effectiveness. Rather, instruments can play different roles: Regulation is often the driving instrument and has proven fundamental for meeting critical environmental objectives, particularly by driving innovation. Market-based instruments (MBIs) as core instruments have led to both relative and absolute decoupling. Voluntary instruments are weaker, but can be useful as a bridge to more ambitious instruments, so in the logic of sequencing they can be valuable first steps.

The main shortcomings in policy design that we identified included:

- A lack of policy coherence or conflicting policy objectives.
- Gaps and loopholes, for example through exemptions.
- A failure to take into account rebound effects.
- Targets and objectives which were not fit for purpose (e.g. not defined in achievable terms).
- A failure to fully integrate international impacts, risking leakage.

The insights gained from the analysis were fed into the policy mix development of the DYNAMIX project, which followed in the next step.

5. Scenarios and new policy mixes (WP4)

In the following, policy pathways towards absolute decoupling were defined. The DYNAMIX team analysed the need for paradigm shifts and identified a set of promising policy instruments and three dynamic policy mixes to move towards absolute decoupling. For the purpose of assessing the policy mixes in WPs 5-6, we also created scenarios to describe how the future might develop without the policy mixes. At the end of the project, we revised the policy mixes based on findings from the assessments and other lessons learnt throughout the project.

The **background scenarios** developed in DYNAMIX describe how the economy, technology, and society in the EU might develop until the year 2030 and 2050 without new policy instruments on resource use and environment beyond what is already implemented. The scenarios are intended to provide a background for the assessments of new policy mixes in the DYNAMIX project. Using several background scenarios is a way to assess the robustness of the policy instruments. This is important due to the inherent uncertainty of the future.

The background scenarios were based on different assumptions regarding the future rate of innovation and different sets of dominating values. A high rate of innovation means that the scenarios include multiple technological breakthroughs in different areas. They can also include many new business models. The technological efficiency increases even when the rate of innovation is low, but only slowly. Materialistic values focus on maximizing production and consumption, while environmentalist values focus on the well-being of all humanity and future generations. We selected these dimensions because they are heavily influenced by factors beyond the control of policy-makers, they are highly uncertain and important for the assessment of policy mixes, and they are important in the public debate.

Most of the policy assessments are made against the background of the reference scenario. This describes a surprise-free future. Improvements in technology continue at a good pace, but the society is not transformed by any major technological break-through. The balance between materialistic and environmental values stays the same as today. Important current trends continue towards, e.g., increased globalisation.

Besides the reference scenario, we present a background scenario for each of the corners in the figure above. These four cornerstone scenarios are important complements to the reference scenario, since the future is actually unlikely to be surprise-free:

- Economic bonanza. This scenario includes a high rate of innovation and a materialistic focus on production and consumption. It is the scenario with the highest economic efficiency and growth. Global competition over rare metals, phosphorus, etc. becomes fierce.

- Safe globe. This is a scenario with a high rate of technological and social innovation and an environmentalist focus on the well-being of all humanity, future generations, and nature. The scenario includes global cooperation on environmental protection, workers protection, product safety, etc. It also has the most advanced technology for environmental protection.
- Divided we trudge. This scenario describes a future with a low rate of innovation combined with a materialistic focus on production and consumption. Lack of cooperation and increased nationalism in Europe lead to diminished knowledge transfer between stakeholders as well as countries, and to a low rate of innovation.
- Back to nature. This scenario combines a low rate of technological innovation and societal values that focus on the well-being of all humanity, future generations, and nature. In this scenario, repeated failures of experts and advanced technology cause distrust, and society becomes dominated by small-scale solutions, local production and trade. The economy to a large extent becomes informal.

None of the scenarios predicts the future as it must be or is most likely to be with the given combination of innovation rate and value. Many different scenarios might be consistent with each corner in the scenario four-field figure above. However, we argue that our scenarios are all plausible, except that they all include the same resource and environmental policy instruments that are in place today.

The **policy mixes developed in DYNAMIX** were designed within three different policy areas to address absolute decoupling in general and, specifically, the use of virgin metals, the use of arable land and freshwater, the input of the nutrients nitrogen and phosphorus, and emissions of greenhouse gases. Each policy mix was developed within a separate author team. Based on findings from WPs 2-3 they identified specific drivers and barriers for resource use and resource efficiency relevant for their policy area. Specific policy objectives and targets were also discussed before the actual policy mix was presented to stakeholders and policy makers. WPs 5-6 performed an ex-ante assessment of the different elements of the policy mixes. Based on the feedback and assessment results, we revised all three policy mixes.

An "**overarching policy mix**" aims at reducing overall resource consumption in the EU and also at reducing the emissions of greenhouse gases and other pollutants. This policy mix includes a broad variety of instruments:

- A circular tax trio consisting of taxes on the extraction of selected virgin materials and on landfilled and incinerated waste.
- Feebate schemes for selected products.
- Reduced value-added tax (VAT) for the most environmentally advantageous products and services.
- Boost of the extended producer responsibility.
- Skill enhancement programmes.
- Local currencies for labour-based services.
- Enabling a shift from consumption to leisure.
- Step-by-step restrictions of advertising and marketing.
- Minimum requirements on the life-cycle performance of products.
- Compulsory sustainability reporting for companies.

The ex-ante assessment of this policy mix did not call for adding further instruments, but for adjustments in the design of individual instruments. Several instruments were revised to increase public acceptability and momentum. The circular tax trio should be presented as part of a larger tax reform. The VAT reduction should be expanded into a wider VAT reform and coordinated with the feebate schemes.

Another "**land use policy mix**" aims at reducing land use, freshwater use and nutrient surplus through improvements in food production, changes in diet, and reductions in food waste. This policy mix emphasises five instruments to improve food production through, for example, revisions of already existing policy documents:

- Stronger and more effective environmental and climate dimension for EU land management in the Common Agricultural Policy.
- Revised emissions levels in the National Emissions Ceilings Directive and additional measures for better management of the nitrogen cycle on farmland.
- Promotion of Payment for Ecosystem Services programmes.
- Revised regulation for land use, land-use change and forestry.
- Revised Pesticides Directive, and guidance to farmers on pesticide management.

These five key instruments are in the policy mix supported by a range of accompanying measures. These include, for example, increased prices on irrigation water, the establishment of EU soil legislation, and the promotion of research and monitoring.

The policy mix on land-use also includes three instruments to influence the food consumption and food waste:

- Targeted information campaigns on changing diets and on food waste.
- Development of food redistribution programmes/food donation to reduce food waste.
- Increased VAT on meat.

The ex-ante assessment did not explicitly call for any additional instruments to be added to this policy mix; however, it highlighted the need to add clear objectives and quantitative targets to several of the instruments. For this purpose, the development of an indicator to reflect the net land use of the EU should be added as a key element in the policy mix. The development of an integrated long-term strategy for land use would also contribute to making this policy mix more effective and feasible.

A "**metals use policy mix**" primarily aims at reducing the use of virgin metals in the EU through increased recycling and material efficiency. At the same time, it aims to avoid merely shifting burdens to the use of other resources or regions in the world, or to increase environmental impacts. For this reason, the metals policy mix was expanded to include also competing materials and includes several instruments of an overarching character. A key element in this policy mix is a gradual green fiscal reform, where tax revenues over time shift from labour to material use, resource use and environmental impacts.

The structure of the policy mix was revised after the ex-ante assessment and other discussions. Extended producer responsibility and retraining programmes were added to the mix. The green fiscal reform was presented in a more disaggregate way to highlight the measures taken to alleviate the negative side-effects of material and environmental taxes. The instruments were also more clearly categorised into primary and supportive instruments. The following primary instruments are included in the revised policy mix on metals and competing materials:

- A substantial tax on materials used in the EU, to increase material efficiency.
- Extended producer responsibility, to increase global recycling.
- Technical requirements, for materials substitution and efficiency.
- Increased environmental taxes, to reduce resource use and environmental impacts.

The policy mix also includes a range of supportive instruments to reduce negative side-effects of the primary instruments and to make the policy more politically feasible:

- Border tax adjustments, to reduce the impact on the competitiveness of EU industry.
- Labour tax reductions, to stimulate employment.

- Removal of harmful subsidies, for a coherent fiscal reform.
- Spending on research and development, to facilitate changes in technology.
- Retraining programmes, to facilitate the change in the economic structure.
- Information campaigns and infrastructure to facilitate changes in behaviour.
- Sharing systems, to facilitate behavioural change.
- Advanced recycling centres, also to facilitate behavioural change.
- Fora for communication, to stimulate networking.
- A common EU strategy, to harmonise legislation in Member States.

