CIRCULAR IMPACTS

Macroeconomic and Societal Impacts of Mainstreaming the Circular Economy

Funded by the European Union

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Abstract

This report summarizes the key findings of the CIRCULAR IMPACTS project and provides an impact analysis setting out impacts of circular-economy transitions on the macroeconomy and society. The results of case studies conducted within the project are included as are results from modelling done by external parties, accompanied by an overview of the methodologies used. This report thus provides an overview of presently available quantitative evidence on the macroeconomic and societal impacts of the circular economy. In addition, an overview of recent policy development on EU level in relation to the circular economy is provided, as are the key conclusions and policy messages from the project. Lastly, recommendations for future circular economy research are given, with the aim of improving scenario-based impact analyses for the European policymaking context.

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LIST OF ABBREVIATIONS

CDW	Construction and demolition waste
CRM	Critical raw materials
EU	European Union
EV	Electric vehicle
GDP	Gross domestic product
GHG	Greenhouse gas
GPP	Green public procurement
LCA	Life Cycle Assessment
OECD	Organisation for Economic Co-operation and Development
RCA	Recycled concrete aggregates
SDGs	Sustainable Development Goals

Executive Summary

The linear economy, wherein natural resources are obtained, turned into products and discarded as waste after a limited time, remains the predominant economic model and its further expansion the means of pursuing economic growth. However, the unconstrained expansion of this linear model is not sustainable in the context of the Earth's finite supply of natural resources. By contrast, a circular economy focuses on regenerative design and maintaining the long-term economic value of natural resources by recycling the re-usable components of products and keeping them longer in the economic process.

The CIRCULAR IMPACTS project was funded under the Horizon 2020 research programme to increase the evidence base regarding the potential impacts of circular-economy transitions. This final report of the CIRCULAR IMPACTS project integrates the project findings and provides an overview of the impact evidence compiled and developed over the two-year period ending in September 2018. The results of case studies conducted within the project are included as is a comparison summary of the quantitative results of macroeconomic modelling studies conducted outside the project. In addition, an overview of recent policy developments on the EU level is provided, along with key conclusions and policy messages from the CIRCULAR IMPACTS project useful to policymakers and researchers working on circular-economy related issues.

Further detail on the issues addressed in this Executive Summary can be found in the main body of this report. Additionally, in-depth treatment of all the topics covered by CIRCULAR IMPACTS can be found in the full set of project reports and via the CIRCULAR IMPACTS online library.[1]

Defining the circular economy

Different perspectives exist on what the circular economy actually entails and what should be included in assessments thereof. At the beginning of the project, the CIRCULAR IMPACTS team found:

- **A lack of clarity on the circular economy concept.** Many ideas of what a circular economy is and what it entails have been developed, and as a result, consensus is lacking on this issue. The definition coined by the Ellen MacArthur Foundation is the most popular one.

[1] CIRCULAR IMPACTS reports are available at http://circular-impacts.eu/deliverables The CIRCULAR IMPACTS library leads to hundreds of information resources and can be accessed via http://circular-impacts.eu/library

- **Studies on the circular economy are often difficult to compare.** Research is fragmented and studies are difficult compare to each other as a result.
- **Impacts of a transition are not fully understood yet.** Studies often calculate the environmental and economic impacts of a circular economy transition, but largely underexpose social impacts and indirect effects.

Based on the available literature, the CIRCULAR IMPACTS project team developed a framework encompassing the main processes considered to be components of a more circular economy (see Table ES-1).

Table ES-1. The description used within the CIRCULAR IMPACTS project

Main circular-economy processes	
Use less primary resources	• Recycling • Efficient use of resources • Utilisation of renewable energy sources
Maintain the highest value of materials and products	• Remanufacturing, refurbishment and re-use of products and components • Product life extension
Change utilisation patterns	• Product as service • Sharing models • Shift in consumption patterns

Source: Based on Rizos, Tuokko & Behrens (2017)

