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Policy Mixes to Achieve Absolute Decoupling: An *Ex Ante* Assessment

Emma Watkins *, Patrick ten Brink, Jean-Pierre Schweitzer, Lucile Rogissart and Martin Nesbit

Institute for European Environmental Policy, 11 Belgrave Road, London SW1V 1RB, UK; ptenbrink@ieep.eu (P.B.); jpschweitzer@ieep.eu (J.-P.S.); lrogissart@ieep.eu (L.R.); mnesbit@ieep.eu (M.N.)
* Correspondence: ewatkins@ieep.eu; Tel.: +44-20-7340-2686

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Abstract: One approach to reducing the environmental costs of economic activity is to design and implement policies that aim at decoupling economic activity from its environmental impacts. Such a decoupling requires an economy-wide approach to policy-making, through broad mixes of policy instruments that create the right framework conditions for decoupling, and which provide coherent and consistent signals to resource-using sectors of the economy. This article summarizes the *ex ante* qualitative environmental assessment of three policy mixes (over-arching, metals, and land use) developed within the DYNAMIX project, highlighting their potential impacts on raw material extraction, greenhouse gas emissions, land use, freshwater use, and biodiversity (parallel assessments addressed economic and social impacts, and governance issues). Whilst the environmental assessments largely identified positive impacts, some policies had potential for minor negative impacts. The key challenges for undertaking such an assessment are identified (including uncertainty, baseline accuracy, the differing nature and scope of policies, policy flexibility, and the challenges of implementing volume control policies). Finally, some conclusions and lessons for policy-makers are presented, to contribute to the development of future policies and improve the reliability of future environmental assessments of policy mixes.

Keywords: resource efficiency; decoupling; environmental assessment; policy mixes; raw material extraction; greenhouse gas emissions; land use; freshwater use

1. Introduction

Between 1950 and 2010, global material use per capita doubled from an average of 5 tonnes to 10.3 tonnes per year. Nevertheless, national contributions to material use differ by a factor of three between the most- (Western industrialized countries) and least- (Sub-Saharan African countries) consuming regions [1]. The Stockholm Resilience Centre [2] warns that four out of nine planetary boundaries have already been crossed, namely climate change, loss of biosphere integrity, land-system change, and altered biogeochemical cycles (phosphorus and nitrogen). The first exceeded boundary, climate change, is very likely to amplify the loss of natural capital already triggered by human activity [3,4].

Despite these threats, material use and waste generation have continued to grow [5,6], and projections do not predict that the trend will reverse without political influence [7–9]. For instance, in a modelled forecast of contemporary production against future demand and supply of different metals, it was shown that copper, zinc and nickel would become scarce within the next 40 years. In addition, the energy intensity and financial costs of extracting aluminum and copper will become uneconomical and environmentally unsustainable over the same timescale [10]. Various efforts have been made over several decades to reduce the negative environmental impacts of economic activity [11–14]. Moreover, the rate of resource extraction per unit of output is globally decreasing [5], especially in high-income countries [1].

Such a reduction of the ratio between resource input and economic output is known as "relative decoupling". However, as this does not prevent rebound effects, most of the literature is now calling for "absolute decoupling" of material extraction from GDP [15–17]. Some authors claim that the goal should be a strict decrease in resource extraction [18]—arguing that decoupling is not relevant in periods of recession—or "absolute decoupling within the limits of biocapacity" [19,20], while some focus instead on the circularity of the economy [21]. Similarly, there is a debate on the appropriate indicators to assess material flows [22]. Taking into account the tendency to shift from domestic to foreign extraction as income increases, some authors recommend a focus on material consumption rather than extraction [23]. As different products and materials have different environmental impacts, some of the literature favors indicators to assess impacts [18,24].

Decoupling has also become increasingly acknowledged in grey literature and public policy, including in the European Union [25–27] and at the international level [28–30]. However, absolute decoupling has rarely been achieved in the EU [19]. The literature on policy efficiency globally recommends policy mixes [4], with different implementation scales [31], combining market-based tools and educational instruments [15], targeting both consumption and production [8,15], as well as the different stages of the materials life cycle [32].

Therefore, achieving an absolute decoupling of human activity from environmental impacts is a huge challenge that requires an economy-wide approach to policymaking. In turn, this necessitates the development of broad mixes of policy instruments which are capable of both creating the right framework conditions for decoupling, and providing coherent and consistent signals to resource-using activities in widely different sectors of the economy [14,33,34].

In an effort to contribute to a growing agenda which aims towards absolute decoupling across a range of resources and their environmental impacts, in 2012 the European Union's Seventh Framework Program for research, technological development and demonstration funded the DYNAMIX research project—DYNAmic policy MIXes for absolute decoupling of the environmental impacts of EU resource use from economic growth. From 2012 to 2016 the project investigated how decoupling policies can be designed and implemented in the form of policy mixes. It used both quantitative and qualitative methods to assess and model the effectiveness of a set of defined policy mixes. This paper investigates three policy mixes aimed at achieving absolute decoupling: land use, metals, and overarching policy mixes. This set of policies (see Table 1) was defined in 2015 in a report which called for an *ex ante* assessment that would be in part quantitative (based on existing models), but also to a large extent qualitative [35].