The ex-ante assessment of the policy mixes indicated that the mixes would contribute to reducing the use of virgin metals, arable land and freshwater, the input of nutrients, and the greenhouse gas emissions. However, no single policy mix would be sufficient to reach all the predefined targets. The three policy mixes illustrate different ways to address the challenge of developing policy mixes for a resource-efficient future EU; however, further work is needed to refine the policy mixes in order to make them ready for implementation.

6. Qualitative Assessment of the policy mixes (WP5)

The policy mixes were analysed qualitatively, with regards to environmental impacts, economic impacts (such as market failures), social impacts and governance-related impacts including legal aspects and public acceptance. First, the team developed a common framework to integrate the various qualitative assessments. The integrated findings from the various qualitative assessments, were presented in an additional synthesis report. The results of the qualitative assessments (and the quantitative assessments of WP6, see next section) were used to iteratively refine the policy mixes proposed in WP4.

The results were presented in a total of four individual reports (one of which includes two different assessments), and one integrating report. The individual reports provide valuable insights into the challenges of delivering broad policy mixes to achieve resource efficiency. The environmental report (Deliverable 5.1), notes the importance of a focus on managing risks (including risks of failure of individual policies) to maximise effectiveness, and the challenge of moving towards control of the total volume of environmental impacts. The economic and social reports (Deliverable 5.2 and 5.3) provide insights into potential broader impacts of resource efficiency policies, and include recommendations for improving the coherence of design, and for accompanying measures to manage social impacts. The governance report (Deliverable 5.4) is divided into a legal report which outlines key issues which need to be resolved, particularly in relation to international trade obligations, and key concepts in EU law; and a public acceptability report, which emphasises the importance of an approach which progressively improves the paradigms for policy work on resource efficiency, enabling progressively more ambitious policies to be introduced.

Further details on the results from each of the deliverables are set out below. The synthesis report (Deliverable 5.5) further identifies some key findings of relevance to policymakers. These include:

- The importance of understanding public acceptability issues, and the potential for policy sequencing to be used to help achieve the required changes in paradigms over time;
- The challenges involved in developing appropriate, and effective, tax instruments, which requires attention to the risk of overlaps between tax instruments, and is confronted with a broad challenge of public acceptability;
- The need to address the impact of extra-EU material flows in the form of imports and exports, both in terms of the potential impacts (often exaggerated in the public

discourse) on EU economic interests, and in terms of the impact of EU policies on environmental and other outcomes in other economies;
- The importance of addressing social impacts at an early stage in policy design, in order to ensure that accompanying measures reinforce and facilitate the shift to resource efficiency among low-income households in particular; and
- The need for coherence and consistency in the development of policy mixes, based on forward-looking roadmapping, effective sequencing, and an awareness of the challenges posed by uncertainty (both uncertainty in relation to the impact of individual policies, and uncertainty as to the broader context in which policies will be implemented).

Environmental assessment (D5.1)
The environmental assessment report comprises a set of individual assessments of the potential impacts of the key policy instruments, addressing impacts on raw material extraction, greenhouse gas emissions, demand for land, and freshwater use (with, in addition, biodiversity impacts and toxicity impacts for a more limited number of policies). In addition to detailed commentary on the impact of each of the policy instruments, some overarching issues were identified, particularly around the management of uncertainty (including uncertainty associated both with public acceptability and with feasibility); a key finding is that this requires a flexible approach to the implementation of the policy mixes, within a clear set of over-arching statements on policy ambition. A further key finding identified was the need for policies to address not just reducing impacts per unit of production, but ensuring that the overall volume of environmental impacts was managed.

Economic assessment (D5.2)
The economic assessment report classifies the policy instruments into four standard groups of policies: market-based (such as green tax reforms, environmental taxes or subsidies); command-and-control instruments (such as product standards); education and information policies (such as skill enhancement programs or public information campaigns); voluntary (and other) measures. It then examines each instrument under four criteria (effectiveness, efficiency, equity and feasibility) in order to determine which are the most promising. Key overall findings are the importance of an effective compliance monitoring system; the need to tackle the challenges associated with meeting targets without overshooting them; and the importance of avoiding incoherence and overlap between policy mechanisms.

Social assessment (D5.3)
The social assessment focuses on three key areas of social impacts: labour market, health, and social inclusion. The report contains discussion and separate assessments of policy instruments for each of these areas. This approach helps to identify and highlight horizontal social challenges that decoupling policies face, in particular, (i) significant reallocation on the labour market, (ii) a decrease in the marginal positive health effects of decoupling policies over time, and (iii) a disproportionate burden of both market and command and control measures on the low-income households. The report concludes with general observations and pointers for revisions of the assessed policy mixes, and identifies accompanying mechanisms which could help to manage the challenges identified.

Governance: legal assessment (D5.4, part 1)
The legal assessment provides a first estimate of legal feasibility and implementability of the selected policy instruments, with a focus on competition and trade law as these provisions are obstacles potentially interfering with or counteracting the policy mix set-up for achieving

decoupling. This is followed by suggestions for possible adjustments in the formulation and design of the instruments as well as the policy mixes. According to the assessments, the majority of instruments seemed to be in accordance with World Trade Organisation (WTO) law, as even the stronger instruments did not discriminate foreign products and thus trade was not distorted. With regards to EU-law some concerns existed, and a detailed case by case assessment was considered necessary. For example, while the promotion of sharing systems may be a subsidy it would remain compatible with EU-law provisions if it is covered under the de-minimis rule. Furthermore, the legal assessment showed that even trade distorting instruments can be legitimate, if following targets such as protecting human health and the environment. For the further development and fine-tuning of the policy mix(es) from a juridical point of view it is advisable to:

- Connect the mixes more strongly to the overall objectives (reducing consumption of virgin metals use by 80% while avoiding large increases in the use of other materials or in environmental impacts). Furthermore the connections to the protection of human health and the environment as well as the reduction of energy resources should be demonstrated. High-ranking objectives such as the protection of health and/or environment may legitimise trade distorting instruments;
- Eliminate any arbitrary or unjustifiable discrimination between countries or disguised restriction on international trade in the design of instruments; and
- Consider the pursuit of (multilateral) environmental agreements to reach targets.
- It is advisable (and sometimes required) to notify the European Commission and the WTO Secretariat of planned measures to avoid collisions with trade law.

Governance: public acceptability assessment (D5.4. part 2)

The public acceptability assessment used innovative methods to identify key challenges in terms of implementation, based on tools including search frequency analysis (using relevant key terms in relation to the policy instruments in a range of EU languages); on the basis of which the report identifies thresholds of public acceptability, and proposes policy mitigations, enhancements and sequencings. Key findings include recommendations for policymakers in terms of explicitly addressing public acceptability challenges, and being prepared to make relevant policy adjustments, but also being prepared to invest political capital in making the case for essential changes, and to frame policy proposals in the context of a longer term transition. Ensuring the positive development of public policy paradigms related to the policies was identified as essential.

7. Physical and environmental quantitative assessment (WP6)

This assessment exercise focused on quantitative estimates of the environmental significance of changes in material flows that can result from specific instruments in the DYNAMIX policy mixes. Our physical/environmental modelling team applied life-cycle assessment (LCA), carbon footprinting, and material pinch analysis to estimate the potential resource and environmental benefits of the following elements of the policy mixes:

- Policy mix on metals:
    - Research and development (R&D) to improve copper removal in car dismantling
    - Product standards that specify material choice in water piping
- Policy mix on land-use:
    - Information campaigns to change diets and food - waste management
    - Redistribution and donation of food to reduce food waste
- Overarching policy mix:

- A feebate system on cars, where the environmentally best products are subsidised while a fee is levied on the purchase of the worst products.

The results indicate that R&D, changes in diets and feebate systems have a large potential for resource efficiency and/or environmental improvements.

A **material pinch analysis** was carried through to estimate how improved **car dismantling** can increase actual copper recycling and the maximum recycling of steel in the very long term. It was assumed that an improved dismantling process can reduce the copper content in the steel scrap from cars by 75%. If such improved car dismantling is applied globally, the increase in copper recycling corresponds to 5-10% of the current use of virgin metals in the EU. Our results indicate that the long-term increase in maximum steel recycling is in the same order of magnitude. Spending on R&D on improved car dismantling alone could potentially give noticeable contributions to reducing the dependency on extraction of metal ores.

As to product standards that specify material choice in **water piping**, it was found that a product standard that prescribes polymers rather than copper in water piping would have little impact on total resource efficiency and GHG emissions, partly because only a small share of the copper is used for water piping and partly because a shift to plastic piping is on its way even without a product standard.