The circular economy and the European Semester

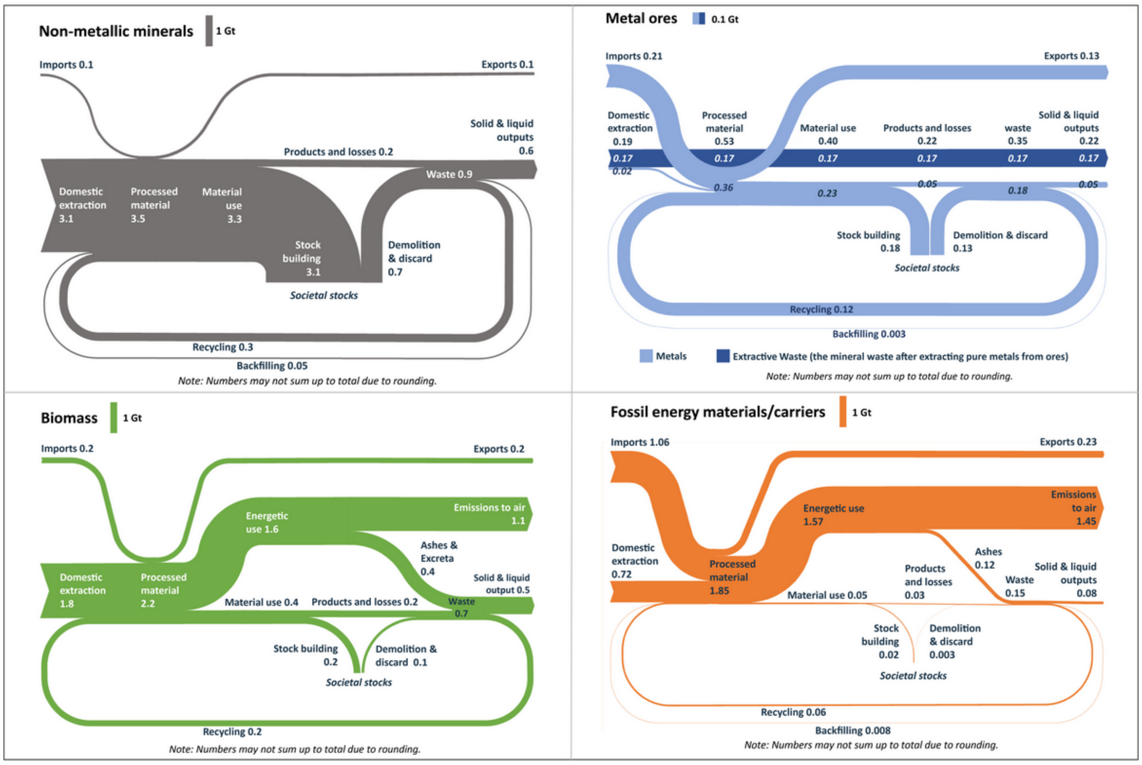
Introduced in 2010, the European Semester is the main mechanism for coordinating the economic policies of the EU Member States. It is an influential policy context for circular-economy transitions and was a key focal point for the CIRCULAR IMPACTS project. The project team found that the European Semester mainly looks at economic policies for growth, jobs and investment with an emphasis on short-term improvement and that information pertinent to the circular economy is either not available or is released too late to be of relevance to the European Semester process. Moreover, the European Semester was introduced in 2010 in the wake of the financial and economic crisis, meaning the political priorities that guided its development are now outdated.

In the European Semester process, the Annual Growth Surveys identify economic and social priorities for the coming year and an examination of the Annual Growth Survey for 2016, 2017 and 2018 show that the Commission has expressed its political commitment to the circular economy. However, to facilitate circular-economy transitions effectively, the European Semester would need to expand its focus beyond achieving short-term impacts. In addition, the lack of macroeconomic and resource data relevant to monitoring the circular economy (and delays in generating the indicators that do exist) still need to be addressed.

Monitoring key components of the circular economy

Introduced by the European Commission in January 2018, the EU's Monitoring Framework on the Circular Economy constitutes an important step toward improving the available evidence base regarding circular-economy transitions. This small set of indicators will be monitored by Eurostat, covering four aspects of the circular economy: production and consumption; waste management; secondary raw materials; and competitiveness and innovation.[2] Indicators focus predominantly on resource-related issues, i.e. secondary raw-material use, recycling and waste. Figure ES-1 provides an overview of material-flow diagrams for the EU-28 showing material flows in 2014 for four key resource groups. Mainstreaming the circular economy would involve significant expansion of the material loops shown in these figures.

Figure ES-1. Detailed flow diagrams by material in 2014 for the EU-28



Source: Reproduced from Eurostat (n.d. (b))

[2] For the most up-to-date version of the Monitoring Framework, please visit https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework

There is an ongoing debate regarding what the EU should consider to be the key components of the circular economy and how it should monitor its progress. A central question is whether the idea of circularity should focus on use and re-use of resources or incorporate broader sustainable-development concepts (e.g. water use, GHG emissions, land-use and land-use change). Broader circular-economy concepts such as product-life extension and changed utilisation patterns (e.g. sharing models) currently fall outside the current monitoring framework and appear quite challenging to integrate in a robust way.

