European Network of the Heads of Environment Protection Agencies (EPA Network) - Interest group on Green and Circular Economy

– Discussion paper –

Input to the European Commission from European EPAs about monitoring progress of the transition towards a circular economy in the European Union

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Graphics

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1. Introduction

Main message: This paper provides input to the European Commission for their framework for monitoring progress of the transition to the circular economy. Our contribution builds on the Resource Efficiency and Raw Materials Scoreboards, but supplements this with elements we regard as relevant for measuring of the circular economy transition. The relevance of our input is anchored in the national experiences of EPAs with working on the interface between environmental science and policy-making on a national member state level.

In 2015, the European Commission adopted an action plan[1,2] to move to a circular economy in the European Union. Circular economy is rooted in various concepts that aim to close product cycles (including materials and substances). A currently prominent definition of the circular economy, as also used by the European Commission[1], is provided by the Ellen MacArthur Foundation[3].

The European Commission[1,2,4,5] sees the transition towards a circular economy as an opportunity to modernise and transform the European economy on its way to sustainable competitiveness, bringing benefits for both the environment and economy. The action plan is an implementation of the European Union's 2020 strategy flagship initiative for a resource-efficient Europe[6]. The primary effects aspired with the circular economy transition concern resources supply security (notably of critical raw materials) and resources efficiency (notably of raw materials), resulting in decreasing absolute quantities of resource flows (see Figure 1). Resource supply security and resource efficiency should go hand in hand with increasing socio-economic gains and declining environmental pressure in absolute terms.

The European Commission's action plan for the circular economy closely ties to several key policy areas in the European Union that should all be in line with the 7th European Action Programme (7th EAP)[1,2,4,5,6]. The 7th EAP explicitly points to the circular economy as its long-term vision to accomplish 'Living well within the limits of our planet' in 2050. This 7th EAP's vision implies that planetary boundaries should be taken into account in the implementation of the transition towards the circular economy.

A recent study[7] indicates that some planetary boundaries have already been exceeded, and that the per capita contributions from the European Union and its Member States are significantly larger than global averages. Furthermore, in many places, present resource use (e.g. raw materials, water, land) and related environmental impacts (e.g. air pollution, climate change, biodiversity) significantly exceed their regeneration capacity [8,9,10]. The 7th EAP, therefore, calls for absolute decoupling of economic growth from resource use (notably of raw materials), and from the environmental pressure caused by production and consumption.

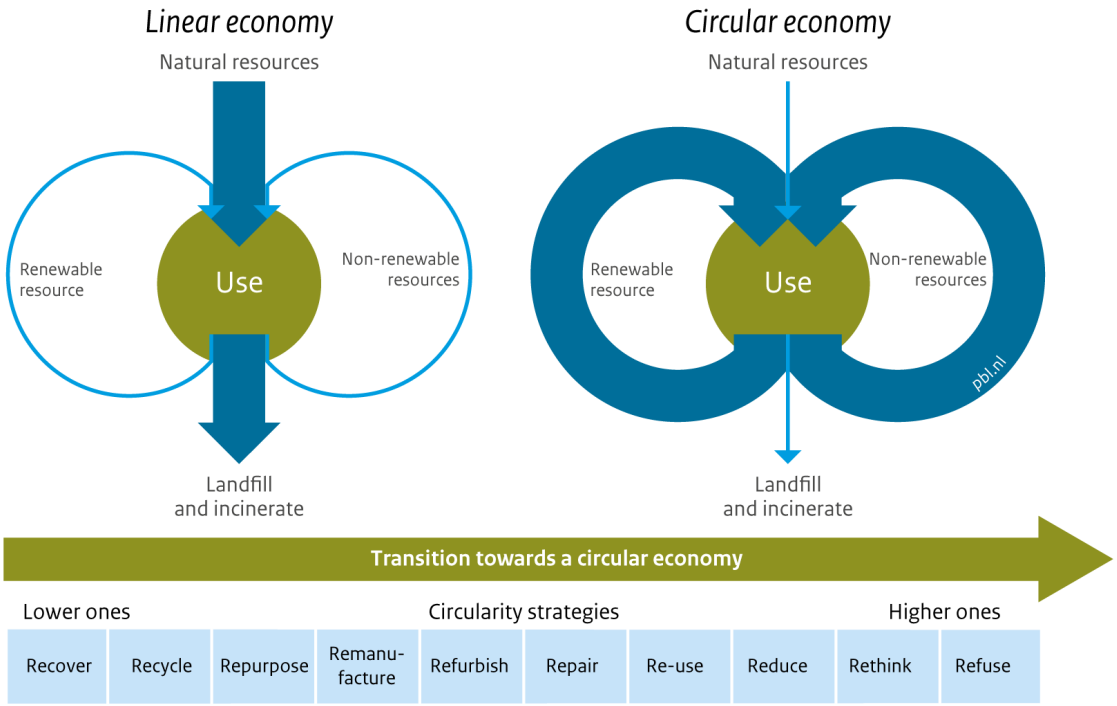
The European Commission's action plan for the circular economy announced that, this year, it will present a circular economy monitoring framework. A draft version of this circular economy monitoring framework became available after rounding up the work for this discussion paper. This discussion paper is written against the background of information that the European Commission would draw its indicators from both the Resource Efficiency Scoreboard[11] and Raw Materials Scoreboard[12]. The Resource Efficiency Scoreboard calculates relative decoupling using productivity indicators (e.g. gross domestic product divided by domestic resource use). Both scoreboards, however, lack indicators for absolute decoupling which would allow for checking if absolute quantities of resource flows decrease. Both scoreboards also lack footprint indicators that allow for checking whether the burden is shifted to outside the European Union. Furthermore, both scoreboards hardly contain indicators to facilitate assessing the progress in

implementing measures needed to achieve the circular economy transition, i.e. the transition process. The Eco-Innovation Scoreboard, as part of the Resource Efficiency Scoreboard, monitors progress in technological innovation. Recent and upcoming publications[13,14], however, point to the importance of social and institutional innovations and changes for the circular economy transition. These innovations and changes are important part of the transition process, and it is essential to be able to also keep track of them as to inform the transition process. Last but not least, many indicators in both scoreboards only allow for measurements for the aggregate level of the European Union and its Member States (including Norway and Switzerland in the rest of the report), but not yet for specific products. It is useful to have comparable data on the level of the European Union and its Member States, but information on the level of products is also needed.