Changes in diets were assessed through a limited LCA that included climate impacts, land use, and water use as these impact categories had available robust data. The greatest potential benefits came from eliminating the overconsumption of protein through lower meat consumption. If the total daily protein intake is reduced from the current 105 g/capita to 59 g/capita, our results indicate that the impacts of food consumption would be greatly reduced: GHG emissions associated with food consumption are reduced by 40%, land use by 30%, and water consumption by 20%. This could be sufficient to reach the DYNAMIX target of no net demand of non-EU arable land. It would also give an important contribution towards the GHG target of 2 tonnes CO_2-equ./capita-year. However, even with this change in diets, the food consumption in the EU alone would still drive emissions of 1.5 tonnes CO_2-equ./capita-year.

Food redistribution and changes in food-waste management were assessed with a similar LCA. The social benefits of food redistribution were not part of this assessment. Environmental benefits are lower than in the case with reduced protein intake and occur, according to our model, only if the reduction in food waste is associated with a corresponding reduction in food production. Future food-waste management in itself is likely to be a source of energy and nutrients, rather than an environmental burden.

The **feebate system on cars** was assessed through calculations of the carbon footprint of the current and future car fleets in the EU. To estimate the potential benefit of the feebate, it was assumed that it would be highly effective in reducing car size and/or stimulating the development and use of electric and more efficient cars. We found that technological changes (more electric and more efficient cars) bring a greater potential for reducing GHG emissions, compared to reductions in car size. When the feebate just affects the car size, the feebate reduces GHG emissions from the car fleet by 15% in our model year 2050. When the feebate shifts the car fleet towards electric and more efficient cars, the model indicates a 40% reduction in the emissions. If the feebate is successful in reducing the car size as well as improving the technology, the feebate can reduce emissions by more than 70% - particularly if the electricity production in 2050 is dominated by renewable electricity. This would, of course, be an important step towards reaching the GHG target of 2 tonnes CO_2-equ./capita-year.

The results above all relate to the potential benefits of the policy mixes. We assumed the policy instruments would be effective in changing the material flows and calculated the

resource and environmental benefits of such changes. In addition, we made rough estimates of the actual impacts of a few other policy instruments:

- Policy mix on metals: Tax on all materials used in the EU
- Policy mix on land - use: i) Changes in the Pesticides Directive and ii) Increase value - added tax (VAT) on meat.

The effectiveness of these instruments was estimated by our economic modelling team by means of a macro- economic model. We then used LCA to estimate the environmental significance of these effects. These estimates are very rough because they are affected by simplifications and assumptions in the macro - economic model as well as the LCA model and because the structures of the two models do not fit well together. Interpreting the results very carefully, we can still state that changes in the pesticides directive and the VAT on meat are likely to have very little impact on the total GHG emissions and resource depletion of the EU. The models indicate that even a high materials tax will only give a limited contribution to reaching the DYNAMIX targets.

This indicates that the ambitious DYNAMIX targets require significantly stronger and more effective policy measures than the preliminary policy mixes we so far outlined in the project. Such strong policies will, of course, be difficult to implement. It might also be difficult to model their consequences, because they are likely to change things that he models take for granted: the economic structure, the level of technology, behavioural patterns, etc.

Even though we modelled individual elements of the policy mixes separately, we can draw a couple of conclusions regarding how policies can be combined. The feebate systems in the overarching policy mix could, for example, be combined with sustained and increased spending on R&D, from the metals policy mix, to increase the likelihood that the large potential benefits of a feebate system are realised.

Further benefits can be obtained if the DYNAMIX policy mixes are combined with policies outside the scope of DYNAMIX. Instruments such as R&D spending and feebate systems can result in electrification of cars and other products. This is more likely to increase resource - efficiency and reduce GHG emissions if combined with an energy policy that makes the electricity production more efficient and carbon - lean.

Economic quantitative assessment

The economic quantitative assessment relied upon three macro-economic models, ICES, MEMO and MEWA, all belonging to the category of Computable General Equilibrium modelling, but with complementary characteristics. More specifically: they all provide a sectoral representation of the EU economic system and endogenous price formation. In practice, they can assess direct and indirect policy effects on the whole economic system and the full macroeconomic feedbacks, beyond the sector initially subjected to the policy intervention. However, ICES representing the EU with a country detail is better suited to capture intra and extra EU trade effects. MEWA and MEMO consider the EU as a single region, but differently from ICES, offer a more realistic representation of technological change, feature forward looking agents and have a richer representation of labour supply choices.

The policies examined by the different models and their slightly different implementation, due to the differences in the models' sectoral and functional details, are the following:

- Green fiscal reform: materials tax (all models)
- Green fiscal reform: internalisation of external environmental costs (MEMO II and MEWA)
- Increased spending on research and development (only MEWA):

- Strengthened pesticide reduction targets under the Pesticides Directive (ICES and MEWA)
- Targeted information campaign to influence food behaviour towards changing diets (ICES)
- VAT on meat (all models)
- Circular economy tax trio (all models)
- Enabling shift from consumption to leisure (MEWA)

The first two policies examined - a **material tax and a tax aimed at internalising environmental externalities** - are based on different designs and implementation strategies. Nonetheless, their common trait is the breadth. They have direct and indirect effects on many sectors, and thus have impacts clearly detectable on the overall EU GDP.
The strongest message from the analysis is that the cost of the policy crucially depends upon (a) the sensitivity of the production system to the dynamic incentive to dematerialize induced by the policy signal, i.e. ultimately upon the reaction (or availability) of technological progress and (b) the use of tax revenues, i.e. on the implementation of an appropriate revenue-recycling scheme.

A combination of technological progress in response to the tax with a reduction in labour taxation can indeed, according to the modelled outcomes, end up stimulating economic growth (a maximum 8% GDP gain in 2050) and increasing material efficiency (in a range between 12 to more than 70% in 2050), reaping a material "double dividend": more GDP and lower material use. Without these two factors, however, especially when taxes are rebated lump-sum to households, the policy can be particularly depressing for EU GDP (-5%), and, as a further drawback, might even worsen, rather than increase material efficiency in many material intensive sectors of the economy. This can happen when the reduction in economic activity outpaces the decline in material use at the sectoral level.

All in all, the tax shift fosters a huge transformation of the production system. Therefore, notwithstanding final net GDP gains, material intensive sectors would be highly penalized (a good example is the iron and steel sector which may experience a production decline up to 60% when exposed to a material tax). This calls for a careful designing and planning of the policies devising a set of accompanying measures to smooth the most adverse social effects.

Increasing **public investment for R&D** dedicated to material efficiency, whether financed through increases in labour, corporate or value added taxation, seems to have the highest potential to boost GDP among the three policies and is also the least burdensome for material intensive sectors. In fact, final material use can also increase, as an economic "rebound effect" materializes with the "production scale" effect being larger than the "material use decline" effect. This raises a caveat: although supporting material efficiency R&D might seem the "optimal" policy to foster absolute decoupling, it should be accompanied by further regulation or incentives limiting material use or promoting dematerialized services.

Despite the obvious differences, the tax to foster pesticide reduction, the increase in the VAT on meat and a targeted information campaign to influence food behaviour towards less meat intensive diets, address a group of sectors with a "low weight" in term of EU value added. Thus, their relevance is prominently sectoral.

Raising the **VAT on meat** to the EU average VAT level can be successful in reducing meat consumption (between 2.5 and 14% in 2050). Meat industry exports are expected to increase in response to the decrease in world meat prices following the contraction of EU demand while effects on 'Non-meat' based food production in the EU is ambiguous but anyway moderate (0.7%, -0.24% in 2050 depending on the model). Potential declines in 'Non-meat' based food production might occur when the demand contraction induced by the tax on

household budget meets higher input costs as some meat products are used as intermediates also by the non-meat food industry. Again, final GDP impacts are determined by the use of VAT revenues. If they are rebated in a lump sum to households, GDP in the EU could decline by 0.05%; if labour taxes are reduced, GDP could increase by 0.35%.

Comparable effects on meat industry production (a contraction by 6% in the ICES model) and slight GDP gains (by 0.04% in the EU in 2050) would be induced by the **information campaign** to shift food consumption habits. Notably, the effect on GDP is positive, rather than negative as in the VAT case, even without an accompanying reduction in labour taxes. This occurs as the recomposition of consumers' preferences is not induced by any active tax policy which ultimately impacts household income, but just by the "persuasion" of consumers. In this sense, inducing "just" a substitution and not an income effect, the action of the campaign is less invasive. However, it has to be recognized that there is a huge uncertainty on the effectiveness of information campaigns and on the time they would need to accomplish the desired results. These issues are not considered in the current analysis though.