Case studies on mainstreaming circular-economy processes

The CIRCULAR IMPACTS project conducted four in-depth case studies to analyse circular-economy transitions in key sectors—construction, agriculture, transport and manufacturing. Table ES-2 shows the case studies examined within CIRCULAR IMPACTS and key findings related to their impacts. Additional details are available in the main body of this report and the various case-study reports.

Table ES-2. CIRCULAR IMPACTS case studies and overview of impact findings

Case study	Headline impacts in 2030
Prospects for electric vehicle batteries	Recycling lithium-ion batteries for electric vehicles could mitigate dependence on imported materials and help retain the value of recovered materials in the EU economy. Materials (i.e. cobalt, nickel, aluminium and lithium) with a value of €408 – €555 million could be recovered and retained in the EU economy (entailing 2,620 – 3,270 jobs for the collection, dismantling and recycling of batteries in the EU).
Concrete recycling in France	Waste concrete can find new life as an ingredient in new structural concrete applications. Consumption of energetic resources, global warming and air pollution indicators were 1-2% lower for recycled concrete in the examined scenario but the extent of these environmental benefits is closely linked to the transport distances of the aggregates.
Phosphorus recycling from manure in the Netherlands	Newly developed manure processing technologies may reduce the cost of the manure policy. In the current policy and economic circumstances, if all Dutch pig manure would be processed by a new process (BioEcoSIM) and cost estimates are correct, this would generate a GDP increase of €15 million and reduce environmental costs (GHG and particulate matter) by about €75 million.
Car sharing in Germany	A circular “green” scenario with higher car sharing saw reductions of 10% in GHG emissions beyond those in the baseline and the

	number of fossil-fuel vehicles was 9% lower with 7% fewer passenger-km travelled by car. In a circular "gray" scenario, car sharing reaches equivalent levels but by drawing people from public transport results in an increase in motor-vehicle passenger-km and GHG emissions.
Biofuels and Renewable Energy (Data Collection Report)	An increased deployment of renewable energy appears to have a minor but positive effect on GDP (0.5% to 0.8% when renewable-energy targets are set at 30% and 35%, respectively) along with a small but positive effect on employment. With increased deployment of renewable energy, the EU's spending on fossil fuels decreases, as do CO_2 emissions.

Results of external modelling scenarios

The CIRCULAR IMPACTS project included an examination of macroeconomic modelling studies to identify the nature and potential magnitude of impacts. We summarize the results of recent studies that have used macro-economic models to analyse circular-economy transitions.

Though modelling studies yield differing results, the circular-economy transition scenarios generally point to a positive macroeconomic impact. In several of the examined reports, benefits in terms of increasing GDP and employment were identified, mainly as a consequence of extra investment, more labour-intensive technologies, and assumed higher efficiency of the circular technologies. Although some of the scenarios do find that the analysed targets or policies can have a negative economic effect, it appears that a careful policy design may mitigate these impacts. The same applies to environmental impacts: although the transition to circular economy has the potential to reduce environmental stressors, the complexity of mechanisms governing emissions and resource effects could lead to countervailing effects (e.g. the potential of ridesharing to attract users away from public transport), confirming the necessity for a well-designed policy mix.

Section 3.3 of this report provides an overview of 15 recent macroeconomic modelling exercises related to circular-economy transitions. While the time horizons range from 2020 to 2050, the numerical summaries of impacts in the EU generally pertain to 2030, the same time horizon used in the CIRCULAR IMPACTS case studies. In an annex to this report, an extensive tabular overview facilitates the comparison of results from the macroeconomic modelling studies included in our impacts summary. Box ES-1 below provides an overview of the overarching insights stemming from our examination of the various studies.