Table 1. Summary of policies within each policy mix.

Over-Arching Policy Mix	Metals Policy Mix	Land Use Policy Mix
• Boosting extended producer responsibility (EPR) • EU-wide introduction of feebate schemes for selected product categories • Local currencies for labor-based services • Reduced VAT for the most environmentally advantageous products and services • Step-by-step restriction of advertising and marketing of certain products • Enabling a shift from consumption to leisure • A program to enhance skills on resource efficiency enhancement • A "circular economy tax trio"—taxes on the extraction and import of selected virgin materials and on landfilled and incinerated waste	• Green fiscal reform: internalization of external environmental costs • Green fiscal reform: materials tax • Product standards to regulate the design of specific products and components • Increased spending on research and development (R and D) • Establishment of (local) sharing systems for cars, bicycles, tools and equipment	*Production-side policies:* • A stronger and more effective environmental and climate dimension for EU land management in the Common Agricultural Policy (CAP) • Improvements to the EU National Emissions Ceiling Directive • Encouraging the establishment of Payment for Ecosystem Services programs • Regulation for Land Use, Land Use Change, and Forestry (LULUCF) • Stronger pesticide reduction targets, and guidance to farmers on integrated pest management *Consumption-side policies:* • A targeted information campaign to influence food behavior towards: reducing food waste and changing diets • Development of food redistribution programs/food donation to reduce food waste • Value added tax (VAT) on meat products

Source: [36].

In order to estimate the efficiency of policies before implementing them, the EU has undertaken *ex ante* impact assessments since 2002 [37]. *Ex ante* assessments of policy mixes for resource efficiency and decoupling are relatively rare. A few *ex ante* assessments of decoupling policies relative to land use have already been undertaken [38,39], whilst such assessments seem to be lacking for policies linked to metals or broader consumption and production structures. The present paper builds on the DYNAMIX *ex ante* assessments of land use [40], metal and other materials [41], and overarching policy mixes [42]. Within DYNAMIX, *ex ante* assessments were undertaken of the environmental impacts, economic impacts, social impacts, legal feasibility, and public acceptability of the various policies within the three selected policy mixes.

This paper draws on the results of the qualitative element of the project, and specifically the *ex ante* assessment of environmental impacts. The individual policies included in each of the policy mixes assessed are shown in Table 1. Section 2 of this article presents the approach taken within the DYNAMIX project to the assessment of the potential environmental impacts of the policies, both individually and as part of their respective policy mixes. Section 3 summarizes the qualitative *ex ante* environmental assessment undertaken. Section 4 outlines the key challenges identified during the DYNAMIX assessments for evaluating the effects of policy mixes over time. Finally, Section 5 draws some conclusions and presents a set of lessons for policy-makers to help inform future *ex ante* assessments.

2. Approach to Assessing Potential Environmental Impacts of Policies and Mixes

The core approach used in the DYNAMIX project for assessing the expected environmental impacts of each of the policies from the three mixes selected for detailed evaluation was to review available evidence on the potential impacts—*i.e.*, level of environmental improvements and evidence on decoupling. This primarily involved reviewing existing literature and case examples, to identify past impacts of similar policy approaches and estimate from that the likely environmental impacts, both positive and negative, of each individual policy. The assessments also aimed to identify the conditions necessary to generate an environmental improvement (e.g., public engagement/trust, successful implementation of other policies, funding/incentives, *etc.*), and identified the assumptions made during the course of the assessment of each policy to help put the result in context. The main focus for the assessment was on impacts related to the key DYNAMIX environmental objectives on raw material use, greenhouse gas emissions, land use, and water use (see Table 2 below). In addition, some of the land use policies were assessed for their impacts on biodiversity.

Table 2. The objectives and indicators for the assessment.

DYNAMIX Environmental Objective	Indicator
Extraction of raw materials: Reducing use of virgin metals by 80% (base 2010)	Change in the extraction of raw materials
Greenhouse gas emissions (GHG): 2 tonnes CO_2-eqivalent per capita per year	Change in GHG emissions
Land use: Zero net demand of non-EU arable land	Change in the global land requirement required for EU consumption and production
Freshwater use: No region should experience water stress	Change in the water use

Source: building on [20].

A simple qualitative scoring system, shown in Box 1, was used to identify the likely direction and magnitude of the change in each of these areas compared with an alternative future in which the instrument is not implemented. Upward arrows indicate a beneficial change (*i.e.*, reduction in the extraction of raw materials, greenhouse gas emissions, land use, water use or negative impacts on biodiversity), whilst downward arrows indicate a detrimental change. This was largely a qualitative assessment based on reviewing various literature assessing previous policies, including some quantitative elements, complemented by the evaluation team's understanding of the effectiveness of different instruments based on past evaluations and judgment.

