DYNAMIX
Decoupling growth from resource use and environmental impacts

POLICY REPORT
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A Policy Mix for Dematerialisation

Assessing instruments for metals and materials use reduction

EXECUTIVE SUMMARY

The welfare of modern societies relies heavily on the use of metals in infrastructure and products, but due to intensive mining in the last decades many metals and minerals are increasingly difficult to obtain. Mining evermore low ore grades leads to high energy use and greenhouse gas emissions, as well as to higher environmental pressures. Policy mixes to reduce metals and minerals use are therefore required. The respective DYNAMIX target is bold: reducing the consumption of virgin metals by 80% in the EU in 2050 – without major increases in the use of other resources or environmental impacts.

To this aim a policy mix was developed that encompasses five main instruments: a green fiscal reform (GFR) including the "*internalisation of external environmental costs*" and a gradually increasing "*materials tax*", "*the promotion of sharing systems*", introducing stricter "*product standards*" that shall increase the repairability and longevity of products, and increasing "*research and development*" for material efficiency and improved recycling. These main instruments were embedded in five supporting instruments: an EU strategy for dematerialisation; information campaigns; the establishment of fora for communication; removal of environmentally harmful subsidies and the establishment of advanced recycling centres.

The main instruments were assessed qualitatively and quantitatively (with up to three different models) for their environmental, social, and economic impact, their legal feasibility and public acceptance. In some cases the assessments were akin, others more contested.

With some caution, the following conclusions can be drawn: Naturally, the environmental impact of the instruments was evaluated to be positive. 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

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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.

Overall, the metals policy mix is considered to have the following effects:

Table 1: Overview of qualitative assessment of the policy mix' effects

Policy instrument	Impacts			Legal feasibility	Public accept-ance
	environ-mental	economic	social		
Green fiscal reform: internalisation of external environmental costs					
Green fiscal reform: materials tax					
Promotion of sharing systems					
Increased spending on research and development					
Product standards					

Legend and colour coding scheme

	likely very positive		*likely rather negative (for acceptance: uncontentious)*		*not assessed*
	likely positive		*likely negative (for acceptance: contentious)*		*likely neutral*
	likely rather positive		*likely very negative (for acceptance: highly contentious)*		*assessment uncertain*

1 Rationale behind the policy mix – what problem(s) does it respond to?

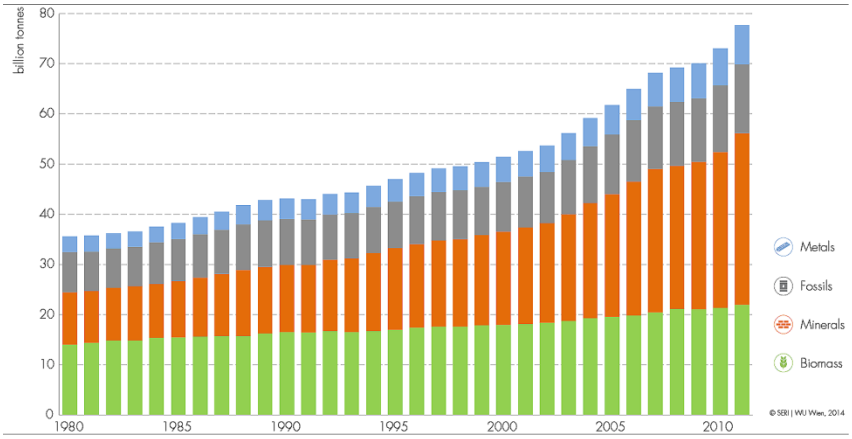
Aim: Reducing the use of virgin metals, without major increases in the use of other resources or environmental impacts

This policy mix[1] has the goal to reduce the use of virgin metals while avoiding major increases in the use of other resources or environmental impacts. The DYNAMIX target is to reduce the consumption of virgin metals by 80% in the EU in 2050.[2]

The welfare of modern societies relies heavily on the use of metals in infrastructure and products. Each year, the EU-27 uses 600-800 megatonnes (Mt) of metals (raw material consumption; RMC) with a slightly increasing trend (+2.3%/year). In contrast to many other resources, metals are often recyclable, albeit big differences exist between metals. Mass metals like iron are abundant and used in large quantities, other metals are rare – or at least not available in high concentrations. For a majority of extracted metals, ore grades in mines are going down, increasing the technical effort needed and thus the costs of metals extractions. Mining increasingly low ore grades leads to high energy use and greenhouse gas emissions, as well as to higher environmental pressures. Today, the metals industry demands over 6% of the global energy.[3] In addition, some metals, such as cobalt, are extracted mainly in politically unstable regions, leading to security and social problems.

Raw Materials Consumption (RMC): A material flow indicator; domestic extraction + imports – exports

Fig. 1: Global resource extraction by material category 1980-2011 (Source: WU Wien 2014)[4]



1.1. Main drivers for the use and barriers to the consumption of virgin metals

Metals are required for all sectors of the economy, and many drivers and barriers influence their use. Naturally, the overlying driver of virgin metals use is our economic system, in which business models focus on the sale of products (rather than services) and which relies on constant economic growth. From this core arise a great number of drivers and barriers, which are often intertwined and reinforcing, such as:

Interlinked barriers hinder resource efficiency – the economic system is at the root of most of them.

- Consumer culture; including the function of products as status symbols;
- High income levels and low material costs, leading to user behaviour which favours throwing products away before the end of life and new purchase over repairing and maintaining (throw-away society);
- This is reinforced by the economic system providing products that cannot be repaired (dismantling is impossible and/or spare parts are not available); and not providing repair services, making repair often not only the more expensive but also the more time-consuming choice;

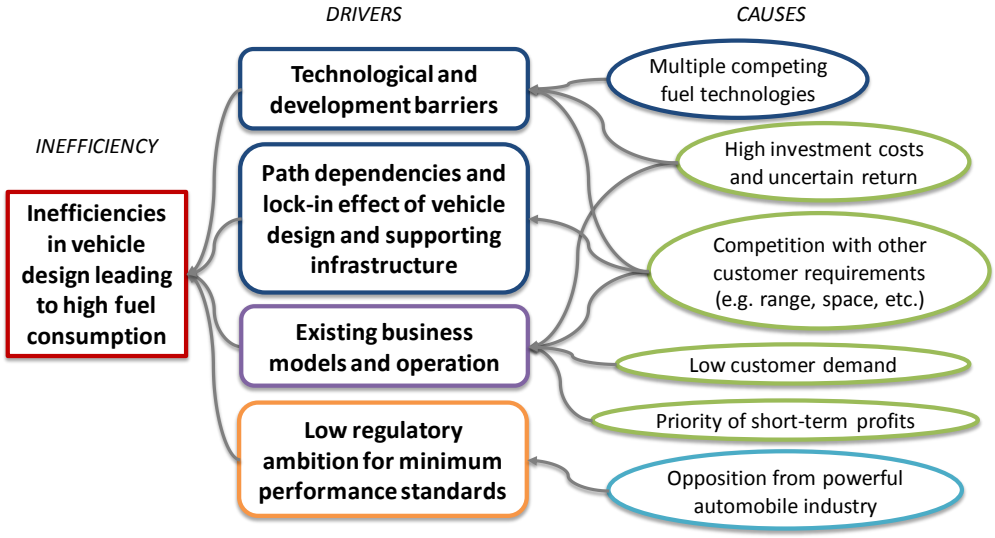
- Preference for private ownership, even if products (or buildings) may be infrequently used.