Box ES-1. Overarching insights from the reviewed modelling studies (comparative assessment)

- **Rebound effects.** Financial savings stemming from particular increases in resource efficiency might be expended on higher consumption of other goods, at least partially offsetting the aims of reducing GHG emissions and resource use. To counteract the rebound effect, a policy mix should not only enhance efficiency, but also limit resource use. This issue is discussed in Cambridge Econometrics et al., (2018), Meyer et al., (2018), UNEP (2017) and Bosello et al. (2016). Other potential "unexpected" effects are possible. For example, Bosello et al. (2016) find that some environmental policies simulated within the EU result in relocating negative externalities to other countries instead of reducing them.
- **Technological feasibility.** In many modelling studies, efficiency improvements are driven by technological progress, sometimes assumed as exogenous effects that are not caused by policies. It is justifiable to question to what extent such technological improvements are feasible, whether their costs have been correctly considered in the modelling, and to what extent the modelling results are insightful. For further discussion of this issue, see McCarthy et al. (2018).
- **Revenue recycling.** The issue of using revenues from potential environmental taxes is a recurring topic in the examined literature. The evidence from scenario analysis suggests that implementing a tax policy that assumes revenue recycling (e.g. to lower labour costs) facilitates higher levels of GDP and employment, based on the assumption that reducing labour taxes will increase employment (e.g. Cambridge Econometrics and BIO Intelligence Service, 2014; Bosello et al., 2016).
- **Global, regional and national perspectives in policymaking.** From both economic and environmental points of view, the geographical scale of the policy in question makes a difference. Not surprisingly, globally implemented targets and policies yield the largest progress in environmental terms (see e.g. Meyer et al., 2015). In terms of economic impacts, it appears that an overarching EU target brings more benefits than imposing the same target on each Member State (Cambridge Econometrics and BIO Intelligence Service, 2014). Apart from impacts in absolute terms, there is also the question of a shift of economic power. An example is the finding of Schandl et al. (2016), that implementing global efficiency policies would result in the EU losing less GDP share to China.
- **New behaviours and societal change.** Several studies find that achieving environmental goals as a result of behavioural changes in society (e.g. changing consumption patterns) may cause losses in traditional economic terms but could have other benefits (e.g. Meyer et al., 2015, Hu et al., 2015, Bosello et al., 2016). This again raises the question of to what extent commonly used economic indicators are able to reflect the full value of human well-being.
- **Distributional considerations.** The results from the examined literature show that achieving an overall positive impact might still generate "winners and losers". The disadvantaged groups could be particular countries (e.g. resource-exporting countries according to Meyer et al., 2018); sectors (e.g. the construction sector according to

Cambridge Econometrics et al., 2018); or societal groups (e.g. lower income groups according to Cambridge Econometrics and BIO Intelligence Service, 2014).

The CIRCULAR IMPACTS project has contributed to a stronger foundation of theory, methodology and evidence for policy action and future research. The following research recommendations are proposed for consideration by funders and researchers.

- **Appropriate research scope and design.** In evaluating the macro-consequences of the circular economy, one must include macro-economic mechanisms in the analysis and make a clear difference between the short term and the long term. Generating original macroeconomic evidence is best done via ex ante macroeconomic modelling. Case-study methods are valuable for their ability to examine specific business cases, policy tools and technologies.
- **Appropriate specificity within a holistic concept.** Key strengths of the circular economy concept include its "solution orientation" (describing a model for how resource-related challenges can be addressed) and its holistic nature (uniting traditional resource-related concerns such as primary/secondary material use with broader concepts such as the sharing economy and behavioural changes). However, the framing of a circular-economy transition and the scope of analysis must also maintain its "problem orientation", never losing sight of the core issues that the circular economy is meant to address.
- **Stakeholder consultation.** As part of the work on the case studies, the CIRCULAR IMPACTS team conducted stakeholders workshops, carried out interviews with experts in the field. This helped the team assess in detail the underlying trends and acquire data and information that could not have been obtained through desk-based research. Such an in depth analysis of the impacts of implementing a process in one sector is often not possible in overarching assessments that include various sectors and processes.
- **Realistic assumptions and scenarios.** It is important to recognise that additional circular investments will typically come at the cost of other investments and to be careful not to be over-optimistic in estimating productivity benefits based on ex ante evaluations. Many circular opportunities are much more complicated than they appear in theory when it comes to actually implementing them or when they scale up.
- **Appropriate impact measures and welfare definitions.** Given that a primary purpose of a more circular economy is to reduce environmental pollution and other resource-related pressures, the benefits from the circular economy are best assessed by taking a broad welfare concept that goes beyond traditional

economic figures (e.g. GDP and employment) to include environmental and social impacts.