Box 1. "Scoring" the impacts of each policy—a qualitative grading system (Source: [36]).

Estimated magnitude of change (↗ = beneficial; ↘ = detrimental):

↗↗↗↗ or ↘↘↘↘ = High (above 100% deviation from business as usual (BaU))
↗↗↗ or ↘↘↘ = Medium high (50%–100% deviation from BaU)
↗↗ or ↘↘ = Medium low (10%–50% deviation from BaU)
↗ or ↘ = Low (less than 10% deviation from BaU)

These qualitative assessments are intended to provide an overview of the potential impacts of each of the policies, and each of the three policy mixes, to demonstrate how they can help to move towards absolute decoupling. The aims were to provide an initial assessment of the magnitude of likely benefits, and to help identify which instruments, and mixes of instruments, have the greatest potential for environmental gains. This, in turn, helped to create a basis for the subsequent in-depth quantitative analysis undertaken within the DYNAMIX project [43]. It should be noted, however, that the qualitative assessments were not intended to provide directly comparable results between the policy mixes. As explained in the next section, there are various reasons why attempting a direct comparison between the impacts of the various policies is not in practice possible, or indeed helpful.

3. The Assessments

Overall, the qualitative environmental assessments carried out within DYNAMIX largely identified positive impacts from the individual policies (see Figure 1); although there are some (particularly in the land use mix—see further comment below) where potential for minor countervailing negative impacts was identified. This overall, rather positive, assessment is perhaps unsurprising, since the policies and mixes selected for the assessment were chosen for the very reason that they were likely to be successful.

The range of different expected impacts is particularly interesting. For example, with VAT on meat, given the carbon intensity of beef production [44], a reduction in demand induced by VAT is likely to have a major effect on GHG emissions as demand shifts to other sources of protein which are less carbon intensive. However, for raw materials, the net effect is unclear, as beef production is not unambiguously more or less resource intensive than other protein sources. With regard to water and land use, beef production does tend to be more resource intensive [45,46], but the difference with the production of other sources of protein is generally less significant than the differences in carbon intensity for different proteins—hence the positive, but lesser, impacts of the VAT instrument on these criteria.

The qualitative identification of the expected impacts from the policy instruments against the various environmental criteria helps to identify areas that merit in-depth assessment and policy attention. The qualitative *ex ante* assessment should, therefore, be seen as a first step in a wider assessment of which instruments can support the objectives of decoupling for different criteria, *i.e.*, a scoping phase. As noted in Figure 1, policy makers concerned about biodiversity impacts could more usefully focus on pesticide use (the policy that ranked highest in terms of positive biodiversity impacts); extender producer responsibility (EPR) can be expected to be one of the most useful policies to bring about a positive impact on the availability and security of supply of raw materials, but would have less relevance for land use, freshwater, or biodiversity policy concerns.

As noted above, it is challenging to attempt direct comparability between the assessments of different policies for the same criteria (e.g., VAT on meat and materials tax within the metals policy mix), given the different scope of the instruments considered. The DYNAMIX assessments, therefore, typically took the approach of assessing the impact in relation to the sectors and products covered by the specific policy being assessed. It should be noted, however, that this may have had the effect of ascribing higher impacts to policies with relatively limited scope; for example whilst the impact of applying extended producer responsibility to a new set of products or materials could be large for those specific products or materials, it is unlikely to be large in terms of the economy taken as a whole. This means it is potentially misleading to set the headline assessments alongside each other and invite comparisons. Figure 1 below should therefore be read as a record of the individual assessments of each policy, rather than as a tool for comparing them or selecting the most promising policies.

	(Potential) Environmental impacts				
	Raw materials	GHG emissions	Land use	Freshwater use	Biodiversity
Land use policy mix					
Information campaign on food waste	↗	↗↗	↗	↗	na
Food redistribution	↗	↗↗↗ to ↗↗	↗↗↗ to ↗↗	↗↗↗ to ↗↗	na
VAT on meat	↗ or ↘	↗↗↗ to ↗↗	↗↗ to ↗	↗ to ↗↗	na
An improved CAP	↗	↗↗	↗ or ↘(?)	↗	↗↗
An improved NEC Directive	↗	↗	↗	↗↗	↗
Payment for Ecosystem Services	↗	↗	↗ or ↘	↗	↗↗
LULUCF regulation	↗ (?)	↗↗	↗	↗ (?)	↗
Pesticide reduction and guidance*	↗	↗ or ↘	↗ or ↘	↗	↗↗↗↗
Metals policy mix					
Internalisation of environmental costs	↗↗	↗↗	↗	↗↗	na
Materials tax	↗	↗	↗	↗	na
Sharing systems	↗	↗	↗	↗	na
Increased R&D spending	↗↗	↗↗	↗	↗	na
Product standards	↗↗	↗↗	↗	↗ to ↗↗	na
Overarching policy mix					
Skills enhancement	↗	↗	↗	↗	na
Consumption to leisure	↗	↗	↗	↗	na
Restricting advertising	↗↗	↗↗	↗↗	↗↗	na
Local currencies	↗ (?)	↗ (?)	↗ or ↘(?)	↗ (?)	na
Circular economy tax trio	↗↗	↗	↗	↗	na
Feebate schemes	↗	↗↗ to ↗↗↗	↗	↗	na
Reduced VAT	↗ to ↗↗	↗↗	↗	↗↗	na
Extended producer responsibility	↗↗↗	↗↗	↗	↗	na