Next to the drivers that derive mainly from the economic system, some other drivers exist:

- High quality and safety standards also drive the use of virgin metals in the EU. Manufacturers must ensure certain standards for products and thus opt for extra materials to reinforce products and ensure robustness;
- Knowledge gaps and underinvestment in research and development.

In the DYNAMIX project, the underlying reasons for inefficient resource use were analysed for a number of specific inefficiencies. The following figure gives an example of the complex web of interlinked reasons for the case of vehicle design.

Fig. 2: Drivers and causes of inefficient vehicle design and fuel consumption (Source: Tan et al. 2013)[5]



Technically, it would be feasible to reduce global metal production considerably (by almost one-third according to Allwood and Cullen 2012) through design. Furthermore, a large part of the demand in the EU could be satisfied through recycling and circular economy strategies. In 2003, the EU had a metal stock of 3200 Mt in use, and an estimated unused stock in landfills of about 2250 Mt. Tapping these potentials and going beyond them requires bold policy interventions.

2 Structure and design of the policy mix[6]

This policy mix aims to reduce the use of virgin metals in the EU in RMC from over 700 Mt (2010) to 150 Mt in 2050. In developing the mix the researchers focused on the one hand on the main bulk metals (ferrous metals, copper, aluminium and gold). On the other hand, they adapted a broad approach, including measures aimed at influencing overlying structures, as the mix aims to avoid an increase in the use of other materials.

For the reduction of metals use as such, the policy mix identifies technical redesign, substitution, a shift from products to services and reductions in

demand stemming from changing consumption patterns, greater longevity and reparability as lines of intervention. Furthermore, recycling of post-consumer scrap metal shall be increased by 20%. The policy mix focuses on five main instruments:

Green fiscal reform: internalisation of external environmental costs

Targets the driver: Economic system based on growth and material intensive production; high labour and low material costs.

Objectives:

Internalisation of 100% of environmental costs. Increasing material efficiency, reducing demand for materials, increasing recycling, reducing pollution, increasing energy and water efficiency and creating jobs

Mechanism and specification: The instrument contains a gradual increase in taxes and fees on emissions and the use of natural resources until 100% of the estimated externalities are covered. The mix does not only target metals, but all raw materials, energy and water; all economic sectors and all physical flows (where emissions and resource use arise). The revenues will be used to fund other instruments of the mix and to lower labour taxes. A precondition for this instrument is the establishment of a commonly accepted method to measure the external cost of each pollutant and resource. Previous efforts to estimate externalities include the EXIOPOL project[7] and Trucost[8]. EXIOPOL estimated the external costs to be ~7% of global GDP (2010); Trucost calculated 13% of global GDP (2009). A perfect estimate cannot be made: the full externalities cannot be objectively set, models to date do not contain all relevant data i.e. on pollutants, and the impacts may vary strongly geographically. Building on the existing studies in the metals mix it is assumed that the external costs correspond to 35% of the value added for material goods and transports.

The instrument will first be implemented in twelve front runner countries, and adapted in 2030 in all EU member states. The increased environmental taxes and fees (IET&F) will then be gradually increased until full internalisation (35% of the value added for material goods and transport) in 2050. Coordination at EU level is required to avoid market distortions.

The IET&F are mainly to be paid by polluting companies and companies extracting resources or using land. The revenues will be used to reduce labour costs. In the long term the instrument shall induce a shift from polluting and material intensive industries to cleaner, material light industries and services, increasing the number of jobs; temporal unemployment, especially on the local level, may occur.

Green fiscal reform: materials tax

Targets the driver: Economic system based on growth and material intensive production, high labour and low material costs.

Objectives:

Reduction of the production of materials; saving resources for future generations and reducing impacts on health and ecosystems

Mechanism and specification: A value-based tax on all materials; applying to the value added in the production of materials, not the value added in manufacturing or wholesale. Target sectors are the manufacturing and construction industries as well as importers of materials and products with a large material share of the full product value. Furthermore, the housing and construction sector should be strongly affected. The tax is levied on imported and domestic materials, but not on exported materials in order to not harm competitiveness of material production in the EU. To allow taxing import duties in particular, an accepted procedure to calculate the material value of products that contain a mix of materials must be established.

The tax shall be introduced in 2020, with a slight increase until 2030 to 30% of the materials value and a steep increase until 2050 to 200% of the materials value. When importing products the value of the material should be at least 50% of the product value in 2020, 20% in 2030 and 10% in 2050. The revenues shall be used to lower labour taxes. The instrument is expected to be contested and requires EU coordination to avoid distortions of the common market.

In the long run the materials tax should increase materials efficiency of the European economy, thus increasing its competitiveness. During a transition period unemployment may occur. In the long term a positive effect on jobs is expected due to a shift to services and due to lower labour costs in comparison to materials costs.

Promotion of sharing systems

Targets the drivers: Private ownership and consumerism; low quality products.

Objectives:

Reduction of metals and materials use though the reduction of products owned

Mechanism and specification: The promotion of sharing systems could be designed in various ways, especially differentiating between publicly set up sharing schemes or private sharing schemes, which could be supported by national or local authorities through funding of part of the investment costs. Tax exemptions are another support option (deductions on income tax on the renting costs, or via differing VAT between goods and services).

The instrument mainly targets households, but also private leasing companies and NGOs. By supporting renting schemes over private ownership the instrument aims to reduce the number of products sold in certain areas, especially cars, bicycles, tools and equipment. Depending on the design, the instrument can be set up or supported by local or national authorities and should be supported by information campaigns. The instrument will most likely not have a significant effect on economic growth and only a limited effect on the total use of materials. However, it may contribute to a shift to a sharing economy in which personal ownership is regarded as less important. This may add to a significant paradigm shift.

Increased spending on research and development

Targets the driver: Knowledge gaps.