- **Assess both direct and indirect impacts where possible.** Though indirect impacts can be of great significance, studies often underexpose indirect impacts of circular-economy processes. The step-by-step methodology used in the CIRCULAR IMPACTS case studies provides a useful approach for ensuring that both direct and indirect impacts are taken into account.
- **Incorporate life cycle assessment (LCA).** Life-cycle assessment (LCA) is a critical tool for exploring circular-economy processes because it can provide insight into the environmental impacts associated with the different stages of a product's life. An LCA indicates what the most resource-intensive stage of a product is or what happens when it reaches the end of its useful life, and therefore discloses where in the life cycle the most potential for improvement lies.
- **Policy context.** Future research can contribute to a better integration of the circular economy into the EU's key policy mechanisms and into achieving sustainable-development objectives. The CIRCULAR IMPACTS project team extensively researched the interplay between the circular economy and the European Semester. Similar analyses could be performed for other processes in the future, such as the Environmental Implementation Review or the Multiannual Financial Framework.

1 :: Introduction

Relative to a linear economy, a circular economy requires fewer natural resources, generates less waste, and supports sustainable economic growth. The European Commission has acknowledged the need for the Member States of the European Union to shift away from linear economic processes in order to realize a more sustainable and competitive economy.

The European Commission has also expressed the need for an improved understanding of the environmental, economic and social impacts of implementing policies that enable circular-economy transitions. Funded under the Horizon 2020 research programme, the CIRCULAR IMPACTS project sought to increase the evidence base on the different impacts of such a transition.

Over the course of 24 months (running from October 2016 to September 2018), the project team:

- **Collected an evidence base** of reliable datasets and projections and made the evidence base available for the development of impact assessments;
- **Analysed the EU policy context** for the circular-economy transition with a focus on the European Semester process
- **Pointed out innovative approaches** based on the circular-economy concept in Member States;
- **Assessed the economic, societal and resource-efficiency impacts** of selected transitions on existing or new markets over time;
- **Compiled model-based estimates and assessments** of macroeconomic, societal and environmental costs and benefits of circular-economy transitions; and
- **Described market and societal impacts** of resource and waste flows and changes to those flows

As this is the final deliverable of the project, this report begins by summarising key findings of CIRCULAR IMPACTS, including those related to defining the circular economy as well as understanding its relation to the European Semester policy process. The project team conducted four case studies on different circular-economy transitions and their potential impacts, and produced a report on biofuels and renewable energy.[3] The step-by-step methodology developed for the case studies is briefly explained and an overview of findings from the project's review of scenario-based methodologies for evaluating circular-economy transitions is provided.

[3] The case studies address the following topics: EV-battery recycling in the EU, concrete recycling in France, car sharing in Germany and phosphorus recycling in the Netherlands. They can be found online at https://circular-impacts.eu/deliverables

The CIRCULAR IMPACTS project also generated and brought together quantitative analyses of important circular-economy transitions. After presenting a summary of the quantitative results of the four case studies carried out in the project, this report provides an overview of recent work done by external parties seeking to estimate the impacts of circular-economy transitions. The overview focuses on presenting the quantitative results of these studies and providing an understanding of the methodologies used. These studies have also been added to the evidence base compiled for the CIRCULAR IMPACTS Library.[4]

In line with the project's aim to improve the foundation for understanding circular-economy transitions, this report concludes with recommendations related to policy and future research.

[4] The CIRCULAR IMPACTS Library provides a searchable database of information resources related to the circular economy. The Library is available online at https://circular-impacts.eu/library

2 :: Key Findings of CIRCULAR IMPACTS

In the initial phase of the project, the CIRCULAR IMPACTS project addressed topics such as definitions of the circular economy, how the circular economy relates to the European Semester and how can we measure impacts of the circular-economy transition. This section brings together key findings of the project.

2.1 Defining the circular economy

The coining of the term 'circular economy' dates back to the 1990s and has achieved broad appeal amongst the academic, policy and business communities. Research on the circular economy is fragmented across disciplines, and different perspectives exist on what it actually entails and what should be assessed. Accordingly, there are many different definitions regarding what a circular economy is. This fragmentation and ambiguity has also lead to the concept being criticized (Rizos, Tuokko, & Behrens, 2017).

The definition from the Ellen MacArthur Foundation is frequently cited: "an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models" (Ellen MacArthur Foundation, 2013, p. 7). Accordingly, it does not limit itself to an increased focused on resource efficiency, but also incorporates other, more circular aspects, such as improved product design.