This discussion paper proposes a broadening of the European Commission's monitoring framework, building on the Resource Efficiency Scoreboard and Raw Materials Scoreboard on the one hand, but addressing the before mentioned issues in addition. We propose amongst others including indicators, particularly those related to the transition process, that will partly not be measurable in the short-term, but need to become measurable in time. This will lift the monitoring framework from measuring compliance, to also facilitate learning needed for accomplishing the circular economy transition. The relevance of our input is anchored in the EPA experience of working on the interface between environmental science and policy-making on the Member State level, but extending also to the international level, i.e. cross Member States and the European Union).

Chapter 2 explains the structure of the monitoring framework, Chapter 3 discusses indicators for measuring the transition process, whereas Chapter 4 addresses indicators for measuring the effects on resource use, and the economy and environment. Chapter 5 summarises some main points.

Figure 1
From a linear to a circular economy



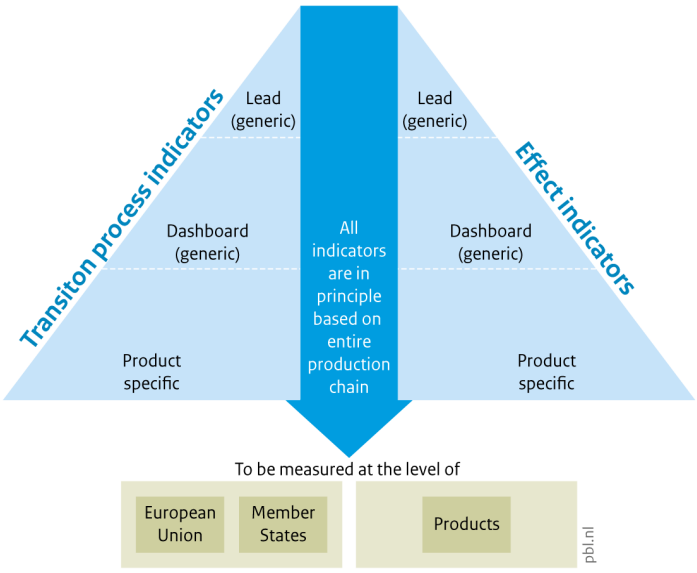
Source: PBL 2016

2. Monitoring structure

Main message: The proposed monitoring structure, summarised in Figure 2, consists of three tiers. The two top tiers cover generic lead and dashboard indicators. The third tier contains product-specific indicators. Each tier contains indicators for monitoring the transition process as well as its effects. Both types of indicators, unless irrelevant, must relate to the entire product chain. They should also be measurable on the level of the European Union, Member States, and products. Setting quantitative targets may provide direction to stakeholders about how to shape the transition process, and to assess progress towards the circular economy.

The overall circular economy transition in the European Union and its Member States will be the sum of many specific circular economy transitions on a product level. Product-specific measures, as well as measures on the level of Member States and the European Union are needed to achieve more circularity in product chains. Figure 1 provides a hierarchy of circularity strategies where, as a rule of thumb, higher circularity strategies increasingly reduce resource consumption and environmental pressure by increasingly lowering the amount of products and primary materials being needed (i.e. needed to be manufactured and produced). The retained economic value preferably also increases with higher circularity strategies. It should be noted that recycling (notably low-grade recycling), which is part of the circular economy, is still close to a linear economy. Hence, a circular economy transition requires moving beyond mere waste management and recycling and should focus on making and using products in a smarter way, and on keeping products and their constituting components and materials longer within the economy by means of the circularity strategies in Figure 1. Lower circularity strategies nevertheless also remain relevant in combination with higher circularity strategies (see Chapter 3). Further, the use of bio-based resources may increase to replace non-renewable with renewable materials in products. Such bio-based products should also follow the hierarchy of circularity strategies in Figure 2. Some food sources can be rethought (e.g. by considering alternative protein sources), and food waste as well as other bio-waste can be reduced in several ways (e.g. by using left-overs for feed or sharing left-over meals).