Objectives:

Enhancement of technology, systems and knowledge for improved recycling and material efficiency

Mechanism and specification: The increased funding of research and development (R&D) shall lead to improved technology and better systems for more and qualitatively improved recycling and materials efficiency. With regards to recycling, R&D shall be intensified on design for recycling, collection systems, and technology (for dismantling, separation and recycling). R&D for material efficiency should focus on improved processes and products, new business models and non-material alternatives for investments (especially alternatives to gold).

R&D spending should be doubled until 2020 from current levels and kept constant from then on. It should be increased on all levels, especially at EU (H2020) and member state level, with some coordination on EU advisable in order to avoid double funding and funding gaps. While the effectiveness of R&D is difficult to predict, it has almost no negative side effects, apart from spending the funds, and it will boost competitiveness in the EU if advances

are made. In the long term, improved technology and systems will diffuse to other parts of the world further improving global materials efficiency and recycling.

Product standards

Targets the drivers: Low quality products, including bad repairability and short life-span of products.

Objectives:

Reduction of virgin metals use through improved product design, increased longevity and reuse

Mechanism and specification: Standards for products (and components) shall be set globally, if possible, via the International Organization for Standardization, or at least on the European level (European Committee for Standardization). Starting point for material standards can be best practices from value-chain co-operation in the last 10 years. Goals include improving modularity in order to enhance repairability and reuse, reducing excess use of materials and substitution of metals.

The instrument targets selected metal products and should be developed from a narrow base of few products to include more and more products, setting ever stricter and more ambitious (including the functionality of products) targets. In the long term standards may include limits to the quantity of materials used in a certain product. If producers fail to hold the EU standards, they will not be allowed in the EU market.

The environmental benefits of this instrument will depend on the specific product standards, but also on the volume of the product. It is estimated[9] that the product standards will affect 1-10% by weight of new metal products in 2030 and 5-20% in 2050. While the instrument does not aim to influence the structure of the economy, manufacturing sites that fail to adjust to the standard lose the EU market. However, adjusting companies have a competitive advantage in the long term if materials become more expensive.

Support instruments

The five main instruments are complemented by a mix of supporting instruments. These supporting measures shall set the scene for the five instruments and make those more feasible.

The supporting measures include

- An EU strategy for dematerialisation;
- Information campaigns;
- Establishment of fora for communication;
- Removal of environmentally harmful subsidies and the
- Establishment of advanced recycling centres.

The main instruments can only have a positive impact if complemented with supporting instruments

The **EU strategy for dematerialisation** will take the form of an official EU document determining the direction and strategy in which the EU aims to develop, including the type of instruments to be used to reach change in market conditions. The work on this strategy should start now, with an agreement to be reached in 2020. Setting a credible long-term framework will give economic actors reliability for the development of their business and investment strategies. The majority of policy instruments also need to be accompanied by **information campaigns**, in order to inform stakeholders and

support changing mind-sets. **Fora for communication** are another supporting instrument that aims to distribute information (i.e. on technological aspects or on market opportunities) between stakeholders and improve communication, throughout the value chain.

The **removal of harmful subsidies** is a politically ambitious supporting instrument, and an important component of a coherent green fiscal reform. In this policy mix, two subsidies that are especially important with regards to virgin metals use should be targeted: the limited reliability for accidents related to metals extraction and the subsidisation of company cars. With the funds saved, labour taxes shall be reduced.

Finally, **advanced recycling centres and reuse mechanisms** shall be set up. In the centres, collection and second-hand trade will take place and repair and redesign will be facilitated.

In chapter three, the results of the ex-ante assessment of the policy mix will be presented. The instruments target an ambitious environmental goal. Despite the boldness of the measures, it needed to be assessed, if the environmental target can be reached – and which other factors – social, legal, economic – are affected in what way.

3 Potential of the policy mix to support a substantial reduction of virgin metals use

3.1. Potential environmental impacts[10]

The metals policy mix was developed to tackle environmental goals, and naturally does have generally positive environmental effects. However, as the instruments are mainly on a comprehensive level and the mix builds strongly on synergies between policies, the effects are difficult to access. Individual policies have usually only a modest impact, and often limited preliminary scientific work exists to draw from. The qualitative and quantitative[11][12] analysis undertaken, however, provides valuable insights on the effects of the policy mix as a whole. The policy mixes developed in DYNAMIX are ambitious or even visionary. Some of the proposed instruments could not be implemented today, but must be prepared using other instruments in a roadmapping process, leading to different socio-economic paradigms. This system change provided a challenge to modelling the policy mix: macroeconomic models (such as the Intertemporal Computable Equilibrium System [ICES]) are set up to function in a certain economic and technological structure, so modelling structural changes is limited.[11]

Broadly speaking, the policy mix will contribute to the goal of a steep reduction of virgin metals and materials use by:

a) Increasing the price of materials and shifting taxation from labour to materials;

b) Reducing material demand by fostering the efficient use of goods and a shift to services;

c) Increasing resource efficiency by investing in technological advances;

d) Improving repairability, longevity and material efficiency through product standards.

The policy mix will have positive effects on a range of environmental impacts, such as the reduction of greenhouse gases, but in the following section we will focus on the main target, reducing metals and materials use.

Target: increasing dematerialisation and fostering a circular economy to achieve a 80% reduction in consumption of virgin metals by 2050

The mix, especially the GFR will support dematerialisation, but assessment results differ strongly to which degree.

The metals policy mix will contribute to this target, but the effect for different resources will differ. The two measures of the green fiscal reform, the *materials tax* and the *IET&F*, are likely to have a strong positive environmental effect. The quantitative assessments (see chapter 3.2, Economic impacts) shows a significant reduction in materials use under the IET&F. However, within Europe, the IET&F will mainly help reducing the extraction of bulk materials while other mining will most likely not be majorly affected, as Europe's mining industry is small.

The effects of the *materials tax* are difficult to assess and might differ strongly between materials. For some materials, limited price elasticity has been observed in the past, but the materials tax planned as part of the policy mix is quite high and has never been tested before. Results regarding quantitative effects differ strongly between the models, but in one case a very positive effect of up to 63% material efficiency gains has been calculated (Macroeconomic Mitigation Option Model [MEMO II]).[12] While the results of the quantitative modelling with ICES of the materials tax also show that the instrument will have a reducing effect (compared to a baseline) on a number of sectors (oil products, metals, minerals, construction and manufacturing), the overall results are less positive: both resource depletion and environmental impacts will be greater in 2040 than in 2007 in the EU according to the ICES model.[11]

The impact of product standards depends on the standards set and the volume of products

Product standards will also contribute to the target, but there is a high range of possible impacts, depending on the standards set and the volume of products. Product standards could encompass a number of parameters, including reusability, recyclability and recovery rates or recycled content. It is foreseen in the mix to start with few products and gradually increase the number of products and the standards. A good option to start would be water piping, which was also assessed: a shift from copper water pipes to polymer water pipes (PEX) was modelled. PEX piping systems showed better environmental performance (i.e. with regards to abiotic depletion and global warming). While the effect of that single measure is naturally small (less than 1% of the targeted 80% reduction of the metals ore use), a larger number of product standards could cumulate higher effects. However, as product standards increase, so does the administrative burden on the government and business side (i.e. continuous adaptation of the standard to new technological advances, monitoring and enforcement, knowledge building). Standards are especially helpful where a continuous market failure persists (material prices do not reflect the negative externalities).