The **pesticide tax**, finally, can reduce the use of pesticides (up to 10% in the models) while exerting a limited effect on the EU agricultural activity (which in 2050 contracts of the 0.08% - 0.8%) and an even smaller one on overall EU GDP. When changes are so small, however, it is possible that indirect effects prevail over direct effects. For instance, in some simulations, an increase, albeit small, in EU chemical sector production is observed. This is explained by the increase in agricultural production outside the EU favored by the higher prices of EU agricultural commodities, which brings about an increased demand for fertilizers and pesticides, including those produced in the EU, which are exported more. The policy thus would not induce a decrease in the negative externality, but its de-location abroad. These unintended secondary effects should thus be dealt with specific corrections.

Like the material tax policy, the **circular tax design** aims to foster dematerialization, recycle and re-use, but with a much narrower scope as it focuses specifically on raw materials (excluding metals) extraction. In the light of the relatively limited economic relevance of the mining sector in the EU, policy effects are mostly felt by raw-material-intensive branches of the production system, while systemic effects are small. Not surprisingly, mining of non-ferrous minerals (experiencing a production contraction in the range of 7-35%) and the non-metallic minerals transformation sector (contracting 7-10% by mid-century) are the more heavily affected. Once again, revenue recycling mechanisms play some role. Nonetheless, the small volume of revenues available to be recycled does not allow for significant GDP and employment expansion. Similarly, the absence of recycling does not cause huge GDP impacts, although they remain slightly negative (-0.32% in 2050). The overall dematerialization potential of the policy, especially in the long term, is limited if compared to that for instance of the material tax, producing at best a 3% material efficiency improvement with respect to the reference scenario.

The last policy examined, is the **shift towards more "leisure consumption"**. Its direct consequence is the decrease in the labour supply. Therefore, the price of labour (wages) will increase, leading to some substitution of labour with capital, energy and materials. In the short run, this will increase the capital-to-GDP ratio, energy-intensity and material intensity. However, in the long run, as the economy will produce less goods to be consumed, an absolute reduction in the use of energy and materials will occur along with the decline in GDP. Exports will also be penalized with potential negative consequences on the current account.

8. In-built stakeholder involvement and dissemination (WP7)

"In-built stakeholder involvement and dissemination" served to ensure that the findings of the project would be delivered to and taken up in the policy process. For that purpose, it involved policy-makers and other stakeholders critical for the effectiveness, efficiency and sustainability of resource policies in an ongoing process of learning and inquiry which aimed to directly provide a platform for knowledge exchange and co-creation, and to support the EU-wide and national policy learning processes in the context of Europe 2020's Resource Efficient Europe flagship initiative and other elements of European resource-use governance.

Work package 7 delivered a "Plan for the Use and Dissemination of Foreground" (D7.1); it created the DYNAMIX website (D7.2); it delivered the reports documenting the 1st Policy Platform (D7.3), the 2nd Policy Platform (D7.4), the 3rd Policy Platform (D7.5), and the 4th Policy Platform (D7.6); the report documenting the DYNAMIX webinar (D7.7); and a report documenting the preparation of the free- access electronic Special Issue (D7.8). In addition, an "Advisory Board" was set up at the beginning of the project's running time and included 7 high-level personalities, representing international organisations (UNEP, OECE), the European Commission (DG Environment), the European Environment Agency, a national government ministry (Italian Ministry of Environment, Land & Sea), and research (including a representative of POLFREE, a project on resource efficiency also funded in FP7) to advice the project in its critical phases. Finally, WP7 organized a final conference for disseminating main project results.

The **Policy Platforms** were key events in DYNAMIX to provide feedback and suggestions for further work in the project and, thus, inform various Work Packages with external stakeholder suggestions. In general, the Policy Platforms offered a chance for different stakeholders to learn more about the project's results, discuss current resource efficiency policy issues, and provide input to the ongoing European wide policy processes for resource efficiency. The results of the DYNAMIX Policy Platforms provided up-to-date and detailed information on policy challenges, assessments, and policy mixes on resource efficiency in Europe. They documented the discussions held at all events, the exchange among the different stakeholders, and the results of interactive group work. The results were then taken up in the various DYNAMIX WPs to refine project deliverables.

The 1st DYNAMIX Policy Platform, entitled "Exploring Opportunities and Challenges of Resource Efficiency Policy in Europe", took place in Brussels on 20-21 March 2013. Through participation and interactive exchange with policy-makers and other experts, the 1st DYNAMIX Policy Platform aimed to explore the current situation and challenges of resource efficiency policy-making in Europe in order to inform the next project steps and thus help the project to respond to and address relevant issues addressed by the participants. In total, 52 participants from 14 European countries attended the event, of which 25% were EU and national policy-makers, 48% were researchers (incl. DYNAMIX project partners), 21 % CSO, EPAs and international organization and 6% from the business sector.

The 2nd Policy Platform, entitled "Policy mixes for resource efficiency in Europe: Lessons learned and ways forward", took place in Brussels on 24-25 October 2013. Through participation and interactive exchange with policy-makers and other experts, the 2nd DYNAMIX Policy Platform focussed on:

- findings on resource (in)efficiencies,
- comparative analysis of existing policy mixes on resource efficiency,
- different stakeholders' approaches, resource efficiency paradigms, and
- promising policy mixes for resource efficiency,

in order to provide input for the next steps in the project and thus help the project to address relevant issues discussed by the participants. In total, 58 participants from 16 European countries attended the event, with the following distribution of institutional backgrounds: 16 policy-makers (27.1% of all participants); 25 researchers (including 18 DYNAMIX consortium partners), 8 CSO representatives; 5 business representatives; 3 representatives of environmental protection agencies, and 1 representative from international organizations (plus the conference moderator).

The 3rd DYNAMIX Policy Platform, entitled "Policy design and assessment: three policy mixes for resource efficiency and decoupling", took place in Brussels on 6 May 2014. The 3rd DYNAMIX Policy Platform aimed at presenting three policy mixes on land, metal and overarching resources, developed within the project. Due to the interactive format at the event, participants not only learned about preliminary project results, but also had the chance to actively contribute to shaping the further work in DYNAMIX by discussing important issues and by bringing in new insights, which served to improve the presented policy mixes in the next steps of the project. In total, 46 participants from 14 European countries attended the event: 19 researchers from DYNAMIX consortium and 27 external participants. External participants were distributed across different stakeholder groups as follow (Fig.2): 10 policy-makers (38 % of all participants), 7 researchers (23%), 7 Civil Society Organisation (CSO) representatives (27%), 2 representatives from international organizations (8%) and 1 business representative (4%).

The 4th DYMAMIX Policy Platform, jointly organized with the sister project POLFREE, was entitled "An ambitious Circular Economy Package for Europe: realizing the social, economic and environmental benefits of resource efficiency in Europe" and took place in Brussels on 13-14 April 2015. By bringing together high-level experts and research findings from two major European research projects on resource efficiency, the 4th Policy Platform aimed (1) to generate a high level expert discussion around a new Circular Economy Package, and (2) to work on policy recommendations to support the European Commission for a more ambitious Circular Economy Package. During the different keynote presentations, interactive working-groups and panel discussions, participants were actively engaged in the discussion of what a more ambitious package should look like, what kind of policies should be considered and what may be the socio-economic opportunities derived from it. In total, 70 participants from 13 European countries attended the event. External participants were distributed across different stakeholder groups as following: researchers (38% of all participants, and including researchers from the two consortia), policy-makers (32%), Civil Society Organisation (CSO) representatives and international organizations (23%), and business representative (7 %). Based on the discussions with the participants, "10 Recommendations to inform the review of the Circular Economy Package" was prepared and submitted to the European Commission. The recommendations were also distributed within the European Commission Stakeholder Conference on the Circular Economy, which took place in Brussels on 24 June 2015.

In order to ensure a broad dissemination of the project results, further dissemination activities took place. These included one DYNAMIX resource policy webinars, the preparation of a Special Issue in an academic journal, and the organization of a Joint Final Conference with DYNAMIX´ sister project POLFREE.