Figure 2
Proposed monitoring structure circular economy

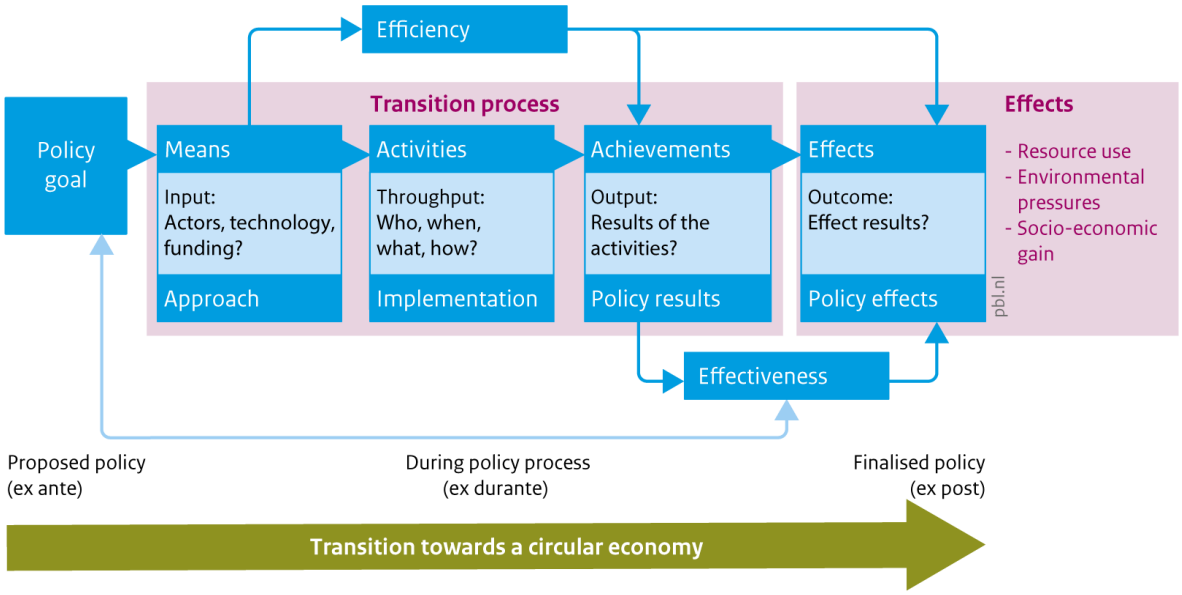


Source: PBL

Implementing a circularity strategy will take time, i.e. more high-grade recycling and people sharing products, and it will also be a while before effects from implemented circularity strategies become visible. Therefore, it will be necessary to monitor the progress in implementing circularity strategies and the measures needed to achieve this (i.e. the transition process; see Figure 3 and Chapter 3), in addition to measuring the effects of the transition process on natural resource consumption (raw material consumption) and on the economy and environment (see Chapter 4). Monitoring the transition process enables assessment of the implementation of the measures needed to achieve a circularity strategy (e.g., monitoring the number of repair shops as a proxy for the diffusion of repairing practices). Hence, it is important to consider (proxy) indicators that are relatively easy to be measured, and which give an indication of the rate of implementation of circularity strategies and all measures needed to achieve that (see Figure 3).

Figure 3

Policy assessment framework for measuring the progress of the transition towards a circular economy



Source: Netherlands Court of Audit 2005; edited by PBL

Similar as the Resource Efficiency Scoreboard[11], the circular economy monitoring framework in this discussion paper builds on a three tiers approach (lead, dashboard, and product-specific indicators). The first two tiers include a core set of generic indicators relevant for all products. The third tier includes indicators relevant only for specific products (e.g. critical raw materials for information technology). All indicators, in principle, should be quantifiable at the level of the European Union, Member States and products (meaning indicators with the same nominator, but differing denominators at each level; see Figure 2 and Appendices 1 and 2). All indicators should, unless irrelevant, encompass the entire product chain. For effect indicators, this means evaluating the effect footprints, especially in order to avoid shifting burdens to outside the European Union. In case of indicators for the transition process, this involves looking at the entire product chain (e.g. looking if all relevant actors in a product chain cooperate in achieving a given circularity strategy). For some indicators, however, it will be less relevant to cover the entire product chain (e.g. an indicator for repair that represents 'just' part of a product chain).

Appendices 1 and 2 provide suggestions for lead and dashboard indicators that are elaborated in Chapter 3 and 4. The monitoring structure and the included indicators should strive for complying with the RACER-

principle put forward in the Raw Material Scoreboard[12]. RACER stands for Relevant, Accepted, Credible (i.e. for interested groups), Easy (to compute and to understand), and Robust.

It is worth mentioning that the European Commission has not yet set quantitative targets for the circular economy transition, beyond waste management targets. Such complementary targets could help stakeholders in setting priorities in the transition process, benchmarking the progress of the circular economy transition against the political agenda, facilitate comparative research on successful measures and single out best practices[15]. Quantitative targets, e.g. reduction targets compared to a base year, could at minimum be put in place for the lead indicators (see Chapters 3 and 4).

3. Transition process

Main message: The transition process towards the circular economy takes time. It will therefore take a long time before a circularity strategy is achieved and its effects become apparent. Monitoring the progress of the transition process is therefore important to see if the right things are happening and the circular economy transition is moving in the right direction, or whether additional measures are needed. We propose measuring the shift from lower to higher circularity strategies, possibly in one consistent indicator, as lead indicator for the transition process. Further efforts are needed to pinpoint dashboard and product-specific indicators, and to make indicators for the transition process in all three tiers operational.

Monitoring the transition process is important to assess the direction and pace of the implementation of measures needed to achieve a circularity strategy. The focus is here thus on the transition process itself, rather than only on the effects it will produce (see Figure 3). This differentiation is important, because the transition process may require a certain period, even years or decades, before a circularity strategy is achieved and its full effects on resource use, environmental pressure and socio-economic gain become apparent. Monitoring progress of the transition process can give an indication of whether the right things are happening and if the circular economy transition is on its way, or whether additional measures are needed. This also facilitates deeper learning about the way to organise the transition process.

As mentioned before, the actual circular economy transition should lead to closing cycles at the level of individual products, i.e. in the related product chains. The transition process may differ across products and between circularity strategies, where lower circularity strategies are still closer to a linear economy and higher circularity strategies are closer to the circular economy (see Figure 1 and 4).