Key insights at a glance:

- **Lack of clarity on the circular economy concept.** Many ideas of what a circular economy is and what it entails have been developed, and as a result, consensus is lacking on this issue. The definition coined by the Ellen MacArthur Foundation is the most popular one.
- **Studies on the circular economy are often difficult to compare.** Research is fragmented and studies are difficult compare to each other as a result.
- **Impacts of a transition are not fully understood yet.** Studies often calculate the environmental and economic impacts of a circular economy transition, but largely underexpose social impacts and indirect effects

Therefore, some studies mainly focus on resource management, whereas others also include additional dimensions such as energy efficiency and conservation, land management, soil protection and water. The latter implies a more radical transformation of the economic system, which is not limited to resources and waste. Due to these different approaches, it often is hard to compare research outcomes with one another.

Ensuring that there is one undisputed definition and understanding of the circular economy on a European level could help to tackle this problem, which then also helps to provide more clarity on its potential environmental, economic and social impacts.

Studies often calculate the environmental and economic impacts of transitioning to the circular economy, whereas they less often identify the social impacts. Especially social impacts on gender, skills, occupational and welfare effects, poverty and inequalities are largely neglected. Additionally, indirect effects on the economy also should more often be taken into account, see e.g. Rizos, Tuokko & Behrens (2017).

When analysing the effects of replacing a linear with a circular process, one should consider all the various parameters as part of considering the potential benefits and costs.

Based on the available literature, the CIRCULAR IMPACTS project team created a framework encompassing the main processes considered to be components of a more circular economy (see Table 1).

Table 1. The description used within the CIRCULAR IMPACTS project

Main circular-economy processes	
Use less primary resources	• Recycling • Efficient use of resources • Utilisation of renewable energy sources
Maintain the highest value of materials and products	• Remanufacturing, refurbishment and re-use of products and components • Product life extension
Change utilisation patterns	• Product as service • Sharing models • Shift in consumption patterns

Source: Based on Rizos, Tuokko & Behrens (2017)

2.2 The circular economy and the European Semester

The European Semester to a large degree does not take into account the circular economy, which is due to the current structure and emphasis of the Semester, the lack of information of macroeconomic relevance, the availability and timeliness of relevant indicators and the political priorities that originally guided the introduction of the Semester (Behrens & Rizos, 2017). It mainly looks at economic growth and public finances. In the Annual Growth Surveys of 2016, 2017 and 2018, the European Commission expresses its political commitment to the circular economy, especially related to investments, which is not followed up on in the country reports and the country- specific recommendations.

Key insights at a glance:

- **The European Semester to a large degree does not take into account the circular economy.** The Annual Growth Surveys for 2016, 2017 and 2018 acknowledge the ambition of the European Commission for the circular economy transition, which is not further elaborated upon (or insufficiently) in the country reports and country-specific recommendations.
- **Better and more reliable data is required to integrate the circular economy into the Semester.** Studies are often incomparable and Member States use different indicators to measure circularity.
- **Timing of when data becomes available is critical.** Statistical offices generally release resource-related data a few years later, which means it cannot be used to increase the accurateness of the country specific recommendations.

Reliable information and data are required to better integrate the circular economy in the European Semester. However, as previously indicated, this proves to be a challenge because studies are often incomparable. Additionally, Member States use different indicators to measure circularity. The European Resource Efficiency Scoreboard and the EU SDG Indicators Set could be used as a basis.

Timing is also of critical importance because data should be available when it is needed. However, statistical offices often publish resource-related data with a delay of several years, which makes it impossible to use for policy-making, whereas figures on GDP are updated frequently. This hampers the formulation of practical and effective country-specific recommendations (Behrens & Rizos, 2017). Figure 1 provides an overview of the European Semester, as well as how the circular economy could be better integrated into it.