Setting the standards requires *research and development (R&D)* in technical feasibility, measuring and data provision. But R&D is also necessary to achieve the technological advances in all other relevant resource fields: i.e. material efficiency, recycling, substitution. The potential may be huge: according to one author 80% of a product's environmental impact is predestined by design,[13] but effects are almost impossible to predict. As an example for the effects of increased R&D the improved dismantling of cars and light trucks was modelled. Under the assumption that improved

dismantling of cars would reduce the quantity of copper cables etc. in the steel scrap by 75%, copper recovery would increase by almost 250 kt/year. In mining copper mines with a 0.5% ore grade this corresponds to 50 Mt Raw Materials Equivalents per year. The RMC of copper in Europe is around 150 Mt/year.[14] Furthermore, steel scrap from the vehicles would be less contaminated (with copper) thus also leading to a reduction in virgin steel (50 Mt/year).[11] While modelling relied on assumptions and crude data and therefore results may be overly positive; it can still be assumed that the positive effect would be significant. Despite these positive results, any policy mix must take into account that an increase in efficiency may lead to rebound effects, rather than reducing environmental effects.

The rebound effect is likely to counter all efficiency gains if not tackled i.e. through a GFR

The effect of *sharing systems* is yet to be fully analysed. Some studies indicate steep reductions of virgin metals use, as they expect the number of products to go down significantly. But results differ widely, according to two studies car sharing schemes replace 4-12.8 private cars.[15] Furthermore little evidence exists on possible negative side-effects, for example on where the money saved by car-sharing is spent.[16]

3.2. Potential side-effects of the policy mix

Economic impacts[17]

Green fiscal reforms (GFR) have been found to be effective[1] in a great number of studies; for example with regards to emissions reductions one study finds a positive environmental effect in 95% of the simulated cases.[18] In theory, GFR are also an efficient instrument. However, apart from the real world limitations to theory (revenue shifts, associated management costs, unfavourable layering with existing measures, etc.), there exists a trade-off between efficiency and equity. GFR are (theoretically) revenue neutral, but do affect some sectors more than others. While pushing for a shift away from polluting industries is a goal of a GFR, this may still create temporary hardships for affected workers and sometimes entire regions. Furthermore, many studies show a rise in regressivity of GFR.[18] As poorer households spend more of their income on consumption, they get taxed relatively higher than richer households, leading to problematic distributional effects.

The economic assessment reveals a mixed picture

The analysis of the specific instruments – *internalisation of external environmental costs* – foresees positive environmental impacts, but the economic analysis shows a more complex picture. Taxing a very wide range of products may lead to a decrease in GDP, especially as the substitution from materials to labour may not always be possible. Furthermore the overlapping of distinct taxes carries an economic risk and the quantification of the externalities, and subsequently the taxes, is a challenge. As the instrument would be quite comprehensive, a strong impact on the competitiveness and income distribution (due to the tax regression) is likely. The former may be healed with sector-specific GFR, which would provide more funds for the transition of the targeted sectors. Some studies also expect an inflationary effect,[18] which negatively affects groups with fixed incomes. The main critique of the *materials tax* from the qualitative economic

Substitution from materials to labour is not always possible

[1] *Effectiveness* defined as the capability of an instrument or mix to reach the objective.

assessment is its similarity with the IET&F, which is considered an inefficient approach. Furthermore, according to the literature,[19] resource demand has low price elasticity; therefore the relative high costs of such a measure may not be mirrored with positive environmental effects. Nevertheless the resources obtained could be invested to support the transition to new technology paradigms.[17]

The different models used for the quantitative assessment yield differing results. The quantitative economic assessment with the MEWA (Material Energy Waste and Agriculture) model indicates that the *materials tax* leads to significant macroeconomic benefits by 2050. According to the assessment, GDP increases by 5.8% and employment by 7.2%. Materials demand decreases by more than 13% below the baseline scenario. However, these positive effects only manifest if significant material efficiency gains can be achieved – so the accompanying increase in R&D is key for sustaining economic growth – and if labour taxation is reduced correspondingly. If instead of reducing labour taxation, transfers are increased, GDP and employment will decrease according to the assessment.[12]

Table 2: GDP and employment impacts of material taxation in the EU in various scenarios according to the MEWA model.

Scenario	GDP		Employment	
	2030	2050	2030	2050
Base case: reduced labour taxation, material efficiency increase via private R&D	0.92%	5.81%	1.11%	7.16%
Alternative 1: no material efficiency increase via private R&D	0.11%	-1.80%	0.14%	0.14%
Alternative 2: increased transfers instead of reduced labour taxation	-0.62%	-6.55%	-0.05%	-1.11%

Source: MEWA model simulations

For modelling the *IET&F*, a flat rate tax of 35% for externalities (as proposed in the policy mix) on all non-service sectors was assumed in the MEWA model. A substantial amount of the revenues were used to decrease taxes on labour (defined as the sum of personal income tax and social security contributions): from 30% to 4.4%. The revenues were also used to reduce VAT in the model. The externality tax paired with the reduction in the VAT levels impacts GDP slightly positively. In contrast, in the MEMO II[2] model

[2] It is important to note that due to the differing model needs the assumptions differed in important respects, which partly explains the differing assessment results: In the simulations of the material tax and IET&F with the MEMOII model it was assumed that 50% of the tax revenue is spent on reducing labour tax, and 50% is transferred as a lump sum to the households. This split was made because lump sum transfer/tax is not distorting in that model, whereas labour tax is, and its decrease causes an increase of labour. The ICES model used a 100% lump sum transfer closure. In MEWA 100% of the environmental tax revenue was spent on labour tax reduction. This is a significant source of differences in results. An additional simulation in MEMO II with a 100% labour tax decrease turned up more optimistic results for GDP and employment developments.

IET&F has a reducing effect on GDP (-5.8% in case of a flat rate tax). The revenue from the tax is approx. 8.5% of GDP. Furthermore, a drop in investment in physical capital can be observed until the tax rate has stabilised in 2050 in MEMO II. Due to a lack of innovation, the IET&F does not even lead to a significant reduction of materials use, even though a switch to services can be noted. This rather negative assessment may underline the importance to link the instrument to a strong R&D instrument.