A recent evaluation of seventy circular economy initiatives shows technological innovation to be mainly relevant for lower circularity strategies. Socio-institutional changes become more important for higher circularity strategies (see Figure 4)[13], as these increasingly involve transforming the whole product chain (i.e. systemic changes). Socio-institutional changes refer to differences in how consumers relate to products, how all actors in a product chain cooperate to achieve circularity, and all institutional arrangements needed to facilitate this. For example, car sharing requires a different attitude with consumers, organisation of a sharing platform and repair and maintenance services, whereas a change in ownership asks for adjusted contracts and insurances. Hence, higher circularity strategies do not make lower circularity strategies redundant. The shared car needs replacing at some point, after which its parts are preferably reused, or else its various materials are recovered for recycling. Circular design innovations can be relevant for all circularity strategies, but particularly help with products that are easier to disassemble. Product manufacturers may be encouraged to increase their circularity practices by new revenue models where products retain their original property, and the revenues come from selling the service provided by their products.

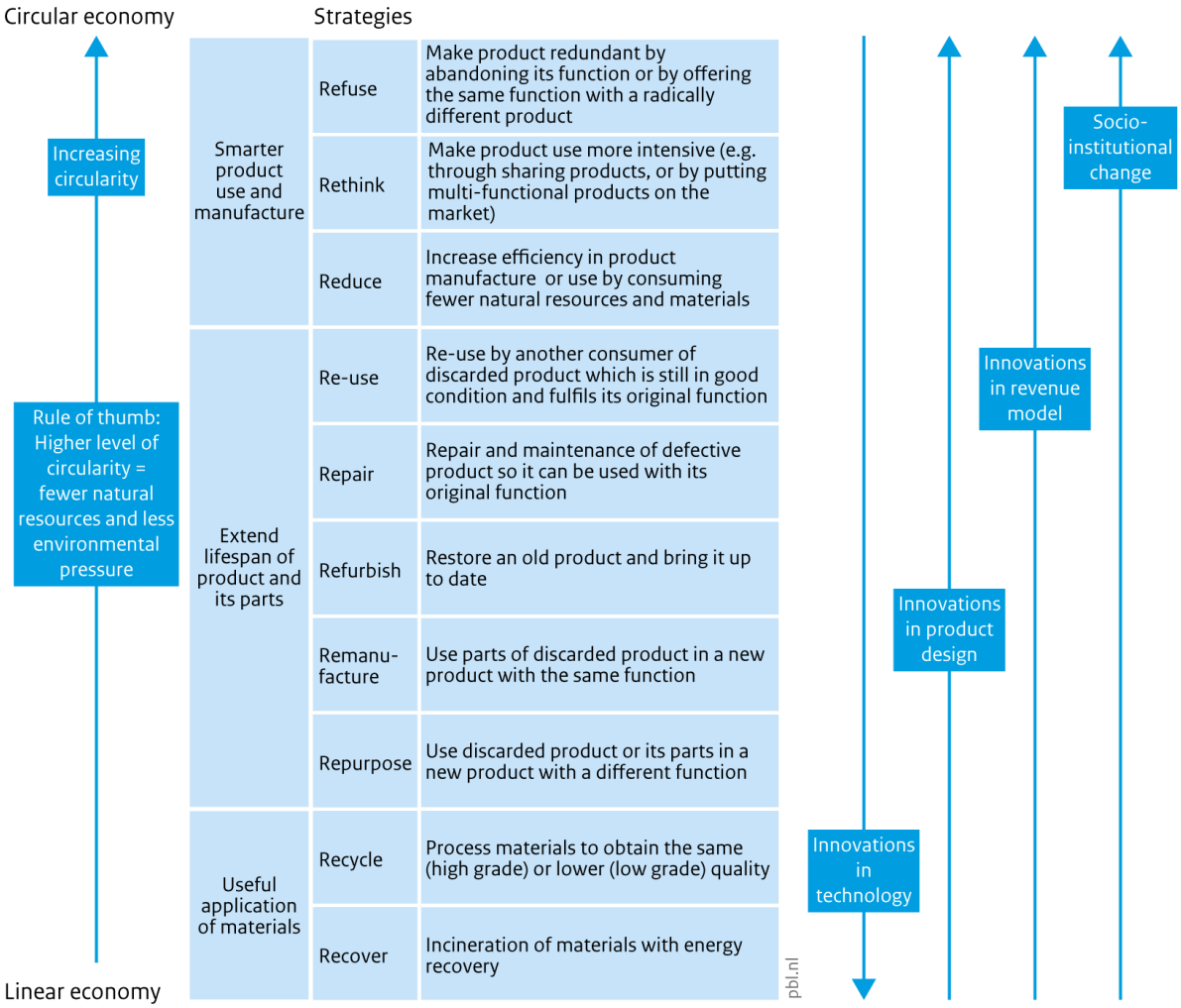
Monitoring the transition process thus includes monitoring socio-institutional change, and innovation in circular design, revenue models and technology. Technological innovations can be monitored with the Eco-innovation index that is included in the Resource Efficiency Scoreboard[11]. The Eco-innovation index measures Eco-innovation performance and is based on sixteen underlying indicators that, amongst others, measure investments, research & development personnel, ISO 14001 registration, patents, and academic publications. To our knowledge, no indicators are available yet to monitor socio-institutional

changes and innovation in circular design and revenue models as important enablers in the transition process.

The policy assessment framework in Figure 3 helps to disentangle the transition process: Achieving circularity strategies may require socio-institutional changes or innovations in technology, product design or revenue model. The achievement of those innovation may involve activities as awareness programs, research or otherwise. Undertaking activities or accomplishing achievements may need means as finances, personnel or otherwise (e.g. legislation or technology if these already exist and are not needed to be achieved by activities).