Key:
Likely very positive
Likely positive
Likely somewhat positive
Assessment uncertain

*NB Also assessed as ↗↗↗ for soil functionality and ↗↗↗↗ for water quality

Figure 1. Overview of the qualitative environmental assessments. Source: developed from [36].

The alternative approach, of assessing all measures on their impacts at an economy-wide level, would have had the alternative drawback of preventing a nuanced summary of the impacts of measures which are only intended to affect a limited number of products or sectors. However, the DYNAMIX assessment has suggested that the impacts of most individual policies are likely to be fairly modest: there are few magic bullets, even given the likely optimism bias of the research team. Thus, the impacts of the policy mixes and comparison between them must be considered with reference to the size of the sectors or products which they address.

Although each individual policy in each of the three policy mixes has been assessed, it remains difficult to draw conclusions on the interactions between policies, given the various uncertainties and assumptions involved. Nevertheless there are some policies, for example, skills enhancement in the overarching mix, or increased spending on research and development in the metals mix, which are clearly aimed at enabling greater impacts from other policies within their respective mix.

The following sections summarize some of the most interesting and policy-relevant findings of the qualitative environmental assessments of the policies. The full assessments are available as DYNAMIX project deliverable D5.1 [36].

3.1. Land Use Policy Mix

Land use change is a major driver of climate change [47], reduction in water quality [48] and biodiversity depletion [49,50]. While FAO [51] estimates that food production will have to increase by 70% between 2009 and 2050, it has to compete with other land uses, including bioenergy crops, mineral extraction and fiber production. There is significant research on the methodology of land use change assessment and modelling [38,52,53], in particular looking at the European Union [54–57]. While some argue that intensification of agricultural processes in low income countries is the key [58], others emphasize the importance of diet [59], although recognizing that meat consumption is relatively inelastic to price changes [60]. Many authors underline the effects that European policies have outside the EU [55], as well as a significant shift of agricultural lands from developed to developing countries [56], in spite of decreasing self-sufficiency in the latter [59].

Most of the production-side policies in the DYNAMIX land use policy mix (in principle, those most directly affecting land use itself) are characterized in the assessment by low, or in some cases ambiguous, impacts on both land use and greenhouse gas emissions. On the one hand, this is due to the scale of the trends being addressed; the likely land use impacts tend to be marginal, even over longer periods, in comparison to the overall scale of agricultural land use, particularly given the global nature of trade in most agricultural products. On the other hand, the relatively low level of impact is due to the feedback issues identified above in relation to reduced productivity and reduced production.

The proposed policy to improve the NEC Directive (which would include a progressive tightening of emissions targets, enhanced regulation of Member States' emissions, action under the CAP to incentivize compliance, and additional Member State action to reduce emissions to air and water) was assessed as one of the policies most likely to have a beneficial impact, in particular through reduced water pollution from nitrates and improved air quality (through a reduced incidence of acidification and reduced tropospheric ozone concentrations). These impacts are likely to have associated benefits for biodiversity; for example Stevens *et al.* [61] identified a broadly linear function of inorganic nitrogen deposition and plant species richness in UK grasslands. Exposure to high ozone concentrations reduces rates of photosynthesis in plant species [62].

The impacts from consumption-side policies within the land use mix need to be treated with caution, since they have been assessed largely on the basis of the impacts associated with the targeted products, rather than wider impacts from agricultural land use. However, they seem to provide initial signals that consumption policies are potentially the most beneficial (albeit likely to be those which face greatest levels of initial public acceptability challenges).

For example, the food redistribution policy was assessed as having considerable potential with regards to its impacts on greenhouse gas emissions, land use, and freshwater use, since it has the potential to significantly reduce food waste. Food waste creates direct environmental damage through emissions associated with waste treatment; it has been estimated that each tonne of food waste prevented results in 4.2 tonnes of CO_2-equivalent (CO_2e) emissions avoided compared with landfilling, or 500 kg avoided for each tonne processed through anaerobic digestion [63]. In addition, food waste represents a significant waste of the natural resources used in food production. Regarding greenhouse gas emissions, the global carbon footprint of food produced and not eaten has been estimated at 3.3 billion tonnes of CO_2e, making food loss and waste the third top emitter of greenhouse gas emissions after the USA and China [64]. With regard to land and freshwater use, the FAO [64] has estimated that around 1.4 billion hectares of land (only a little less than the total land area of Russia) and around 250 km^3 of water are used annually to produce food that is subsequently lost or wasted [64]. Reducing food waste arisings could, thus, bring about reductions in the greenhouse gas emissions, land use and freshwater use associated with food production, if less food needed to be produced due to reduced wastage resulting from the food redistribution and donation policy. However, finding the best approaches to reducing food waste in practice remains challenging, since it requires significant adaptation of consumer behavior; policy experimentation is, therefore, likely to be essential.