Further conclusions can be drawn from the assessment of the materials tax with MEMO II, in which it was also assumed that 50% of the revenues will be used to reduce labour taxes. Here a more positive picture comes about: GDP is 1.9% higher than in the baseline scenario in 2050 and an initial drop in investment rebounds. Employment increases by approximately 6.2% in 2050 and the tax revenue is with 10.7% of GDP slightly higher than for the IET&F instrument. The final 200% tax rate in 2050 will reduce materials use strongly (up to 63%), contributing strongly towards the 80% reduction goal. The more positive assessment of the materials tax in comparison to the IET&F is mainly due to additional investments in more resource efficient technologies. [3] [12] The assessment of the materials tax with the ICES (Intertemporal Computable Equilibrium System) model calculates a decreasing GDP (-5% in 2050), whereby individual countries are affected differently. Material intensive industries are naturally affected strongest by the tax, but a cascading effect to energy sectors and construction is observed in ICES. Material intensity declines by ~ 12% in 2050.

Companies underinvest in R&D due to the creation of positive externalities – government R&D can help closing the gap

Increased spending on *R&D* can lead to technological innovation, but results are unpredictable and technological breakthroughs occur erratically. Research has shown that companies invest less in R&D than would be socially desirable, which justifies public support for R&D.[20] This underinvestment can be explained by the fact that R&D creates positive externalities: innovative companies create a benefit that can be used by other companies. While the copying of more advanced technology by other firms augments the positive effect for the environment as a whole, it leads to a competitive disadvantage for the investing firm, as it bore the research costs.[21] By inversion of the argument research policy needs to foster the diffusion and mass adoption of better technologies to enhance the positive environmental effect. The combination of R&D policies and appropriate policy measures is important for both the adoption of technologies and the effectiveness of environmental and innovation policies.

From an economic standpoint, technological innovation will shape the cost functions of products. But due to the reasons mentioned above companies will usually underinvest in R&D. Government R&D helps to compensate for this gap and is especially important for basic R&D which has uncertain and not

[3] Why the materials tax raises innovation and the IET&F does not in MEMO II modelling: The *materials tax* raises the price of the intermediate input for firms. To offset this effect, they invest in material efficiency. The *IET&F* were modelled as a tax on the output of the industry sector. This leads to an increase in the price for goods, which in turn decreases demand. For the firm no clear link between price (tax) signal and the material input arises. Therefore the firm has no incentive to invest in material efficiency in the model logic. The main difference between these simulations is the placement of the price signal brought about by the two taxes. It must be noted that the IET&F could also be designed in a way that firms have incentives to invest in efficiency.

immediately marketable results.[21] The very rough quantitative assessment of increased R&D indicates that the measure will significantly increase European GDP (~14%) and materials efficiency (~10%), in the long term, advancing technologies and encouraging private companies to increase their R&D investment. But the efficiency gains will be consumed by the rebound effect – in the above calculations materials consumption will rise 4% and emissions will also rise.[12] These mechanisms make increasing R&D an important component of the policy mix, but in order to not increase environmental impact, it must be connected with the above measures.

The economic analysis of environmental policies deems *product standards*, as a command-and-control instrument, inferior to market-based instruments. If the objective is to reach a specific (technological) standard, then a regulation may be a suitable instrument, especially as product standards are simple to design. However, from an economics point of view, more generic environmental endpoints such as the reduction of materials use would be better served by a materials tax. Additionally, market-based instruments require less monitoring and enforcement efforts.[21]

The *stimulation of sharing systems* is seen as an instrument with limited effectiveness to reduce environmental pressures, as the amount of materials used in the typical sharing sectors is not very high. Plus, with regards to the most relevant sharing system – car sharing – the impact on fuel consumption and GHG emissions is not yet clear as people who never owned a car may now use sharing systems. At the same time, this effect contributes to more equality. However, until now only limited research has been undertaken and the effect may become more positive if the sharing systems foster a value shift away from the ownership paradigm.

Nevertheless, it is questioned if public support for sharing systems is needed, as in recent years sharing systems flourished without state intervention. The assessment therefore suggests dropping this instrument in order to not misallocate funds that would better be used elsewhere. If support is given, the economic assessment favours support to private firms running sharing schemes. As the design of the sharing system is important for its efficiency, a low governance level (to address the local barriers to sharing schemes) should be in charge.

In summary, the broad range of instruments in the mix ensures no major aspect is left out, and the supporting tools “removal of EHS” and information campaigns round off the mix. On the downside, the overlapping of the IET&F and the materials tax is inefficient, and both should be integrated, with the IET&F as the starting point.

Social impacts[22]

The social impact assessment focussed (after a selection process) on three key social impacts, which also have interlinkages: labour market impacts, health impacts and social inclusion impacts.

The mix will have strong positive effects on health and safety issues

The metals policy mix will have strong social impacts, especially regarding health and safety issues. All main instruments with the exception of R&D were identified as having potentially significant impacts on health.

The analysis of the **labour market impacts** focussed on “job creation and destruction” and the “changing nature of jobs.”[22] The main impacts of the mix on the labour market result from the *IET&F* and the *materials tax*. Taxing pollution and resource use will impact industries, especially manufacturing

where metal consumption is central. The decrease in market demand for material intensive goods will likely decrease employment in the short term. Decreasing labour taxation provides fiscal incentives for labour reallocation; also, the gradual strengthening of price signals allows companies and workers to prepare the transition. The employments structure should shift to services.

The promotion of sharing systems is not expected to affect the labour market strongly. Sharing systems may, over the long term, affect the number of jobs in manufacturing (if the systems are very successful and less products are needed to satisfy demand), but due to the high level of automation this effect will remain small, if it occurs at all. On the other hand, employment may increase in the service sector, as sharing systems are relatively labour intensive (albeit many successful sharing systems are highly digitalised and thus not as labour intensive as classic rental systems). The impact on the labour market is likely to be small but positive. As shared items are used more efficiently, prices should go down and access to services increased. Product standards will not affect the labour market strongly as a whole, but may have strong local effects if companies or regions depend highly on an affected product.

Investing in *R&D* may have a significant impact, but outcomes are uncertain and effects would come with a time lag. If breakthroughs occur, new opportunities arise; but skill mismatches are likely, as reallocations of labour have to be undergone.

Public health impacts were assessed through the impact on production and consumption, especially the resulting changes in pollution and dietary patterns. If successfully improving resource efficiency, the metals mix should lower industrial pollution. In the wake of this, the reduction of air pollutants will have positive impacts on health. Nevertheless, life cycle emissions should be monitored, as also renewable technologies emit some pollutants.[23] Furthermore a reduction in materials use will reduce transport and air pollution from landfilling.