Figure 4

Circularity strategies within the production chain, in order of priority



Source: RLI 2015; edited by PBL

The first challenge in measuring the transition process, which also applies to the proposed lead indicator for the transition process, consists in finding the right indicator to measure the achievement of the circularity strategies. This circularity indicator could measure the shift from low to high circularity strategies by measuring the relative shares of the circularity strategies (i.e. Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose. Recycle; see Figure 1 and 3). It needs further thinking how to express this in one indicator, but such indicator should one detail level lower indicate, for example, that a yet less well developed country may perform well on the reuse of products and less well

on recycling and landfill. This circularity indicator should also be able at one detail level lower to measure higher circularity strategies, like repair and rethink (see Figure 1 and 3). Indicators for measuring recycling (and incineration) are available, but do not yet exist for the other circularity strategies. Their measuring may not be feasible with the current state-of-the art in knowledge and data-availability, but is nevertheless important for measuring progress of the circular economy transition, and efforts are therefore needed to make indicators for the other circularity strategies operational, as well as to be able aggregating them into one circularity indicator.

Appendix 3 contains diagnostic questions to measure the transition process. These questions still need to be translated into measurable indicators. This will be done in the short term, as part of a circular economy monitoring framework which is being developed in the Dutch context. Some of the diagnostic questions in Appendix 3 are expected to be relevant as dashboard indicators. Some of the diagnostic questions will be product-specific (specific tier). Examples of the diagnostic questions in Appendix 3 are:

- Are all relevant product chain partners actively involved in realising circular economy solutions?
- Is there a clear vision among product chain partners of the pursued circularity strategy?
- Is sufficient knowledge available to develop circular economy -solutions?
- Do entrepreneurs experiment enough with circular economy solutions and revenue models?
- Does the design foresee the use of recycled materials?
- Do circular economy products have a longer lifespan or are they used more intensively?
- Do companies use fewer substances which are hazardous to human health and ecosystems?

The process indicators in Appendix 3 are distinguished into whether they address means, activities or achievements. Some of these means, activities and achievements are already addressed by actions in the European Commission's action plan for the circular economy, and some of these actions can already be measured with indicators (see Appendix 4). This is usually the case for actions related to waste management that are more tangible in terms of achievement, meaning that these could be directly measured as waste and recycling quantities. This is however less the case for other actions intended to stimulate the circular economy, where indicators need to be defined and measured. These actions include amongst others: Tackling planned obsolescence, Promoting Sharing/ Collaborative economy; Facilitating food donations, Promoting 'Best before date' good practices. Supporting Small and Medium Enterprises s and Social Enterprises active in the fields of recycling, repair and innovation (see Appendix 4 for a complete overview). A next step following this rapid exercise might be to map the actions that are already proposed by European Commission with the diagnostic questions to follow the transition process (see Appendix 3).

4. Effects

Main message: Effect monitoring should focus on footprint indicators as an extension of the indicators that cover effects in the European Union only. Therefore we suggest raw material consumption (RMC) and raw material productivity (GDP/RMC) as lead effect indicators, instead of using domestic material consumption (DMC) and domestic material productivity (GDP/DMC). Effect monitoring should also cover environmental and socio-economic effects.

Globalisation of economic activities has created a world in which it is no longer expedient to stop at country boarders when monitoring resource use and the environmental effects of production and consumption. Footprint indicators are able to unveil a major share of the environmental benefits of a transition towards the circular economy by considering the whole product chain, including the part occurring abroad. A product chain starts from resource extraction (in a linear economy), goes through material production and product manufacturing to product consumption and the processing after discarding (including all transportations needed). In the past, data limitations have been one of the reasons why a focus on the domestic part of the product chain was preferred. However, data availability for footprint indicators has meanwhile improved considerably[10,16,17,18]. The advantages of the footprint indicators have been discussed on a European level[19,20,21] and the footprint approach is currently being developed by the European Union. Furthermore, footprint indicators are integrated in the UN's monitoring framework for the SDGs, including SDG 12 (ensuring sustainable consumption and production patterns) and SDG 8.4 (in short, improving resource efficiency and decoupling economic growth from environmental degradation).

Material productivity, referring to gross domestic product (GDP) divided by domestic material consumption (DMC), is currently used as lead indicator in the resource efficiency scoreboard[11]. This indicator may show a decoupling per euro (relative decoupling), which does not necessarily mean absolute decoupling as absolute values may still increase despite relative decoupling. Moreover, relative efficiency conceals differences between countries in absolute (per capita) material consumption (e.g. between developed and less developed countries). Furthermore, DMC is relatively sensitive to the economic structure of countries[22]. Therefore we suggest the material footprint as an additional lead effect indicator, i.e. raw material consumption (RMC; per capita for the European Union and Member State level). RMC measures absolute material volumes and includes the overall raw material extraction both domestic and abroad, as caused by domestic consumption, and thus is less sensitive to the economic structure than the DMC. Disaggregation of the RMC into separate types of raw material helps to address specific problematic types of raw materials (e.g. rare metals) and those that are less problematic (e.g. sand)[23]. Slightly different from the Resource Efficiency Scoreboard, we propose to also keep raw material productivity (i.e. GDP/RMC) as a lead indicator (instead of GDP/DMC, as in the Resource Efficiency Scoreboard).

Similar as the Resource Efficiency Scoreboard, we suggest to keep non-material resources in the dashboard (i.e. land use, water exploitation, and cumulative energy demand; the latter disaggregated by renewable and non-renewable energy), but then land use and water exploitation also as footprint indicators. Furthermore, we suggest to also keeping the carbon footprint renamed as greenhouse gas footprint in the dashboard (to make crystal clear all greenhouse gases are covered). The greenhouse gas footprint should be included because of its policy relevance and the supposed contribution of a circular economy to emission reduction.