The resource policy **webinar** was organized as a half-day long online event to present the project results before their finalization and discuss them with a selected crowd of policy makers. The DYNAMIX Webinar, entitled "Results from the resource efficiency policy mix assessment: grand challenges for implementation", took place on 28 October 2015. The webinar took place towards the end of the project, after three years of intensive research and analysis. Therefore, the webinar had the general aim to disseminate the project's preliminary

results and evidences on policy mixes for an efficient resources use in the EU. In particular, the webinar aimed at presenting the DYNAMIX results on policy mix assessments, and at triggering discussions around challenges of policy implementation, both from an ex-ante evaluation perspective (e.g. in relation to public acceptance and political feasibility/will), and from practical experiences made by the webinar participants. During the webinar, presenters and participants also discussed potential linkages and conceptual relations between resource efficiency and a circular economy. In particular, it was highlighted that circular economy is an essential part of any ambitious policy aiming at increasing resource efficiency in the broader understanding of the EU's Roadmap to a Resource Efficient Europe. Finally, potential links between project results and current policy issues were addressed, and the outcomes of the EU consultation processes for the Circular Economy Package were presented. In total, 30 participants representing different stakeholder groups attended the webinar: 11 researchers external to the project, 8 policy makers from the EU and national level, 2 representatives from Civil Society Organizations, and 9 researchers from the DYNAMIX project. Several of these participants took already part in previous DYNAMIX events (Policy Platforms) and were thus familiar with the DYNAMIX project.

The **Special Issue** on resource efficiency policies, published in the peer-reviewed, open access, academic journal "Sustainability", offered the chance to disseminate the most relevant DYNAMIX results and other research findings on resource efficiency policy to the scientific community.
The preparation of the Special Issue started in September 2014 under the responsibility of WU Wien (WP7 leader). Due to the long process of academic journal preparation and publication, the work on the special issue was still in progress at the time of writing this report (May 2016). The special issue, entitled "Policy mixes for resource efficiency – conceptual issues, design and assessment challenges", was guest- edited by DYNAMIX consortium partners. The special issue aimed at contributing to the scientific debate on resource efficiency policies and policy mixes, mainly drawing on findings from the DYNAMIX project on policy mixes for more sustainable resource-use. For this purpose, the special issue has foreseen the publication of papers building on the lessons learned from the DYNAMIX project, and from a number of external contributions. Therefore, an open call for papers was distributed to announce the special issue to the consortium partners and to the wider scientific and policy community (which included the stakeholders in the DYNAMIX database). The special issue is currently being finalised for publication in the journal Sustainability (published by MDPI), an open access, peer reviewed, online academic journal, specialised on sustainability issues. The current impact factor of the journal is 0.942 (2014) and it is indexed in the Social Science Citation Index. At the time of writing D7.8 eight papers were already published online, one was accepted and in the process to be published, and 6 papers were under 2nd or 3rd review round. The finalization of the special issue is foreseen in June 2016. Papers are available online at: http://www.mdpi.com/journal/sustainability/special_issues/resource-efficiency2015:

The papers address a variety of aspects related to resource efficiency policies and policy mixes. These range from qualitative and quantitative assessment of policies, policy development and modelling, but also theoretical underpinnings of resource efficiency, and the development of theoretical and conceptual frameworks. In this sense, it was intended that the Special Issue would contribute to the academic debate on policy mixes for resource efficiency, while at the same time providing policy makers and practitioners with latest results and evidences from research on resource efficiency policies.

Finally, The DYNAMIX – POLFREE joint **final conference** on "Policy mixes promoting resource efficiency for a circular economy", took place in Brussels at the DIAMANT conference centre on 15- 16 February 2016. The conference was organized in cooperation

with the sister project POLFREE in order to address a larger audience, increase synergies, and avoid duplication of efforts. The conference was organised into six sessions, focussing on a different elements of resource efficiency and the circular economy, and exploring answers to the questions the two projects sought to address. Each session contained a combination of keynote presentations, panel sessions and audience Q&As. A report on the final conference was prepared in cooperation with POLFREE project. The documents and presentations of the Joint Final Conference are published on the project website. In total, 134 participants from a range of backgrounds, including academia, policy-making and industry took part in the conference.

9. Synthesis for policy guidance and recommendations" (WP8)

In the final phase of DYNAMIX the work done in the previous work packages was synthesised and translated into politically implementable guidance documents and recommendations for policy mixes that foster resource efficiency.

In the first two years of the DYNAMIX project the work package 8 team has focused on the identification of key target audiences in close cooperation with WP7, and suitable modes of communication for these target audiences were selected. Furthermore, the results from the ex-post assessments of the main drivers of inefficiencies (WP2) "Reasons for inefficiency" and of successful policies for achieving decoupling in WP3 "Assessing existing policies and policy mixes" have been condensed in the first policy brief D8.1 "Ex-post policy brief". The main work of WP8, however, was finalised in the final year of DYNAMIX, bringing all project results together and presenting them in condensed policy briefs and reports, which contain clear policy recommendations while also communicating the assumptions and limitations of the results.

In the final project year the results of the synthesising exercise were condensed in three "policy reports" corresponding to the three policy mixes developed in WP4: "A policy mix aimed at reducing impacts of agricultural production and consumption – Synthesis of potential impacts. DYNAMIX Policy Report No. 1, February 2016.", "A Policy Mix for Dematerialisation. Assessing instruments for metals and materials use reduction. DYNAMIX Policy Report No. 2, February 2016", and "An overarching policy mix for fostering sustainable consumption and production – synthesis of potential impacts. DYNAMIX Policy Report No. 3, February 2016". The synthesising documents provided, as much as the quantitative and qualitative results allowed, explicit recommendations and policy guidance, in order to enhance policy makers' capacity to act. It also included key assumptions and uncertainties underlying the modelling and their interpretation so as to reduce the risk of oversimplifications or misinterpretations.

Two other main outputs of the final project phase of WP8 synthesis brief on the results were a synthesis brief "Policy mixes for decoupling economic growth from resource use – Synthesis brief. DYNAMIX Policy Brief No. 2, March 2016", which presented the key results of the DYNAMIX project on eight pages and a comprehensive synthesis report "Policy mixes fostering resource use", with the aim to give an overview and an orientation of the various outputs of the DYNAMIX project.

Synthesis of the policy mixes: Impacts and side-effects

In the context of the ex-ante assessments, the three policy mixes (and the policy instruments contained therein) were analysed as to their potential environmental impacts, as much as

possible in relation to the key environmental targets. The main results of these analyses were condensed and discussed. For the list of instruments, please check section 5.

Synthesis of results for the land policy mix

Overall, the land policy mix can be considered to have positive environmental effects. It is *likely to contribute* to the following DYNAMIX key environmental targets for the EU for 2050:

- Limiting annual per capita greenhouse gas (GHG) emissions to 2 tons of CO2 equivalent.
- Reducing consumption of arable land to reach zero net demand of non-EU arable land.
- Reducing nutrient surpluses to levels achievable by the best available techniques.
- Managing freshwater use so that no region experiences water stress.

Although the actual contributions to each target are not quantifiable, the policy mix can be expected to be particularly beneficial for limiting GHG emissions and for reducing nutrient surpluses. The impact on the consumption of arable land is the most uncertain, as there is a risk that crop yields decrease due to more sustainable production practices, which in turn could lead to an increased demand for land in the EU and beyond.

Regarding its socio-economic impact, a positive side effect of the land policy mix is an overall favourable impact on human health. This is mainly due to a reduction of harmful pollution as well as healthier diets. However, potential negative socio-economic impacts and issues of public acceptance might prevent this policy mix from being implemented or might reduce its effectiveness. In particular, the policy mix is expected to result in rising prices for food, which might increase social inequalities. Furthermore, while for the majority of the instruments public approval is likely, the VAT on meat products faces problems with regard to public acceptance and legal feasibility. On the whole, it can be stated that the land policy mix is relevant sectorally, but much less at the aggregated economic level. Therefore a rather low impact on GDP and employment can be expected.

The policy mix was designed to be consistent, i.e. minimising conflicts and maximising positive interactions between instruments. For instance, the decline in meat consumption due to the VAT on meat products will be intensified through the accompanying information campaign. The mix of price signals and awareness-raising policy measures in the land policy mix appears likely to prove an efficient approach. Despite the consistent design, the assessment results indicate that:

- A number of negative side effects will have to be addressed through additional policies; and
- some of the instruments will likely face significant challenges as regards public acceptance and legal feasibility.

The political feasibility of the land policy mix could be fostered by adjusting the potentially contentious policy instruments so that potential negative side effects are minimised. For example, in order to mitigate the aggravation of income inequalities caused by the VAT on meat products, a VAT decrease on cereals, vegetables or fruits could be introduced. Furthermore, advisory services could be offered to help farmers avoid potential losses associated with limitations of sustainable farming methods.

However, it needs to be considered that the ex-ante assessments undertaken in the DYNAMIX project could only partly be based on harmonised assumptions and parameters.