IET&F are among the strongest instruments to tackle negative health impacts. The policy instrument intends to increase taxes and fees to equal 100% of the external costs – including health costs. Thus a price signal will be provided to switch to less deleterious alternatives. The *materials tax* will, by design, target the material consumption of manufacturing and construction industry, leading to emissions reductions in industries that produce materials, but also in the manufacturing industries itself. These industries are also responsible for very large pollutant emissions. The *promotion of sharing systems* should also have a small positive effect – due to the more efficient use of goods and to the nature of some of the sharing systems (e.g. bike sharing). Increasing recycling rates and resource efficiency through innovations (i.e. *R&D* increase) and higher *product standards* will also have (small) positive health effects.

The effect on social inclusion is mixed.

Impacts on **social inclusion** were assessed via the distributive effects. Decoupling policies will often have a progressive effect on poorer households, because decoupling should make economies less prone to shocks (which poorer households cannot prepare for) and also the reduced disaster risk benefits more vulnerable households and groups. Increases in market prices for resource intensive goods will affect poorer households disproportionally. Households with low GDP per capita spend a larger share of their income on resource intensive goods and food, so rising prices may even negatively affect nutrition in these households. These segments of society are also more

likely to be affected by labour reallocation and a reduction in wages brought about by decreasing labour productivity. On the other hand, new job opportunities will arise in the circular economy, and a decrease in labour taxes will increase the disposable income. Of all the instruments, the green fiscal reform is expected to have the strongest impact. The reduction in labour taxes which is part of the *GFR* should increase employment, but the taxation of emissions (*IET&F*) as well as the *materials tax* will lead to higher prices of final goods, thus putting more pressure on poorer households. Also, the producers may shift the higher costs on to their workers, which would also affect certain groups of workers.

The *promotion of sharing systems* should have a significant positive effect on social inclusion. As sharing systems increase the availability of goods and services at lower prices (due to efficiency gains), more people gain access.

Assessing the effects of *increasing R&D* always involves an element of uncertainty. Historically, technological progress has increased labour productivity and, as a consequence, living standards (especially those of low skilled workers). If these trends remain is unclear, effects in the short and medium term are ambiguous: benefits from increased productivity may not be distributed evenly and R&D may further the technological development in such a way that low-skilled jobs become obsolete, especially through automation and digitalisation. Also, the budget spent for R&D cannot be spent elsewhere.

Legal feasibility[24]

The instruments are in accordance with WTO law

According to a first assessment, the instruments seem to be in accordance with World Trade Organisation (WTO) law, as the indirect taxes foreseen in the mix (*materials tax* and *IET&F*) do not discriminate products not produced in the EU, and reverse discrimination (discrimination of own products) is allowed. *Increased R&D* is compatible as the subsidies have "no, or minimal trade-distorting effects"[25] and don't provide price support to producers. The *promotion of sharing systems* is also compatible, as long as foreign companies can participate and receive the subsidy. *Product standards* are, in the legal sense, a technical regulation under the "Technical Barriers to Trade"[26] (TBT). The standards shall be developed under the International Organization for Standardization (ISO) framework, or subsidiary, under the European Committee for Standardization (CEN) framework. Both frameworks are recognised under the TBT. As the standards shall apply to imported and national goods, no discrimination occurs. The standards have to be notified to the WTO Secretariat at draft stage for conformity assessment.

Some concerns arise regarding conformity with EU law – but legal bases exist to justify ambitious environmental policies

With regards to EU-law some concerns exist:

a) As the *materials tax* would apply to imported and domestic materials alike when introduced at Member State level, Article 110 of the Treaty on the Functioning of the European Union (TFEU) does not seem to be infringed. However, the harmonisation of such an indirect tax requires a unanimous vote of the Council and the tax must be "necessary to ensure the establishment and the functioning of the internal market and to avoid distortion of competition" (Art. 113 TFEU).

b) The same difficulty as under a) applies to the *IET&F*. Furthermore, with regards to the emissions part of the instrument, it would need to be checked how the instrument would interact with existing EU Emissions Trading and other related existing regulations. From a judicial point of

view, IET&F is also too broad to be an "instrument," more specification would be necessary for a thorough assessment.

c) While the *promotion of sharing systems* might be a subsidy, it would remain compatible with EU-law provisions if it is covered under the de-minimis rule that is if a single company does not receive over EUR 200,000 in three years. If higher, the Guidelines on environmental and energy aid for 2014-2020 may apply: Measures may be compatible with internal market under Art 107 (3) (c) TFEU if aid is given for environmental protection going beyond Union standards (or in case of lack of such standards). So if the instrument actually leads to a more efficient use of natural resources (this might need to be proven) higher aid might still be compatible with internal market rules. In taking a decision for one of the differing designs of that instrument emphasising the above would be a sensible strategy.

d) The *product standards* as presented in the policy mix seem compatible with Art 34 TFEU (free movement of goods); however, further specification of the design would be needed for a final assessment. The standards would be compatible if the "national provisions restricting or prohibiting certain selling arrangements [do not] hinder trade between Member States, […] so long as those provisions apply to all relevant traders operating within the national territory and so long as they affect in the same manner, […] the marketing of domestic products and of those from other Member States."[27]

Protecting human health and the environment can legitimise trade distorting instruments

For the further development and fine-tuning of this (or other) policy mix(es) from a juridical point of view it is advisable to:

a) 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;

Arbitrary or unjustifiable discrimination between countries must be avoided

b) Eliminate any arbitrary or unjustifiable discrimination between countries or disguised restriction on international trade in the design of instruments; and

c) Consider the pursuit of (multilateral) environmental agreements to reach targets.

d) It is advisable (and sometimes required) to notify the European Commission and the WTO Secretariat of planned measures to avoid collisions with trade law.

Public acceptance[28]

Public acceptability is strongly linked to the dominant paradigms in society

Public acceptability of policy instruments is strongly linked to the dominant paradigms in society. Those paradigms are usually very stable and change only slowly through new evidence and experience in public discourse. Nevertheless change does happen and can be fostered through policy mixes and the right sequencing of policies. From a current standpoint, however, the ex-ante assessment expects low public acceptance of:

- The green fiscal reform (GFR) – *internalisation of externalities* and *materials tax* – are expected to be met with resistance. GFR is a

confined professional discourse with only the tax component likely to enter the public discourse, and some strong opposing lobby groups (motorists, etc.) exist. Therefore it would be important to capture the benefits in the public debate, and a fair and even imposition of the tax.