There are two basic approaches to calculate footprints. The first one is a top-down approach in the form of environmentally extended multi-regional input-output (MRIO) models. MRIO models are typically used to calculate footprints at the aggregate level of the European Union and its Member States. The other one is a bottom-up approach that is based on process analysis as typically used for footprints of specific products (life cycle assessment; LCA). The two approaches can be considered complementary[18], and are sometimes combined (hybrid approaches). Eurostat has MRIO models for the European Union and its Member States, but not for countries or regions outside Europe. The domestic part of a footprint can be derived with Eurostat's MRIO models for measuring at the level of the European Union and its Member States, and for specific products with process analytical data (e.g. detailed national statistics or databases, such as ecoinvent[24]). The footprint part outside the European Union can be approximated using the global MRIO model EXIOBASE2[17]. Eurostat could link EXIOBASE2 to their own European MRIO models or, alternatively, extract material-dependent factors from EXIOBASE2 for the part of the footprint that is outside the European Union. Such material-dependent factors can also be useful to supplement process analysis for specific footprints.

It is important to keep in mind that, like the DMC, the RMC does not provide direct information on the environmental effects of resource extraction, and subsequent downstream production processes. Cumulative fossil energy demand often is a reasonable proxy for the environmental effects of materials[25,26], but RMC aggregates a wide range of (raw) materials with a large variation in environmental effects. Additional monitoring of environmental effects may therefore be needed for specific products, depending on the materials they are made from, in order to assess progress and identify levers for action.

Land use in particular, but also the other resource uses, and environmental effects may have a negative influence on biodiversity. Inclusion of a biodiversity footprint in the dashboard therefore becomes relevant as soon as consensus is reached about its quantification and when this is technically feasible.

The overuse of resources has in the long run also negative consequences for an economy that relies on a secure supply of raw materials. On the other hand a circular economy also provides opportunities for innovative companies and can contribute to green growth and prosperity in countries. This is why it is necessary to look at both the environment and the economy when measuring the effects of a circular economy[27]. So ideally the aspects security of resource supply, added value and jobs are also covered.

As already indicated above, security of resource supply is for some materials (e.g. rare metals) more critical than for others (e.g. sand). Resource security or self-sufficiency, therefore, only needs to be monitored for critical materials. Such an indicator has been elaborated as part of the Raw Material Initiative. The remaining challenge, however, is that of also taking the future into account. This concerns aspects such as depletion time (compared to production), growth of annual demand, and substitution rate for specific resources[28].

In terms of economic opportunities, the number of circular jobs and added value in circular products and services seems logical indicators. These indicators, however, also have major drawbacks, as a circular economy will affect the whole economy. It may yield benefits in one economic sector and/or product chain, while causing losses in others. It will also lead to a shift from 'linear' to circular jobs which, in practice, are difficult to identify in available statistics. The current measurable economic sector 'Environmental Goods and Services', which mainly consists of waste management, only covers a small part of the intended changes in the transition towards the circular economy.

Positive developments for the waste management sector include recycling, but this not necessarily equals positive developments in the circular economy. The other way round, decreasing added value in the waste management sector may not be bad for the circular economy if caused by product chains being closed and the value of products and materials being utilised more effectively (e.g. by refurbishment in the manufacturing industry).

5. Closing remarks

This discussion paper proposes a broadening of the monitoring framework for assessing progress towards the circular economy, building on the Resource Efficiency Scoreboard and Raw Materials Scoreboard on the one hand, while supplementing these with elements relevant for measuring progress of the transition towards the circular economy on the other. Measuring some of these additional elements may not be feasible with the current state-of-the art in knowledge and data-availability, but is nevertheless important for measuring progress of the circular economy transition. These additional elements will furthermore lift the monitoring framework from measuring compliance, to a smart information system that also facilitates learning needed for accomplishing the circular economy transition, without substantially increasing administrative burdens. The relevance of our input is anchored in the experience of the EPAs in working on the interface between environmental science and policy-making, on both a Member State and European Union and international levels. The main elements proposed to be included in the European Commission's monitoring framework, as discussed in this paper, are listed below.

Monitoring structure:

- The proposed framework consists of three tiers:
  - The first tier, with a generic lead indicator for the transition process, and two indicators for its effects
  - The second tier, with dashboard indicators for both the transition process and its effects
  - The third tier, with product-specific indicators for the transition process and its effects.
- Each tier, thus, contains indicators for monitoring the transition process as well as its effects.
- Indicators on the transition process and its effects must relate to the entire product chain (unless irrelevant).
- All indicators should be measurable on European Union, Member State and product levels.
- Quantitative targets should help stakeholders to shape the transition process, and to assess the progress towards a circular economy.

Indicators for the transition process:

- Monitoring progress of the transition process is important for assessing if the right things are happening and the circular economy transition is on its way, or whether additional measures are needed.
- The shift in circularity strategies is proposed as a lead indicator for the transition process. How this could be expressed in one indicator needs to be discussed further, but this circularity indicator could aggregate the relative shares of the circularity strategies (i.e. Recycle, Repurpose etc.; see Figure 1 and 3).
- The European Commission, in its discussions with stakeholders, needs to identify dashboard and product-specific indicators.
- Indicators for the transition process in all three tiers need to be made operational, i.e. conceptually defined and technically feasible.

Effect indicators:

- Effect monitoring should focus on global footprint indicators as an extension of indicators that cover effects only within the European Union.

- We suggest raw material consumption (RMC) and raw material productivity (GDP/RMC) as lead effect indicators, per capita on European Union and Member State levels, instead of domestic material consumption.
- Effect monitoring should also cover environmental and socio-economic effects.