Therefore, the results of the qualitative and quantitative assessments differ – in some cases significantly. In particular, the quantitative assessment of the information campaign was based on very optimistic assumptions about its effectiveness. Furthermore, the assessments undertaken were not able to assess actual cumulative effects of the instrument combination in the policy mix beyond individual effects. This remains a methodological challenge requiring more research.

Synthesis of results for the metals policy mix

With some caution, the following conclusions can be drawn: Naturally, the environmental impact of the instruments was evaluated to be positive (as this was the main goal of policy mixing in the first place). Especially the green fiscal reform instruments were evaluated predominantly as having the strongest impact. However, one model result indicated that the GFR instruments – in isolation – may not yield such positive results, which highlights the importance of policy mixing and further observance. The promotion of sharing systems and product standards will reduce materials use, but only in low total numbers. Nevertheless sharing systems might support a shift away from a consumer culture that is focussed on private ownership and in which consumption has a function beyond the actual use of a product. While green fiscal reforms were preferred over product standards as more efficient in the economic assessment, they can play a role where market failures persist and material prices do not reflect the externalities of a certain material. Also, standards can be considered superior i.e. when trying to improve repairability and longevity – as the green tax reforms will mainly work towards a reduction of materials use and pollution, but not towards qualitative changes. While the effect of increasing research and development (R&D) is notoriously difficult to assess, this instrument was judged as being a necessary precondition for the success of all other instruments. Especially the green fiscal reform, which entails a certain restructuring of the economy, needs to be accompanied by increased R&D to smoothen the transition. GFR in combination with R&D led to higher gross domestic product (GDP) and employment rates in 2050 than the baseline scenario, whereas the GFR alone had rather negative effects. R&D is also needed for setting thresholds in the instruments i.e. to estimate externalities and to develop a procedure to calculate the material value of products, or for setting product standards.

The supporting instruments are also of paramount importance for the success of the mix. The public acceptance for the GFR and new product standards is expected to be rather low, which illustrates the need for roadmapping a policy mix, starting with information campaigns and an official EU strategy for dematerialisation, to set a reliable and transparent political framework, giving businesses the chance to adjust, and providing citizens background information on the overall concept and the need for the measures. As citizens care primarily about the economic situation and employment rate, especially the shift of the taxation from labour to materials should be highlighted. A credible and coherent overall concept requires also the elimination of environmentally harmful subsidies.

The economic assessment of the GFR brought up differing results from the different models. The materials tax is expected to foster dematerialisation and improve material efficiency (12-20% lower material intensity of GDP; up to 63% material efficiency gains). The two models that assume that the tax provides an incentive for technological advances in material efficiency resulted in a significantly more efficient policy. The recycling of the tax revenues to reduce labour taxes also added strongly to the success of the measure. An expansion of the service sector can also bring additional GDP and employment gains in the restructuring of the economy. Regarding the internalisation of externalities roughly the same logic applied: assuming technological advances and shifting taxation from labour to materials, positive

effects on GDP and employment were observed. In the model without these assumptions a decrease in GDP was noted.

In line with these results modelling the effect of increasing R&D individually brought up very positive results for the development of European GDP. Without a combination with a materials tax or internalising externalities, however, increasing R&D would lead only to relative decoupling, while total material consumption might increase: the rebound effect.

The results of the quantitative assessments differed in some cases significantly. While all models applied in DYNAMIX are well established and reliable, this does also highlight the limits of quantitative modelling. Not least because models usually function in a certain system logic portraying a systemic change provides challenging. It cannot be stressed enough that the assumptions going in the model define the outcome to a great degree.

Strong positive effects on health and safety issues are expected by the author team of the social assessment. Only the effect of social inclusion is less clear cut: while vulnerable households benefit from decoupling (as the resilience of the economies increases), rises in market prices for resource intensive goods will affect poorer households disproportionally. The legal feasibility assessment showed that no major collisions with World Trade Organisation legislation are expected. Regarding EU legislation some concerns regarding conformity emerged, but the protection of human health and the environment can legitimise distorting instruments. The assessment of the public acceptance turned out less optimistic. It is expected that the majority of the instruments, especially GFR, are to be met with resistance. This seems a bit at odds with the overall positive assessment of the social impacts, but can be explained at least in part with the fact that the majority of citizens care strongly about the economic development and therefore any major transformation is regarded somewhat sceptically. This highlights the role paradigms play and the need to develop a long term roadmap for dematerialisation, which in the beginning lays the ground for ambitious resource policy.

Synthesis of results for the overarching policy mix

While the assessments indicate a likely, but not quantifiable, contribution of the overarching policy mix to achieving the DYNAMIX key targets, potential socio-economic impacts and issues of public acceptance might prevent this policy mix from being implemented or might reduce its effectiveness. Socio-economic impacts include increasing compliance costs for businesses and enforcement effort for administrations or potential job losses in the advertising sector. Partly linked to socio-economic impacts, public acceptance is likely negative for instruments potentially leading to job losses in certain sectors or for lower qualification levels.

The policy mix was designed to be consistent, i.e. minimising conflicts and maximising positive interactions between instruments. For instance, boosting EPR schemes and the Circular Economy Tax Trio use different mechanisms (regulatory and market-based) to encouraging resource efficient product design. Most importantly, skill enhancement programmes can capture skilling needs in the formal economy, e.g. for resource efficient processes and product design, hence (i) improving match-making between businesses' skill needs and employees' skills and (ii) alleviating employment and distributional effects of other instruments in the over-arching policy mix.

Despite a consistent design of the policy mix, the assessment results indicate that some of the instruments will likely face significant challenges as regards political feasibility; and that the policy mix will not be able to achieve the environmental key targets set out, even if all instruments were politically feasible.

By adjusting the potentially contentious policy instruments so that the potential negative side-effects are minimised (e.g. using voluntary instead of mandatory approaches to labour market reform and to local currency schemes; including a recycling of tax revenues as close as possible to the affected actors), political feasibility of the overarching policy mix could be fostered.

Furthermore, strengthening a smart and effective time-sequencing (roadmapping) of the policy instruments can further help to improve political feasibility. A sequenced approach should

1. First introduce less contentious measures (e.g. information campaigns accompanying or preceding taxation; first targeting misleading claims and visual pollution in restriction of advertising) that can help pave the way for;
2. Later introducing more ambitious policy proposals (because these first measures provide targeted actors with potentially positive empirical experiences and thus might trigger more positive responses to later policy proposals which without the first measures would not have been as acceptable); and
3. Ensure instruments fit for mitigating potentially negative side effects (e.g. skill enhancement programmes, subsidies for poorer households) are introduced sufficiently early to be functioning when side effects of other instruments start occurring.

Lessons learned

Applying and adapting the heuristic framework for policy mix design proved very interesting in the context of DYNAMIX project. It allowed us to use different methods for identifying relevant drivers (literature review, the Sensitivity Model, and workshops) and helped guide both discussion on as well as the actual selection of potentially promising policy instruments aimed to achieve a wider set of environmental key targets.

Our findings point to the usefulness of comprehensive ex-ante assessments for designing promising and theoretically robust policy mixes. However, as the policy mix could be a combination of any instrument(s) that will support achieving the set policy objectives, the crucial design component is to select and combine those instruments which have the potential for maximising synergetic effects and for mitigating negative side effects of the use of other instruments.

Any policy mixing effort will have to undergo several adaptations along the life cycle of the policy mix, which may change it fundamentally from what is was based on an(y) initial scientific ex-ante assessment. Nonetheless, neither the DYNAMIX approach nor any other ex-ante assessment for that sake can navigate the political processes, which may impact both on the eventual policy mix design and on the implementation – and hence on the overall effectiveness of the mix.

The potential impact and the main dissemination activities and exploitation of results

DYNAMIX aimed to develop dynamic policy mixes that would support the EU to shift to a pathway to absolute decoupling long-term economic growth from resource use and environmental impacts. These policy mixes were to be built on solid knowledge about reasons for inefficiencies and successful policy instruments and, where possible, mixes, from real

world applications. The mixes were then to be assessed ex-ante quantitatively and qualitatively.

Next to these scientific targets DYNAMIX aimed to develop policy options that would be applicable in the "real world". To this purpose, a systemic participatory learning process was created, in which policy-makers and other stakeholders were able to shape the projects' design and direction of research, in order for the project to come up with results that are of relevance for policy makers.

1. Scientific results

All main scientific goals of DYNAMIX have been reached throughout the project.