GFR is likely to be met with resistance

- The economic situation, unemployment and public finances are frequently mentioned as the most important issues facing the EU.[29] To achieve public acceptability it is, therefore, important that the *materials tax* shall be applied to imported and domestic materials. Any instrument design should ensure the competitiveness of the European industry isn't threatened, in order to ensure public acceptability. Furthermore the revenues shall be "recycled" to those facing the tax as much as possible to retain trust. The (fiscal) benefits of the reform should be communicated clearly.
- Regarding *product standards*, public acceptability is likely to vary strongly between Member States. While in many countries the topic is expected to be un-contentious, there exist some exceptions, such as the UK, which is rather Euro-sceptic. To counter resistance, sequencing of standards – starting with standards that improve the consumer benefit and later introduce standards of sole-environmental benefits – is beneficial. Country tailored implementation timeframes may also affect acceptance positively. More independent technical oversight on standard setting would increase transparency and reduce manufacturers influence on product standard setting.

3.3. Consistency and coherence of the policy mix

The instruments of this policy mix were designed to minimise conflicts between instruments (consistency) and to maximise synergies between instruments (coherence).[30] While the instruments in general complement each other well, there is one exception:

- The two instruments of the GFR *IET&F* and the *materials tax* are a double punishment of materials use. If full IET&F is reached, then by definition all externalities would be internalised, making an additional materials tax redundant. As long as not all environmental impacts are internalised the IET&F could be set at the time-specific maximum instead of adding a materials tax. If an IET&F is not feasible due to knowledge gaps (to assess externalities) or lack of public acceptance, a materials tax can be implemented. Implementing both instruments reduces the consistency and the coherence of the mix. It increases the administrative burden on the tax payer and the government side. Double taxation is furthermore likely to reduce acceptance of the instruments.[31]

While all other instruments complement each other, light shall be shed on some combinations that are especially important to be implemented together. Especially the supporting instruments play an important role:

- *GFR* and *R&D* are very coherent policy instruments – as materials cannot easily be substituted by labour, investment in material efficiency is the most important channel. For designing the various instruments – setting product standards, estimating externalities for the IET&F or the materials value for the materials tax –sound scientific assessments are required, to have a solid base for political discussions.

- Furthermore, the provision of information – ensured in the policy mix through the supporting instruments "information campaigns" and "fora for communication" – are important to unlock the potential for materials efficiency.[12] External environmental costs cannot be decided objectively, as for example the willingness to take risks (i.e. on the health of citizens) is a political decision, but scientifically solid information can be provided. Provision of information and activities that break into the consumption and ownership paradigms – such as sharing systems – may also help to increase public acceptability – which was assessed to be low in the current system.
- The elimination of environmentally harmful subsidies should be a main goal for consistent environmental policy making in general.

Despite the overall largely consistent and coherent design of the policy mix, the available assessment shows that the environmental and economic impacts are sometimes problematic and difficult to assess. The environmental targets may not be fully reached. While the social impacts are majorly positive and legal feasibility is also not a major problem, public acceptability is expected to be low.

Hence, in the following we will provide some pointers for revising the policy instruments that may have the potential to improve political feasibility and also environmental impacts of the policy mix in the longer term.

4 Pointers for revision and policy recommendations

Green fiscal reform

(1) Internalisation of external environmental costs

(2) Materials tax

- The shift in the economic structure should be accompanied by skill enhancement measures to buffer job losses in the transition period. Communities or regions strongly affected by the shift should receive support from the national government;[22]
- Regressive impacts on the socially vulnerable by the policy instruments need to be balanced by redistributive measures;
- Life cycle thinking needs to be ensured: while some resources may have a negative environmental impact in the extraction phase, the materials may provide functions for renewable technologies. A policy mix must ensure that resources for a transformation of the economy are sufficiently available;[10]
- Overlapping of taxes is to be avoided or at least minimized. Options to integrate the IET&F and the materials tax should be elaborated further;[31]
- The materials tax should differentiate between materials, as some materials have stronger environmental impacts than others;[10]
- The application of the materials tax according to a threshold material value to total value might need an adaptation for resource intensive luxury goods, as these goods have a high total value and might thus not be covered by the tax;

- Material lightness and longevity must strike a balance. A solution needs to be found which fosters greater materials use if necessary for longevity, but targets excess material use. A combination between material tax and guarantee times might be a solution;
- If recycling is to be encouraged, the materials tax should not apply to recycled materials;
- In the case of high price inelasticity for materials a combination with a waste tax or similar to reach material efficiency should be considered.

Furthermore, the following points should be taken into consideration:

- Every policy mix must take the global dimension into account. Minerals policies that lead to a reduction of extraction in Europe (without a reduction in minerals use in Europe) will increase mining outside of Europe, which is not only generally more resource and energy intense, but which requires the resources to be transported to Europe.[10] A possible strategy for this is to implement border-tax adjustments also for the environmental taxes, and not just for the materials tax;
- Any policy mix aiming at efficiency gains needs to tackle the rebound effect.

The effectiveness of the policy mix depends not only on in the effectiveness and efficiency of the single instruments and the coherence of the mix, but also on the right timing and sequencing (roadmapping) of the instruments.[17]

A sequencing approach needs to start with the less contentious instruments and those that pave the way for more ambitious instruments. A lot of the instruments will not have to be built from scratch, but rather build up leverage; so many instruments should be pushed in parallel. Nevertheless, some preparatory policy making to set the scene is necessary:

1 Information campaigns on the need and benefits for dematerialisation help increasing public understanding, an official "EU strategy for materialisation" provides a long term framework and predictability, especially for businesses. Both instruments should be implemented as soon as possible. Information needs to be provided continuously, explaining also the more ambitious policy instruments. The clearance of administrative and political obstacles – including the removal of environmentally harmful subsidies – should also start immediately, especially as this is a longer process. The support for sharing systems does not necessarily have to be financial, but may encompass facilitation, such as i.e. special parking spaces for car-sharing vehicles. While only playing a minor role for dematerialisation in total numbers the sharing economy is likely to support a paradigm shift away from a consumer and ownership culture to a user and sharing culture.

2 Increasing R&D should play a major role in upcoming budget negotiations on member state level; at EU level further funds can be distributed for the next Horizon 2020 phase from 2020 onwards. Increased R&D funds are especially important to go hand in hand with the IET&F and/or the materials tax.

3 IET&F already exist today; the task is a roadmap to increasing IET&F ever more steeply to reach a 100% internalisation of externalities in 2050. A materials tax could be developed now, introduced around 2020, increased slowly until 2030 and then steeply until 2050.

4 While also product standards exist today, highly ambitious product standards may be introduced rather later in the process.

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DYNAMIX Deliverable D8.2.2 Policy field Roadmap – The metals policy mix

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DYNAMIX PROJECT PARNTERS

5 References

1 The policy mix is developed and presented in: Ekvall, T. et al. 2015. Development of DYNAMIX Policy Mixes.Deliverable D4.2. Gothenburg, Sweden: IVL Swedish Environmental Research Institute.

[2] Umpfenbach, K.. 2013. Common Approach for DYNAMIX. Deliverable 1.2. Berlin: Ecologic Institute.