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Appendix 1: Proposed lead indicators for the circular economy

			EU, member states	**Product chains**	
		Units↓→	- Numerator / European Union or Member State - Numerator / economic sector - Numerator / capita	- Numerator / functional product unit - Numerator / economic (product) sector	Generic breakdowns: - Domestic, import, export - Life cycle stages - Economic sector
	↓Indicator type	↓Numerator	↓Data sources	↓Data sources	
Effect	**Raw material footprint** (raw material consumption; RMC)	10^n kg	Eurostat for the European Union, supplemented for outside the European Union with: - Short term → EXIOBASE-derived factors - Long term → Factors derived by Eurostat global MRIO[1] model	Process analysis for product specific data (foreground processes; data from e.g. UNEP-SETAC Life Cycle Initiative, ecoinvent and others) & MRIO-based for generic and global data (background processes): - Short term → EXIOBASE-derived factors - Long term → Factors derived by Eurostat global MRIO[1] model	Additional breakdown to material types
	Raw material productivity (GDP/RMC)	10^n euro/kg			
Transition process	**Circularity strategies**[2]	Pro Memory	Pro Memory	Pro Memory	Additional breakdown to circularity strategies[2]; see also Figure 1

[1] Environmentally extended multi-regional input-output (MRIO) models

[2] This indicator should measure whether there is a shift from low to high circularity strategies by measuring the relative shares of the circularity strategies in Figure 1 (i.e. Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose. Recycle). More thinking is needed to make this indicator operational and possibly to adding up to one number.

Appendix 2: Proposed dashboard indicators for the circular economy

The effect-indicators in below table, which build on the Resource Efficiency Scoreboard, are based in relatively solid science. This is less so the case for indicators measuring the progress of the transition process in the direction of the circular economy. It should be noted that below indicators for the transition process are suggestions, and this applies as well for suggestions of how to make them operational. More thinking and work is needed for the indicators for the transition process to make them operational and to make them adding up to one number.

			EU, member states	**Product chains**	
		Units↓→	- Numerator / European Union or Member State - Numerator / economic sector - Numerator / capita - Numerator / GDP	- Numerator / functional product unit - Numerator / economic (product) sector	Generic breakdowns: - Domestic, import, export - Life cycle stages - Economic sector
	↓Indicator type	↓Numerator	↓Data sources	↓Data sources	
Effect	**Land use footprint**[1]	10^n m^2	Eurostat for the European Union, supplemented for outside the European Union with: - Short term → EXIOBASE-derived factors - Long term → Factors derived by Eurostat global MRIO model	Process analysis for product specific data (foreground processes; data from e.g. UNEP-SETAC Life Cycle Initiative, ecoinvent and others)) & MRIO-based for generic and global data (background processes): - Short term → EXIOBASE-derived factors - Long term → Factors derived by Eurostat global MRIO model	Additional breakdown to land use types
	Water exploitation (water footprint)	10^n m^3			Additional breakdown to water scarcity classes
	Energy footprint (cumulative energy demand (CED)	10^n MJ_{pr} ($MJ_{primary\ energy}$)			Additional breakdown to energy carriers (fossil, nuclear, renewable), End use types
	Greenhouse gas footprint (Renaming of carbon-footprint) [2]	10^n kg CO_2-equivalents			Additional breakdown into biogenic and non-biogenic
	Added value	10^n EURO			
	Jobs				
Process	**Circular economy interaction between product chain actors**[3]				
	Circularity-innovation index[4]	Dimension-less[4]	Eurostat	Data sources for Eurostat	
	Circular product design[5]	Pro Memory	Pro Memory	Pro Memory	
	Switch from selling products to selling product services[6]	Pro Memory	Pro Memory	Pro Memory	
	Regulation facilitating EPR-schemes[7]	Pro Memory	Pro Memory	Pro Memory	

[1] This indicator in the Resource Efficiency Scoreboard only covers domestic built-up area and productivity of artificial land. We propose replacing this indicator in the Resource Efficiency with another indicator measuring the land use footprint, i.e. also outside Europe, and all kinds of land use.

[2] This indicator is referred to as 'carbon footprint' in the Resource Efficiency Scoreboard, but also includes other greenhouse gasses than carbon dioxide. However, the term 'carbon footprint' is sometimes also used for a footprint exclusively measuring carbon dioxide. Therefore we propose to call this indicator here unambiguously 'Greenhouse gas footprint'.

[3] This indicator should measure whether actors are actively talking and working on making their product chain more circular. There can be a long time-lag between talking and the implementation of circularity strategies in a product chain. The fact that actors are talking, however, is a first and crucial step in moving to implementation. More thinking is needed to make this indicator operational and adding up to one number

[4] The Eco-innovation index from the Resource Efficiency Scoreboard relates to (raw) material and fossil energy efficiency. We suggest to focus in this monitoring framework on (raw) materials efficiency only, which would make it then a circularity-innovation index. This indicator can be made operational by adjusting the Eco-innovation index.

[5] Building on, but slightly deviating from the EEA-report about circular economy indicators (EEA 2015), this indicator could measuring the lifetime of products compared to the average lifetime for similar products, time and number of tools needed for product disassembly, share of high grade recycled material that can be recovered for high grade recycling. More thinking is needed to make this indicator operational and adding up to one number.

[6] This indicator could be made operation by measuring e.g. the revenues from services, or the number of new services providers, or the number of companies switching from products to services. More thinking is needed to make this indicator operational and adding up to one number.

[7]Implementation of Extended Producer Responsibility (EPS) schemas (with clear requirements, that may become more stringent in time) is crucial to get actors in product chains working on circularity. Policy measure are instrumental in facilitating this. This indicator should measure the extent to which policies are indeed in place to do so.