3.2. Metals Policy Mix

Metals are a finite resource, and metal extraction saw the highest growth rate of all material used between 1980 and 2002 [5]. Moreover, the demand for industrially-important metals, such as steel, is expected to at least double, and aluminum triple, globally, by 2050 [65,66]. With the current technology, the entire stocks of zinc and copper would be needed to provide to the global population with the services so far enjoyed by highly-industrialized countries [67]. More than potential scarcity, the main threat lies in the ability to achieve the 50% reduction of GHG emissions between 2000 and 2050 required to meet the target of stabilizing the global mean temperature rise to 2 °C above preindustrial levels [65]. If sectors were to contribute proportionally, the aluminum industry would have to achieve an 85% reduction in its emission intensity. Recycling aluminum from post-consumer scrap could improve energy intensity by 90% [66] but like other metals, recycling potential is dependent on in-use stocks, so other strategies, such as the reduction of primary material output, should be supported simultaneously [65].

Within the metals policy mix, many of the instruments considered are generic approaches that can theoretically be applied to a range of products and sectors. The implementation challenges of, for example, the full internalization of environmental costs were not addressed in detail in the DYNAMIX assessment, and can be assumed to add an element of uncertainty to the political acceptability issues already addressed in the policy mix. The metals mix relies more explicitly than the other two mixes on the synergies between policies, since several of the policies will work simultaneously on the same sectors of the economy, potentially resulting in cumulative impacts which could be mutually reinforcing. The qualitative assessments suggest that each of the policies in this mix has the potential for modest positive environmental impacts, in particular in terms of raw material use and greenhouse gas emissions. This is due in large part to a potential reduction in material extraction and demand for virgin metals that should result from increased reuse and recycling of metals that should result from the policies assessed.

For example, the DYNAMIX policy on product standards proposes the development of standards to regulate the design of specific products and components, for example, standards to improve modularity to increase reparability and reuse of components, to reduce the unnecessary use of material, and use alternatives to metals when appropriate (e.g., shifting from copper water-piping to polymer piping) [36]. The aim of the policy is, therefore, to reduce the use of virgin metals through product redesign, increased longevity, and increased recycling. It has been estimated that around 80% of a product's environmental profile is set during the concept creation stage [68]. If product standards were to include requirements for recycled material content, this could drive material savings and reduce greenhouse gas emissions; for example recycling source-segregated waste could save up to 8143 kg CO_2e per tonne of aluminum cans and foil collected [69], whilst recycling PET fibers from plastic bottles offers 40%–85% non-renewable energy and 25%–75% material savings [70].

3.3. Overarching Policy Mix

Research into reducing the environmental impacts of economic activity has typically considered both production and consumer orientated policies. There are disagreements as to which aspect should be the primary focus of environmental policy. Supporters of consumer-orientated policies, such as labelling or consumer awareness campaigns, recognize that a "critical mass of informed, ecologically conscious consumers can apply pressure on producers" [71]. Neoliberal economic thinking might also err away from market restrictions, leaving the onus on consumers to make informed choices. In contrast, presenting the consumer as the most important agent in the market is not without its risks [72]. Akenji [71] describes this as "consumer scapegoatism", arguing that a market of supposedly ecologically certified or efficient products might not necessarily result in reduced negative externalities, for example if there is an absolute increase in overall consumption. However, some analyses have identified real opportunities to reduce externalities, such as GHG emissions, through consumer choice [73,74]. For example, Girod [73] identifies a range of between five and 17 tonnes of CO_2e between high and low consumption households in Switzerland. Lorek and Spangenberg [75] recognize that sustainable production and consumption systems are needed. They argue that sustainable consumption cannot be limited to consumers, as this considers just one part of the product chain. Like other research on efficiency, as well as life cycle analysis, opportunities exist across product chains [74]. The policy mixes considered within the DYNAMIX project were identified in order to consider multiple aspects of the economy—thus, avoiding an explicit focus on either production or consumption policies.

Many of the policies within the DYNAMIX overarching policy mix are, by design, fairly generic approaches which can be applied to a range of individual products (for example feebate systems, producer responsibility, and restrictions on advertising). Impacts are therefore linked to the range of products to which they can be applied in practice, and are also likely to be highly dependent on feasibility, and on public acceptability. It should be noted that the qualitative environmental assessments of several of the policies were made on the basis of the specific product groups to which the particular policy would be applied, which may have resulted in slightly more optimistic assessments than would have been the case if the impact had been assessed at the scale of the European economy as a whole. In addition, it was typically assumed that the policies would gain public support and would be successful to at least some degree in achieving their aims. For example, the assessment of restricting advertising for certain products may be overly optimistic, since it assumed that it would both be possible to restrict advertising on resource-intensive and luxury goods (such as sweets, fast food, jewelry, and sports cars), and that this would have a discernible impact on consumers' choices resulting in reduced purchase of such items and/or the purchase of more sustainable alternatives.