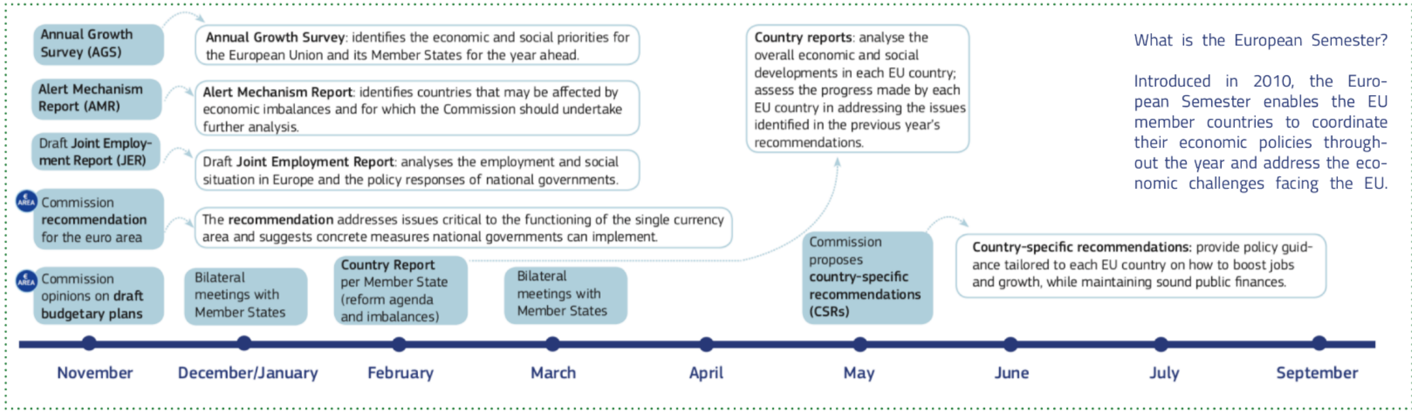
Another important policy context for assessing the impact of circular-economy transitions is the EU's Better Regulation Agenda (see Box 1 for an overview). An important outcome of the CIRCULAR IMPACTS project is the improved knowledge base for conducting future impact assessments within the context of the Better Regulation Agenda.

Figure 1. Infographic: Integrating the circular economy into the European Semester

CIRCULAR IMPACTS

Integrating the circular economy into the European Semester

The Commission's role in the European Semester



Obstacles to integration

01 The European Semester mainly looks at economic policies for growth, jobs and investment, with an emphasis on achieving short-term improvement. However, the impacts of the circular transition are long term.

02 Lack of information on the growth, investment and employment impacts of the circular economy and related policies. This makes it difficult to include circular-economy issues in the Semester process.

03 Statistical offices publish resource-related data with a delay of several years. This hampers the formulation of practical and effective Country-Specific Recommendations.

04 The political priorities that originally guided the introduction of the European Semester have become outdated. The Semester was introduced in 2010 in the wake of the financial and economic crisis and as a way to monitor progress towards the targets of the Europe 2020 Strategy.

Suggestions for integration

01 Consider devoting more attention to the circular economy in the Annual Growth Survey, going beyond sustainable investment and short-term goals. There is also a need to take a more harmonised approach to include circular economy-related issues in the Country Reports and the Country-Specific Recommendations.

02 Increase the evidence base on the macroeconomic and societal impacts of the circular-economy transition. The CIRCULAR IMPACTS project team conducted four case studies on circular-economy processes and developed a methodology for this purpose. The project's Evidence Library provides additional reports and studies.

03 Publish resource-related data with shorter intervals. The European Resource Efficiency Scoreboard, the EU Sustainable Development Goals Indicator Set, and the Monitoring Framework for the Circular Economy can be used to foster increased data availability.

04 Review the political priorities of the Semester. The focus could partly shift to other pressing issues such as climate change. The circular-economy concept could be used as a policy framework to this end.

Checklist for successful integration

Political commitment (☑)
In the Annual Growth Surveys of 2016, 2017 and 2018, the Commission has expressed its political commitment to the circular economy.

Long-term vision (☐)
The circular-economy transition takes time, so expand the focus of the European Semester beyond achieving short-term impacts.

Data availability (☐)
Address the lack of macroeconomic data on the circular economy, and make resource indicators available in a timely fashion.

Visit the CIRCULAR IMPACTS website: **www.circular-impacts.eu**

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Box 1. The Better Regulation Agenda

The European Commission introduced the Better Regulation Agenda in 2015, with the goal to "… work more transparently and inclusively to produce higher quality proposals, and ensure that existing rules deliver important societal goals more effectively" (European Commission, 2015a). As part of this effort, the 'Task force on subsidiarity, proportionality, and doing less more efficiently' was established, chaired by Frans Timmermans, Commission First Vice-President (European Commission, n.d. (a)). The underlying idea of Better Regulation is to ensure that a wide variety of actors affected by EU policy, such as business, public administrations and researchers, can help to shape it to increase the transparency of the policy and law-making process. Additionally, this helps the Commission to reach its goals cost efficiently, while simultaneously addressing the concerns of EU citizens.

The Better Regulation Agenda seeks to guarantee the following:

- Decision-making is open and transparent
- Citizens and stakeholders can contribute throughout the policy- and law-making processes
- EU actions are based on evidence and an understanding of the impacts
- Regulatory burdens on businesses, citizens or public administrations are kept to a minimum (European Commission, n.d. (a)).