Appendix 3: Indicators for transition process

Below table contains diagnostic questions which serve as a basis for translation to indicators for measuring the progress of the transition process towards a circular economy in the Dutch context. The table is taken from a preliminary Dutch study[13], and is now in the process of being translated to indicators. It is included here to make concrete what indicators for the transition process are about.

	Diagnostic questions to measure the progress of the transition process toward the circular economy
Means	**Mobilisation of means** - Are all relevant product chain partners actively involved in realising circular economy solutions? - Is there sufficient funding for realising circular economy solutions? - Are there specific physical means limiting the realisation of circular economy solutions?
	Knowledge development - Does the available knowledge suffice to develop circular economy solutions (with regard to technology, patents, consumer and chain actor behaviour)?
Activities	**Knowledge exchange** - Is the level of knowledge exchange on circular economy solutions high enough in the product chain?
	Experimenting by entrepreneurs - Are entrepreneurs experimenting sufficiently with circular economy solutions and revenue models? - Is upscaling of circular economy solutions already taking place?
	Giving direction to search (vision, expectations of governments and core-actors, regulations) - Is there a clear vision among product chain partners of the pursued circularity strategy? - Do product chain partners broadly share this circularity strategy? - Does this circularity strategy structure the activities of the product chain partners?
	Opening markets - Are product chain partners active in creating consumer awareness of circular economy solutions? - Are companies investing sufficiently? - Does the government have supplementary policies, and do they help in opening markets?
	Overcoming resistance - Is there resistance against circular economy solutions (among product chain partners, or in the form of regulatory barriers)? - Is sufficient action being taken to overcome resistance against circular economy solutions?
Achievements	**Circular Economy design** - What is the present lifespan of a product and has it increased compared to its original lifespan? - Have products become easier to disassemble? - Does the design foresee the use of recycled materials? - Are the components designed for high-grade recycling (without increasing environmental pressure)?
	Production - Is the overall (primary and secondary) consumption of materials by companies decreasing? - Do companies use fewer substances which are hazardous to human health and ecosystems? - Is production moving towards lower levels of waste generation? - Are companies moving to circular economy revenue models with increased reuse of products and components, or models based on providing a service rather than offering a product?
	Consumption - Is the consumption of circular economy products increasing (compared to conventional products)? - Do circular economy products have a longer lifespan or are they used more intensively? - Is reuse of products leading to less waste?
	Waste - Is the volume of landfill decreasing in favour of incineration? - To what extent is high grade-recycling applied? - To what degree is recycling effective with regard to costs and environment?

Source: EEA (2016b); Hekkert et al. (2011)

Appendix 4: European Union Actions on circular economy and possible indicators

The left column in below table contains actions as extracted from 'An EU action plan for the Circular Economy'[1], and the right column suggests possible indicators to measure the progress of these actions.

	Suggested indicator (…comment…)
Production	
Promoting Product Ecodesign[1,2]	
Promoting best available technology (BAT) for waste management and Resource Efficiency in industrial sector	- Number of new patents related to circular economy [amount/capita] - Number of new best available technologies (BATs) relevant for waste management and resource efficiency[amount /capita]
Promoting extended producers responsibility (EPR)	New national regulation on extended producer responsibility (EPR) [?]
Consumption	
Improving labelling for energy	
Increasing repair services	- Number of repair shops per capita [n. shops / capita] (data on Eurostat available? Available in the future?) * Availability of spare parts [?] - annual revenue of repair shops [total revenue / capita] (data on Eurostat available?)
Tackling planned obsolescence[2]	- Technical lifetime of products [years] - National regulations: implemented bans on planned obsolescence [number of regulation compared to baseline year] (e.g. as in France)
Action on green public procurement (GPP) integration of circular economy requirements	Uptake of green public procurement at national level for which the European Commission is also developing a monitoring framework
Promoting waste prevention	
Promoting sharing/ collaborative economy	The use of collaborative platform (see Flash Eurobarometer 438)
Waste management	
Contributing to achieve long-term recycling targets (municipal solid waste and packaging)	
Monitoring of waste quantities	waste quantities for specific waste streams [tons]; [tons/capita]
Improving/ Investing in waste management infrastructure	Amount of funding spent into waste management infrastructures sector [euro]
From Waste to resources: Boosting the market for secondary raw material and water reuse	
Contributing to Improve quality of standards of secondary raw material	Number of quality standards approved
Contributing to recycling of nutrients	

Contributing to combat water scarcity	
Reducing the presence of hazardous substances in purchased products and services	
Plastic	
Increasing plastic recycling	Recycled waste [tons] ; [tons / capita] ; [%] Total amount recycled waste [tons, tons/capita]
Reducing marine litter	
Food	
Preventing food waste	Food waste reduction from a baseline year [%]
Measuring food waste	Food waste reduction from a baseline year [%]
Facilitating food donations	Amount of food donated [tons]
Promoting "Best before date" good practices	
Critical raw materials	
Improving recovery of critical material such as waste electrical and electronic equipment (WEEE)	
Construction and demolition	
Contributing to recovery of valuable resources and adequate waste management in the construction and demolition sector	
Facilitating the assessment of the environmental performance of buildings	
Biomass and biobased products	
Promoting efficient use of bio-based resources and wood	Cascading factor, biomass utilisation factor
Other horizontal measures	
Mobilising the involvement of stakeholders for GPP and circular economy	
Supporting small and medium enterprises (SMEs) and social enterprises active in the field s of recycling, repair and innovation	- New business created [shops / capita] - Total revenue for new business [euro]
Monitoring progress towards a circular economy	
Contributing to develop indicators to measures progress towards a circular economy	

[1]EC (2015): Eco-Innovation Scoreboard

[2] EEA (2017): Circular by Design