On the other hand, the positive assessments of some of the policies which have already been tried and tested to a certain extent are more easily justified. For example, extended producer responsibility has already proved to be successful for product groups including waste electrical and electronic equipment (WEEE) and end-of-life vehicles (ELV). Evidence exists that EPR can lead to reduced raw material extraction. The full implementation of the WEEE Directive is estimated to result in a reduction of 131–340 kilotons of lead per year in the EU [76], whilst the first eight years of operation of the European Recycling Platform (2005–2013) saw the collection of 2 million tonnes of WEEE, equating to the recovery of 16 tonnes of gold, 130 tonnes of silver, and 160,000 tonnes of copper [77]. In 2007, 28 tonnes of platinum and 31 tonnes of palladium were recovered worldwide from automotive catalysts, representing almost 15% of the global mining production [78]. It is, therefore, reasonable to assume that if carefully designed and appropriately applied to additional product groups, such as graphic paper and oils, extended producer responsibility could generate additional positive environmental impacts. Studies have already indicated that EPR schemes for graphic paper and industrial oils can lead to recycling rates of over 80% for both materials [79]. One gallon of used oil can be processed to produce 0.25 gallons of new high-quality lubricating oil (as opposed to 42 gallons of crude oil required to make the same quantity, albeit alongside a range of other products) [80]. However, as noted above, the impacts may not be of the same magnitude as those for the product groups already targeted (on the assumption that the initial targeted products were chosen on the grounds of being particularly well-suited to the policy).

4. Challenges in Assessing Potential Environmental Impacts—and How to Address Them

There are numerous challenges when assessing the potential environmental impacts of a policy in an ex ante manner. This section identifies some of the key challenges that were identified during the DYNAMIX *ex ante* assessment, and outlines how the assessment attempted to address them to provide as reliable an assessment as possible of each of the individual policies, and of the three policy mixes.

4.1. Uncertainty

One of the key challenges identified during the DYNAMIX *ex ante* environmental assessment is the various drivers of uncertainty in the impact of policies. These include governance challenges, both in terms of the legal feasibility of introducing a policy, and in terms of the public acceptability of the policy, both of which are likely to have a significant impact on the implementation and effectiveness of an individual policy. In addition, such governance challenges depend in turn on the likely (or perceived to be likely) economic and social impacts, which may vary from country to country based on specific national conditions. Similarly, the perception of potential economic impacts depends on the existing and future economic conditions in which the policies will need to operate. This introduces another area of uncertainty, since economic developments can only be predicted to some degree. An additional complication is the existence of multiple layers of governance; individual EU countries function within the wider European economy [81], which functions within the global economy, and additional uncertainty and complexity is added at each level.

Uncertainty over the feasibility of a specific policy in a specific context can be particularly difficult to predict. Prior to agreement being reached on the finer details of a policy's design, and prior to the testing of its implementation in practice, it is difficult to predict how feasible it will be to implement. In several cases (e.g., the broader application of extended producer responsibility policy in the overarching policy mix), the DYNAMIX environmental assessments assumed that it will be possible to implement policies before assessing their impacts. This is a valid simplification, since a detailed assessment of deliverability was left to the separate governance assessment. In some cases it is proposed that existing policies be extended to new sectors. It is worth noting that the existing policies are likely to have targeted the sectors where implementation is easiest and where the outcomes will be the most successful. This means that extending policies into new sectors may lead to relatively disappointing results in the new sectors targeted.

In the case of many of the policies selected for the DYNAMIX *ex ante* environmental assessment, there are also uncertainties over the nature and extent of the potential impacts, beyond the immediate first order effects targeted by the policies. One example of this problem is reducing the environmental footprint of land use in the EU, particularly in the agriculture sector. Many of the policies developed by DYNAMIX imply, or create risks of, reductions in the level of production. Even if a reduction in consumption is achieved (in response to the consumption policies which are also included in the land use mix), there would be an opportunity cost to that reduced production, and the impact on the global supply and demand of agricultural products needs to be taken into consideration. This could potentially have impacts through expanded land use in other economies (*i.e.*, displacing production to non-EU countries). Similarly, reduction in EU demand for metals may lead to reduced commodity prices, creating the potential for increased consumption elsewhere. One possible lesson to draw from this is that—as with climate change—the full benefits of resource efficiency policies, and their full cost implications, are likely to depend on the extent to which similar policies are adopted in other economies in the world.

There is also a difficulty in reliably identifying the behavioral responses that will result from the introduction of new policies. In some cases, it is possible that the introduction of a policy will not gain enough broad support to actually result in the amount of behavioral change needed to create a significant environmental impact. In the absence of clear evidence, for example on cultural attitudes to resource efficiency, it is, therefore, difficult to accurately predict whether enough of the target audience for a policy will change their behavior to bring about the desired level of environmental improvements.