Three DYNAMIX policy mixes were developed through a systematic systems approach elaborated based on the heuristic framework adapted from Givoni et al. (2013)[2]. This encompasses the following stages:

(1) Defining longer-term objectives and setting of short- to medium-term, more concrete targets for the respective policy areas;

(2) Elaborating a theoretical causal model for problem solving in the policy areas (what is the problem situation? What are contributing drivers? What does impede changes?);

(3) Selecting, based on heuristics and expert guessing, promising instruments from known potentially relevant policy instruments contributing to problem solving to form an initial policy mix;

(4) Undertaking ex-ante assessments (literature based qualitative assessments, participatory scenario building and quantitative computer model simulations) of the initial policy mix as to its potential effectiveness and impacts. This usually entails comprehensive scientific analyses, which then enable substantiated decision-making as to whether or not to include the instrument analysed into the mix;

(5) Adding, if the initial mix was found sub-optimal against the set objectives and targets, further instruments to the mix or revising existing instruments and re-running the assessment (repetition of steps (3) and (4)) to finalise the policy mix;

(6) Preparing the final policy mix for implementation, enforcement and monitoring.

The first three steps were realized in the DYNAMIX project. The final stage of the framework was not undertaken as the DYNAMIX project aims to give recommendations to European and national policy makers, but not to prepare a mix for implementation or enforcement.

Designing, implementing and evaluating policy mixes is much more difficult than individual instruments loosely bundled. Political realities as well as the dynamics and path dependencies of legislative periods run counter to a strategic and more long-term implementation procedure of policy mixes. Therefore, compiling a policy mix needs to consider political process in multi-actor polycentric governance systems to identify and exploit opportunities for long-term, adaptive policy formulation.

In this context, designing a policy mix needs to ensure a good fit between instruments and targets within a single level of policy (horizontal mixing) as well as with institutional framework conditions (i.e. various policy fields and governments active in these fields =

[2] Givoni, M.; Macmillen, J.; Banister, D.; Feitelson, E. From Policy Measures to Policy Packages. Trans. Rev. 2013, 33, 1–20.

vertical mixing). This encompasses the need to consider both consistency and coherence of the instruments sequentially linked in a policy mix. While consistency in a more narrow sense denotes the absence of conflicts and contradictions, coherence refers to ensuring synergetic effects and positive interactions between instruments as well as between different policy and administrative levels.

Consistency and coherence can be fostered by combining primary with supportive instruments. Primary instruments mainly serve to achieve the/a set objective and should be as little controversial as possible; supportive instruments serve to minimize or mitigate unintended negative side-effects of primary measures and hence to increase their acceptability and feasibility.

The DYNAMIX project has considerably added to the scientific knowledge about policy mixing and developed an improved heuristic framework. Especially the extensive ex-ante assessment of policy instruments and mixes has, to our knowledge, been applied for the first time in such a thorough manner in a European research project (alongside the ex-ante assessment approaches chosen in the sister project POLFREE and going in scope beyond what was done in the FP7 project SPREE "Servicizing Policy for Resource Efficient Economy", http://www.spreeproject.com/). The insights gained on ex-ante assessments could, if applied in the political context, significantly improve policy making (and mixing), thus making pursuing policy targets more effective and (cost) efficient.

Scientific outreach

The scientific results of DYNAMIX were disseminated to the scientific community by publishing scientific papers and taking part in the most relevant conferences in the area of resource efficiency. A full list of all dissemination activities follows in table A2.

Selection of paper submissions and presentations:

- World Resources Forum, Davos, Switzerland, October 2015 (2 presentations and a joint workshop with POLFREE)
- Science for the Environment conference, Aarhus, Denmark, October 2013
- World Resources Forum, Davos, Switzerland, October 2013 (2 presentations)
- EC website: Online Resource Efficiency Platform, July 2013
- Most importantly, a **Special Issue** on resource efficiency policies, guest edited by the DYNAMIX consortium partners, is currently being finalised for publication in the journal Sustainability (published by MDPI). "Sustainability" is an open access, peer reviewed, online academic journal, specialised on sustainability issues. It offered the chance to disseminate the most relevant DYNAMIX results and other research findings on resource efficiency policy to the scientific community. The special issue will be titled "Policy mixes for resource efficiency – conceptual issues, design and assessment challenges" (finalisation in June 2016).

  The current impact factor of the journal is 0.942 (2014) and it is indexed in the Social Science Citation Index. Papers are available online at: http://www.mdpi.com/journal/sustainability/special_issues/resource-efficiency2015:

Exchange with other FP7- projects

During the running time of DYNAMIX a number of resource related projects were pushed forward. In order to avoid double work and create synergies DYNAMIX exchanged with

- CECILIA2050 - Optimal EU Climate Policy
- DESIRE - Development of a System of Indicators for a Resource Efficient Europe
- ERMITAGE - Enhancing Robustness and Model Integration for The Assessment of Global Environmental Change
- EUREAPA - Scenario Modelling and Policy Assessment Tool
- FUSIONS - Food Use for Social Innovation by Optimising waste prevention Strategies
- OPEN:EU - One Planet Economy Network: Europe
- POLFREE - Policy Options for a Resource Efficient Economy
- SPREE - Servicizing Policy for Resource Efficient Economy
- Most importantly, DYNAMIX and its sister project **PolFree** were in close cooperation, with Paul Ekins, scientific coordinator of the PolFree project, being part of the DYNAMIX advisory board and both projects holding their final conference together.

2. Political and social impacts

Also DYNAMIX' main political goals – providing tangible advice on policy mixes for resource efficiency – have been achieved.

- As DYNAMIX increased the knowledge on resource efficiency policy making and policy mixing, policy makers have the chance to take up this knowledge and make progress towards resource efficiency. Policy makers were directly involved in the project (see below), to ensure that the gained knowledge reached the main target group.
- Furthermore, DYNAMIX provided direct input to the development of the second Circular Economy Package. Based on the discussions with the participants of the 4th Policy Platform, "10 Recommendations to inform the review of the Circular Economy Package" were prepared and submitted to the European Commission. The recommendations were also distributed within the European Commission Stakeholder Conference on the Circular Economy, which took place in Brussels on 24 June 2015.

Outreach to policy makers and other stakeholders – stakeholder involvement

DYNAMIX compiled existing knowledge and generated new knowledge that can be significant for future policy-making in the area of resources efficiency. This knowledge was disseminated in many different ways, besides the reports that are the deliverables of the project:

- With **WP7 "in-built stakeholder involvement and dissemination"** DYNAMIX had an entire work package dedicated to including stakeholders and disseminating results, which also elaborated a "Plan for the Use and Dissemination of Foreground" (D7.1).
- The key events to involve stakeholders were the DYNAMIX **Policy Platforms**. The platforms provided feedback and suggestions for further work in the project and, thus, informed the project with external stakeholder suggestions. The results of the DYNAMIX Policy Platforms provided up-to-date and detailed information on policy challenges, assessments, and policy mixes on resource efficiency in Europe. They documented the discussions held at all events, the exchange among the different stakeholders, and the results of interactive group work. The main target groups of the Policy Platform were policy makers, researchers, civil society organisations and representatives from international organisations. Furthermore a small group of business prepared.
- In total four Policy Platforms were held:
    - The 1st DYNAMIX Policy Platform, entitled "Exploring Opportunities and Challenges of Resource Efficiency Policy in Europe", took place in Brussels on 20-21 March 2013. In total, 52 participants from 14 European countries attended the event.
    - The 2nd Policy Platform, entitled "Policy mixes for resource efficiency in Europe: Lessons learned and ways forward", took place in Brussels on 24-25 October 2013. In total, 58 participants from 16 European countries attended the event.
    - The 3rd DYNAMIX Policy Platform, entitled "Policy design and assessment: three policy mixes for resource efficiency and decoupling", took place in Brussels on 6 May 2014. In total, 46 participants from 14 European countries attended the event.
    - The 4th DYMAMIX Policy Platform, jointly organized with the sister project POLFREE, was entitled "An ambitious Circular Economy Package for Europe: realizing the social, economic and environmental benefits of resource efficiency in Europe" and took place in Brussels on 13-14 April 2015. In total, 70 participants from 13 European countries attended the event.
- A DYNAMIX resource policy **webinar** was organised as a half-day long online event to present the project results before their finalisation and discuss them with a selected crowd of policy makers. The DYNAMIX webinar, entitled "Results from the resource efficiency policy mix assessment: grand challenges for implementation", took place on 28 October 2015. The webinar took place towards the end of the project and had the general aim to disseminate the project's preliminary results and evidences on policy mixes for an efficient resources use in the EU. In total, 30 participants representing different stakeholder groups attended the webinar: 11 researchers external to the project, 8 policy makers from the EU and national level, 2 representatives from Civil Society Organizations, and 9 researchers from the DYNAMIX project.
- Furthermore a total of 5 **press releases** were published to national media, including e.g. three to the Swedish media.