[3] IEA. 2015. World Energy Outlook 2015.

[4] SERI/WU Wien. 2014. MFA ppt slides. Available at: http://www.materialflows.net/trends/download-slides/.

[5] Tan, A. R. et al. 2014. The Underlying Reasons for Resource (In)efficiencies. Deliverable D2.2 of the DYNAMIX Project. Report for the European Commission, DG Research.

[6] This section is adapted from Ekvall, T. et al. 2015. *Development of DYNAMIX Policy Mixes.Deliverable D4.2*. Gothenburg, Sweden: IVL Swedish Environmental Research Institute.

[7] EXIOPOL. 2014. Website. http://www.feem-project.net/exiopol/scheda.php?ids=45. Accessed November 12th 2014.

[8] Trucost. 2013. Natural Capital at Risk: The top 100 externalities of business. Trucost PLC.

[9] Estimation by the author team of Ekvall, T. et al. 2015. Development of DYNAMIX Policy Mixes.Deliverable D4.2. Gothenburg, Sweden: IVL Swedish Environmental Research Institute.

[10] The findings presented in this section build on Nesbit, M.; Watkins, E.; Harris, S. (2015). Environmental assessment of DYNAMIX policy mixes. DYNAMIX project deliverable D5.1. Gothenburg, Sweden: IVL Swedish Environmental Research Institute; and especially the quantitative assessments undertaken as part of the Dynamix project Ekvall et al. (2015) and Antosiewicz et al. (2016).

[11] Ekvall, T. et al. 2015. Environmental Physical and environmental assessment. DYNAMIX project deliverable D6.1. Gothenburg, Sweden: IVL Swedish Environmental Research Institute.

[12] Bosello, F. et al. 2016. Report on Economic Quantitative Ex-Ante Assessment of Proposed Policy Mixes in the EU. DYNAMIX project deliverable D6.2. Milano: Fondazione Eni Enrico Mattei.

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

[14] Ekvall, T.; Fråne, A.; Hallgren, F.; Holmgren, K. 2014. Material pinch analysis: a pilot study on global steel flows. Metallurgical Research & Technology, 359-367.

[15] Bundesverband CarSharing. date unknown. The state of European car-sharing: final report D2.4 WP 2 of the momo car-sharing study.

Steer Davies Gleave. 2015a. Carplus annual survey of car clubs 2014/15: England and Wales (excluding London), URL: http://www.carplus.org.uk/wp-content/uploads/2015/04/Carplus-Annual-Survey-of-Car-Clubs-2014-England-and-Wales_Final1.pdf.

Steer Davies Gleave. 2015b. Carplus annual survey of car clubs 2014/15: London, URL: http://www.carplus.org.uk/wp-content/uploads/2015/04/Carplus-Annual-Survey-of-Car-Clubs-2014_London_Final1.pdf.

Steer Davies Gleave 2015c. Carplus annual survey of car clubs 2014/15: Scotland, URL: http://www.carplus.org.uk/wp-content/uploads/2015/04/Carplus-Annual-Survey-of-Car-Clubs-2014-Scotland_Final1.pdf.

[16] Gunther, M. 2014. Is sharing really green?, in Ensia magazine, URL: http://ensia.com/voices/is-sharing-really-green/.

[17] The findings presented in this section are based on Bigano, A.; Zotti, J.; Bukowski, M. and Śniegocki, A. 2015. Qualitative assessment of economic impacts. DYNAMIX project deliverable D 5.2. Milan/Venice: FEEM.

[18] Gago, A., X. Labandeira and X. López-Otero (2013). A Panorama on Energy Taxes and Green Tax Reforms. WP 08/2013. www.eforenergy.org.

[19] See Ekvall et al. (2015) (Section 4.4.1), IEEP (2011), Söderholm (2011), and ECOTEC (2001).

[20] Arrow, K.J. 1962. "The Economic implications of learning by doing". Review of Economic Studies 29, 155-173.

[21] Popp, D.; Newell, R. G.; Jaffe, A. B. 2009. Energy, the Environment, and Technological Change, NBER Working Paper No. 14832. NATIONAL BUREAU OF ECONOMIC RESEARCH. Cambridge, MA.

[22] The findings presented in this section are based on Bukowski, M.; Śniegocki, A.; Gąska, J.; Trzeciakowski, R. and Pongiglione, F. 2015. Report on qualitative assessment of social impacts. DYNAMIX project deliverable D 5.3. Warsaw, Poland: WISE Institute.

[23] Bruckner, T. et al. 2014. Energy Systems. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O. et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter7.pdf.

[24] The findings presented in this section are based on Lucha, C.; Roberts, E. 2015. Legal assessment of DYNAMIX policy mixes, Deliverable 5.4.1. Berlin, Germany: Ecologic Institute.

[25] WORLD TRADE ORGANISATION. AGRICULTURE NEGOTIATIONS: BACKGROUND FACT SHEET. AVAILABLE AT: https://www.wto.org/english/tratop_e/agric_e/agboxes_e.htm.

[26] World Trade Organization. 2016. Technical Information on Technical barriers to trade. Available at: https://www.wto.org/english/tratop_e/tbt_e/tbt_e.htm.

[27] Judgment of the Court of 24 November 1993, Criminal proceedings against Bernard Keck and Daniel Mithouard, Joined cases C-267/91 and C-268/91. Furthermore the "Cassis de Dijon" ruling may be applicable. According to this ruling, restrictions can be justified if they serve a purpose which is in the general interest and takes precedence over the requirement of the free movement of goods.

[28] The findings presented in this section are based on Vanner, R.; Bicket, M.; Elliott, B.; Harvey, C. 2015. Public acceptability of DYNAMIX policy mixes. DYNAMIX project deliverable D5.4.2. Report on governance assessment: public acceptability; London: PSI.

[29] European Commission. 2014. Standard Eurobarometer 82. Public Opinion in the European Union. First results.

[30] On consistency and coherence between policy instruments please see del Rio, P. and Howlett, M. Beyond the "Tinbergen Rule" in Policy Design: Matching Tools and Goals in Policy Portfolios. Annual Review of Policy Design 2013, 1, 1- 6; and Rogge and Reichardt. Towards a more comprehensive policy mix conceptualization for environmental technological change: a literature synthesis. 2013. Working Paper Sustainability and Innovation No. S 3/2013, Fraunhofer ISI.

[31] Note: The economic assessment and the assessment of public acceptability recommended to avoid double taxation, however, it may also be argued that double taxation is necessary to overcome certain systemic barriers: companies are likely to underinvest in environmental technology even if it would be profitable and products are usually not optimized with regard to life cycle costs. Please see Ekvall, T. et al. 2016. A systemic approach to the development of a policy mix for material resource efficiency. *Sustainability* (submitted) for further discussion of the matter.