4.2. Baseline Accuracy and the Differing Nature and Scope of Policies

In general terms, it is difficult to ascertain the potential impacts of a wide-ranging policy mix against a stable economic background, when the purpose of that policy mix is precisely to alter the economic background, at least in a qualitative assessment (some quantitative models are able to take into account economic changes to a greater or lesser degree).

The policies selected for the DYNAMIX *ex ante* environmental assessment vary in their nature, and in particular in their scope. Some of the policies are particularly targeted at specific products, for example boosting extended producer responsibility for products where it is already applied (e.g., waste electrical and electronic equipment, end-of-life vehicles, packaging, and batteries) and extending it to other product groups (e.g., tires, graphic paper, waste oils, children's toys and construction materials). Other policies are aimed at specific sectors, for example applying VAT to meat products. Still others have a broader, in some cases economy-wide, scope, such as taxes on landfill and incineration. It is difficult—and perhaps not even desirable in this, case given these differences in scope—to attempt a direct comparison of the potential impacts of policies that have such varying levels of ambition and potential magnitudes of impact on economic activity.

In some cases, it is also difficult to establish a reasonably fixed baseline to use to ascertain the impacts of the individual policies within a policy mix. Baselines can be established in various ways, for example attempting to include the impacts of other policies within the mix in the baseline-setting (which is likely to add to the uncertainty of the baseline), or focusing only on the status quo with regards to the target product or economic sector of the policy being assessed. Various assumptions are also necessary to undertake an assessment, for example assumptions on whether the policy will be successfully and fully implemented. Within the DYNAMIX qualitative environmental assessment, a pragmatic approach was taken to the establishment of the baseline for assessing each policy. In cases where a policy was focused on a particular product or sector, the baseline was typically taken as only that product or sector, whereas for policies that could impact upon the wider economy, the baseline was broader. In addition, it was typically assumed that the policy would be successfully and fully implemented, reaching all of its stated targets and objectives. It should be noted that in reality, this is rather unlikely to be the case.

When policy implementation is likely to create significant impacts outside the EU, it can be significantly more difficult to identify, assess, and value such impacts. This is particularly true for European resource flows, including those covered by the DYNAMIX project, as they are often dependent on third country inputs. Examples include the land use implications of policies leading to improved environmental performance but reduced productivity on EU farmed land—which, in the absence of a simultaneous reduction in EU consumption, creates pressures for increased production (and environmental cost, including deforestation) elsewhere. Likewise, resource efficiencies in one sector may provoke inefficiencies in other sectors, for example where competition for substitute resources increases. For these reasons, there is a need to apply pragmatism when defining boundaries, as well as in determining the attention which should be given to environmental impacts outside the system under analysis (such as those outside the EU Member States). On the issue of extra-EU impacts, whilst the DYNAMIX assessments focused mainly on European markets, where impacts outside of the EU were identified, the approach taken was to note their potential to mitigate the environmental benefits experienced within the EU; although the extent of that mitigation could not be identified. This approach naturally added some limitations and uncertainties to the assessments, as more often than not markets and environmental impacts are transboundary and interrelated. Further work to develop mechanisms for reliably estimating the short-run and long-run impact of such extra-EU impacts would be valuable.

4.3. Flexibility of Policy

One response to the problems of uncertainty identified above is to build a degree of flexibility into policies and policy mixes, to ensure they can be flexible to a range of responses. In this way, policies can recognize, and to some extent take into account, both the difficulty of predicting behavioral responses and the reality of the democratic process. Similarly, in order for absolute decoupling to be achieved resource use must decline irrespective of the growth rate of the economy [29]. This means that, for growing economies or sectors, resource productivity must increase at least at the same rate. The future state of markets is difficult to anticipate, and dependent on variables beyond the policy mix itself. There is a risk that during periods of economic downturn (such as the major global financial crisis in 2008), reduced output can be confused with decoupling. Consequently, policy mixes must integrate some degree of flexibility from the onset in order to respond to external signals.

Each of the DYNAMIX policy mixes has some elements designed to have an immediate impact, and others designed to ensure a gradual change in attitudes, taking a pragmatic approach to the challenge of developing the range of policies needed to secure a sufficient shift in resource efficiency. Other policies are capable of being progressively made more ambitious, to allow them to respond to greater political feasibility when it comes about.

One disadvantage of allowing flexibility in approaches, however, is that it makes it more difficult for the private sector to predict what is likely to be required in terms of innovation within products and processes. Consideration is therefore needed in many cases as to whether a clear direction of travel can be indicated, for example through over-arching policy statements, or by enshrining specific resource use objectives in legislation.

4.4. Volume (Quantity) Control

Perhaps the most significant challenge for addressing resource efficiency and the need to live within planetary limits via policy mixes is the difficulty of developing mechanisms to manage the volume of resource consumption. Environmental policy is largely built around mechanisms to control quality, such as minimum requirements for the safety and environmental impact of products, or controls on the emissions from production facilities.