- The DYNAMIX team presented results directly to national policy-makers and stakeholders at **national and local fora**, such as the Waste Council of the Swedish Environmental Protection Agency.
- A **website** was created, on which all results were presented. The website had 9148 visits (unique visitors) and 29758 page views, (21504 unique page views) between 13/12/2012 and 23/05/2016. A total of 4266 **downloads**, (3727 unique downloads) of DYNAMIX deliverables and policy briefs were registered during that time.
- Under the **twitter** handle **@EUresources** results were furthermore regularly twittered to a community of 420 people (see https://twitter.com/euresources).
- A **newsletter** containing news about DYNAMIX and indicating to recent research results and activities in DYNAMIX was sent to 300 stakeholders, mainly targeting policy makers and researchers. A total of 4 newsletters have been sent.
- The DYNAMIX – POLFREE joint **final conference** on "Policy mixes promoting resource efficiency for a circular economy", took place in Brussels at the DIAMANT conference centre on 15- 16 February 2016. The conference was organized in cooperation with the sister project POLFREE in order to address a larger audience, increase synergies, and avoid duplication of efforts. The conference was organised into six sessions, focussing on a different elements of resource efficiency and the circular economy, and exploring answers to the questions the two projects sought to address. In total, 134 participants from a range of backgrounds, including academia, policy-making and industry took part in the conference.

Policy Briefs and Reports

In order to make the results of DYNAMIX more accessible for the non-scientific audience, a total of two policy briefs and four (short) reports were published:

- Ecologic Institute, IEEP, Bio Intelligence Services, PSI and IVL (2013). What creates a successful resource efficiency policy? DYNAMIX Policy Brief No. 1. Berlin: Ecologic Institute
- Langsdorf, S. (2016). Policy mixes for decoupling economic growth from resource use – Synthesis brief. DYNAMIX Policy Brief No. 2. Deliverable D8.3. Ecologic Institute: Berlin.
- Hinzmann, M. (2016). A policy mix aimed at reducing impacts of agricultural production and consumption. DYNAMIX Policy Report No. 1. Berlin: Ecologic Institute
- Langsdorf, S. (2016). A policy mix for dematerialisation. DYNAMIX Policy Report No. 2. Berlin: Ecologic Institute
- Hirschnitz-Garbers, M. (2016). A policy mix for sustainable consumption and production. DYNAMIX Policy Report No. 3. Berlin: Ecologic Institute
- Hirschnitz-Garbers, M. (2016). DYNAMIX Synthesis Report. DYNAMIX Deliverable D8.4. Ecologic Institute: Berlin.

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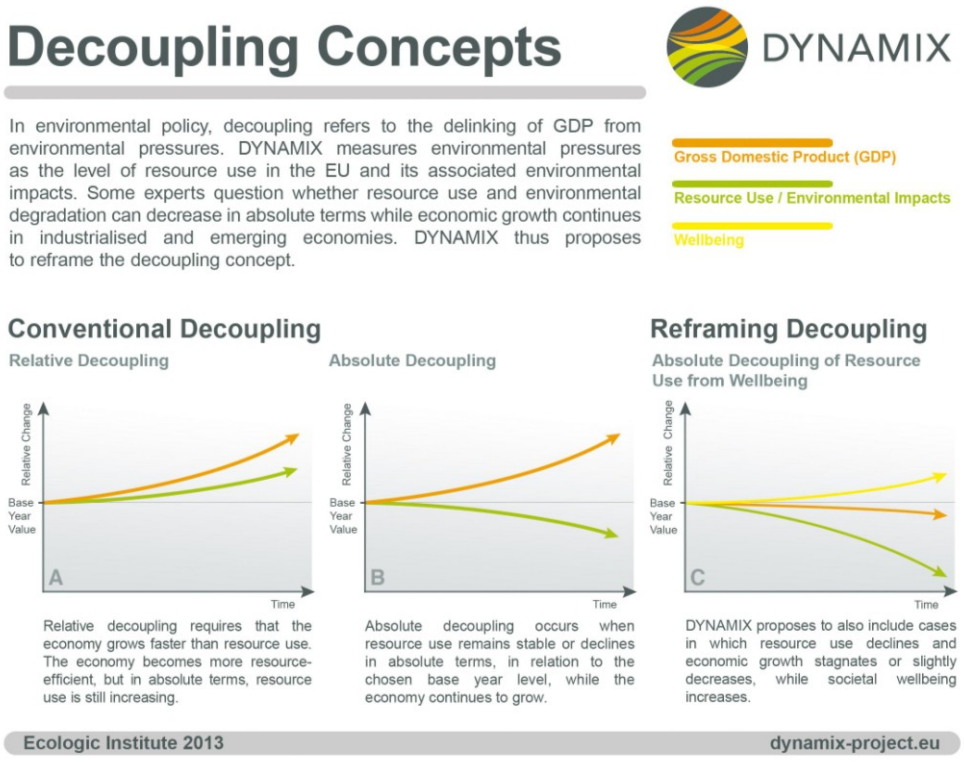
The address of the project public website and other relevant contact details

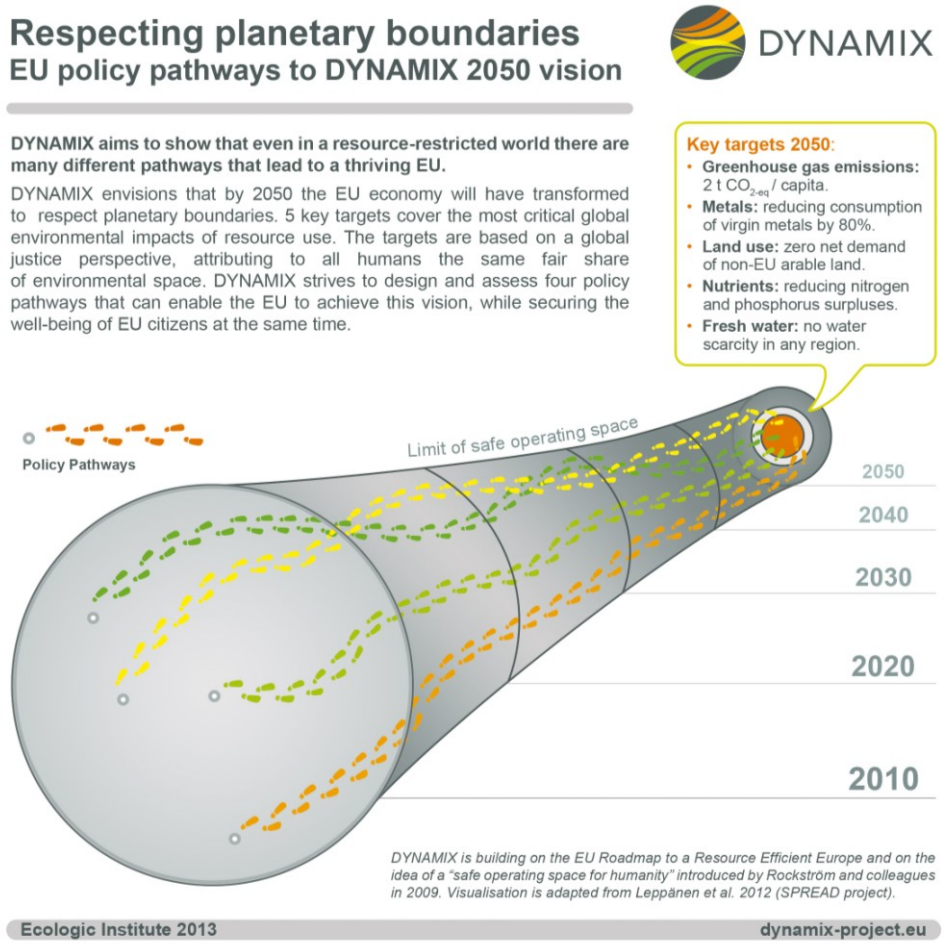
Project website: http://dynamix-project.eu/
Contact: Martin.Hirschnitz-Garbers@ecologic.eu

Project logo, diagrams or photographs illustrating and promoting the work of the project as well as the list of all beneficiaries with the corresponding contact names can be submitted without any restriction.

DYNAMIX



Umpfenbach, K. and Vargová, B. (2013), Ecologic Institute



Umpfenbach, K. and Vargová, B. (2013), Ecologic Institute