Whilst volume control instruments have been developed in some areas (for example the EU Emissions Trading System for greenhouse gas emissions and the National Emissions Ceilings Directive), it has only been possible so far where governments are able to both monitor and exercise regulatory control. In effect, these are volume control instruments that have been added to existing mechanisms for quality control. It is much more challenging to design constraints on the overall volume of raw materials and other resources used in the economy, since this implies a significantly greater degree of government influence over the inputs to production processes. Furthermore, placing absolute limits on markets is highly controversial and arguably conflicts with existing overarching socio-economic priorities to generate economic growth. Many recognize existing contradictions and difficulties of ongoing political objectives for economic growth within a planet of finite resources and already stressed environmental thresholds [34,82,83].

Exploration of new options for volume control policies would therefore be useful. These could for example be based on monitoring of resource use, with pre-identified indicative trajectories consistent with resource efficiency, or with triggers set in legislation for the introduction of more constraining policies or higher taxes if particular levels of resource use intensity are crossed.

5. Conclusions and Lessons for Policy-Makers

Following the qualitative environmental assessments undertaken within DYNAMIX, several conclusions can be drawn with regards to lessons for policy-makers and areas for additional research in the future.

A purely programmatic approach to future policy development is unlikely to be sufficiently responsive to medium-term changes in the underlying economy, cultural attitudes, political acceptability, and technological feasibility that will affect the implementation of the various policies proposed. On the other hand, a more flexible approach runs the risk of failing to provide adequately reliable signals to private operators to predict what is likely to be required in terms of innovation within products and processes. This may mean they are reluctant to take the actions that are necessary, from the policy-makers' point of view, to achieve the desired environmental outcomes of the policies. It can, therefore, be recommended that a focus be placed on creating the conditions for culture and behavior change, for example by rewarding positive innovations and penalizing inefficient uses of resources. This, accompanied by clear principles, for example in over-arching policy statements or through enshrining specific policy objectives for resource use in legislation, could provide clarity of direction and give the policies the best possible chance of achieving their environmental goals.

Since policies that attempt to control volumes (e.g., volumes of material extraction or production) are currently rather limited, it could be useful to examine additional options for approaches to volume control policies. These could, for example, be based on monitoring of resource use with appropriate indicators, accompanied by indicative trajectories that are consistent with resource efficiency and are identified in advance. Another option would be to include triggers in legislation (which would be activated if measures of resource use or other key indicators exceeded a pre-defined level) that would then lead to the introduction of more constraining policies, or higher levels of resource taxes.

Future assessments of the environmental impacts of policies should, as far as possible, aim for a greater level of consistency between the approaches taken in assessing policies, in particular with regards to clarifying how baselines should be developed, and attempting to achieve similar approaches in assessing the magnitude of impacts (for example, whether impacts should be assessed on the basis of the limited number of products affected by a policy, on a wider sectoral basis, or on the economy as a whole). The main value of the DYNAMIX *ex ante* assessments lies in the detailed information they provide in relation to each policy; future assessments, in particular assessments of policies that are already in their implementation phase, could perhaps provide more robust comparisons between the impacts of various policies and policy mixes. The scaling of both the required resource productivity and environmental impacts in relation to wider global objectives is critical to implementing adequate policies for decoupling.

The accuracy of environmental policy assessments can also be improved by taking into consideration other issues affecting the conditions for implementation of the policy mixes. Implementation is dependent, to some extent, on securing a greater degree of public acceptability and political feasibility of the policy option being considered. In some cases, the overall mix of policies may be as important, if not more so, than the individual policies within the mix. Some policies may be either a necessary precursor to, or likely to contribute significantly to the success of, other policy options, so in some cases it will be useful to identify the sequence of policies that is likely to be most effective in delivering the full advantages of the mix. In addition, measures to mitigate potentially negative economic, social, or public acceptability impacts can help to ensure the successful implementation of policies, and therefore to ensure the best possible environmental outcomes from those policies.

Finally, it may also be valuable to consider whether responses are available to some of the general assessment issues identified above (uncertainty; the need for flexibility; and the challenge of achieving volume control), and to consider whether significantly different outcomes are likely in the event of other economies outside the EU either pursuing, or failing to pursue, similar policy approaches. With this in mind, it would be valuable to carry out additional work to develop mechanisms for reliable estimates of the short-term and long-term impact of environmental impacts outside the EU that result from EU policies.

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Abbreviations

The following abbreviations are used in this manuscript:

BaU	business as usual
CAP	Common Agricultural Policy
DYNAMIX	DYNAmic policy MIXes for absolute decoupling of environmental impact of EU resource use from economic growth
EPR	extended producer responsibility
EU	European Union
GHG emissions	Greenhouse gas emissions
LULUCF	Land Use, Land Use Change and Forestry
NEC Directive	National Emissions Ceiling Directive
R and D	research and development
VAT	value added tax

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