The Better Regulation Guidelines describe the principles that the Commission follows during the preparation of new initiatives and proposals and the management and evaluation of existing legislation (European Commission, n.d. (b)). Additionally, a Toolbox provides further assistance for this purpose.

Interested citizens and stakeholders can express their opinion on a variety of issues, such as road maps, legislative proposals and impact assessments, among others. To strengthen the preparation phase by the Commission for each law-making process, impact assessments are conducted. These impact assessments analyse what the potential economic, social or environmental effects of policy might be and are checked by an independent Regulatory Scrutiny Board. Other initiatives focus on increased cooperation between EU institutions and improved international regulatory cooperation.

From 2015-2017, there were 109 proposals for withdrawal, 74 repealed laws and 137 initiatives for regulatory simplification. Additionally, whereas there were around a 100 priority initiatives in 2014, in 2017 this had been reduced to 21 (European Commission, 2017).

2.3 Methodologies for analysing the impacts of circular-economy transitions

In this subsection, both the case-study methodology developed within the CIRCULAR IMPACTS project and scenario-based methodologies used by external parties are critically assessed. The aim of all these methodologies is to provide guidance for producing sound evidence via improved analyses of the various impacts of circular-economy transitions.

2.3.1 Case-study methodology

The CIRCULAR IMPACTS project developed a methodology to conduct case studies on new business cases exploring the potential of circular-economy processes, not only focusing on direct impacts at sectoral level, but also on environmental, economic and social knock-on effects, thereby providing a more complete picture of the expected changes (Smits & Woltjer, 2018).

The case-study methodology consists of eight steps:

- Step 1: Defining the baseline
- Step 2: Defining the new business case
- Step 3: Changes in the key sector
- Step 4: Expected effects on other parts of the economy
- Step 5: The impact on society
- Step 6: Are alternatives available?
- Step 7: Policy options
- Step 8: Overall conclusions

The first step provides an overview of the existing situation and the current (linear) business case. Next, the new business case is introduced, along with the changes it brings along. Subsequently, the key sector is identified and the impact of the new business case analysed in a quantitative manner, focusing on important impact categories, such as resource use, emissions, and the required workforce. The expected effects on other parts of the economy are also taken into account. Then, the impact on society is investigated and (better) alternatives to the new business case are elaborated. Policy options are formulated, and in the eighth and final step, conclusions are drawn (Smits & Woltjer, 2018). Throughout, one should seek to provide the highest level of clarity with regard to where the figures come from.

In practice, the project team found that the case-study methodology did not completely fit the specifics of a particular case-study topic. For instance, since the electric vehicle (EV) is a relatively new phenomenon, it will still take years before their batteries reach the end of their useful life. As a result, the business case of recycling EV batteries case will only become relevant in the future. With concrete recycling, the ‘new’ business case turned out not to be entirely new as the European aggregates industry has been recycling aggregates for many years. Nevertheless, the eight steps provided a solid framework to base the analysis on and do not have to be performed sequentially, which is also mentioned in the methodology.

Due to a lack of available data, it was not possible to estimate all economic, environmental and social impacts, such as the use of resources, emissions, productivity, investment, employment, health and inequality. The extensiveness of the macroeconomic and societal impact analyses were closely related to data availability, which differed per case-study topic. In this regard, it was also a challenge to create links between the different levels of the outcomes. Nevertheless, identifying the data gaps was also a useful exercise, for it helped to see where additional research could be of benefit.

The methodology provides detailed results but these have a limited scope. It is difficult to analyse how and to what extent the introduction of the new business case in one Member State affects other Member States. The OECD confirms this by stating that sectoral assessments on resource efficiency lack the linkages to the rest of the economy (OECD, 2018). Nevertheless, by conducting case studies in specific sectors, it was possible to provide a high level of transparency regarding the origin of the data used as well as the calculations, which is often not possible with larger macroeconomic assessments.

Figure 2 provides a succinct overview of the case-study methodology and is intended as a guide for researchers and those seeking to understand the process.

Figure 2. Infographic: Step-by-step methodology for case studies on the circular economy

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Step-by-step methodology for case studies on the circular economy

Background

A step-by-step case study methodology was developed as part of the CIRCULAR IMPACTS project.

It provides guidelines to policy-makers, interest groups and researchers who want to explore the potential of circular-economy transitions.

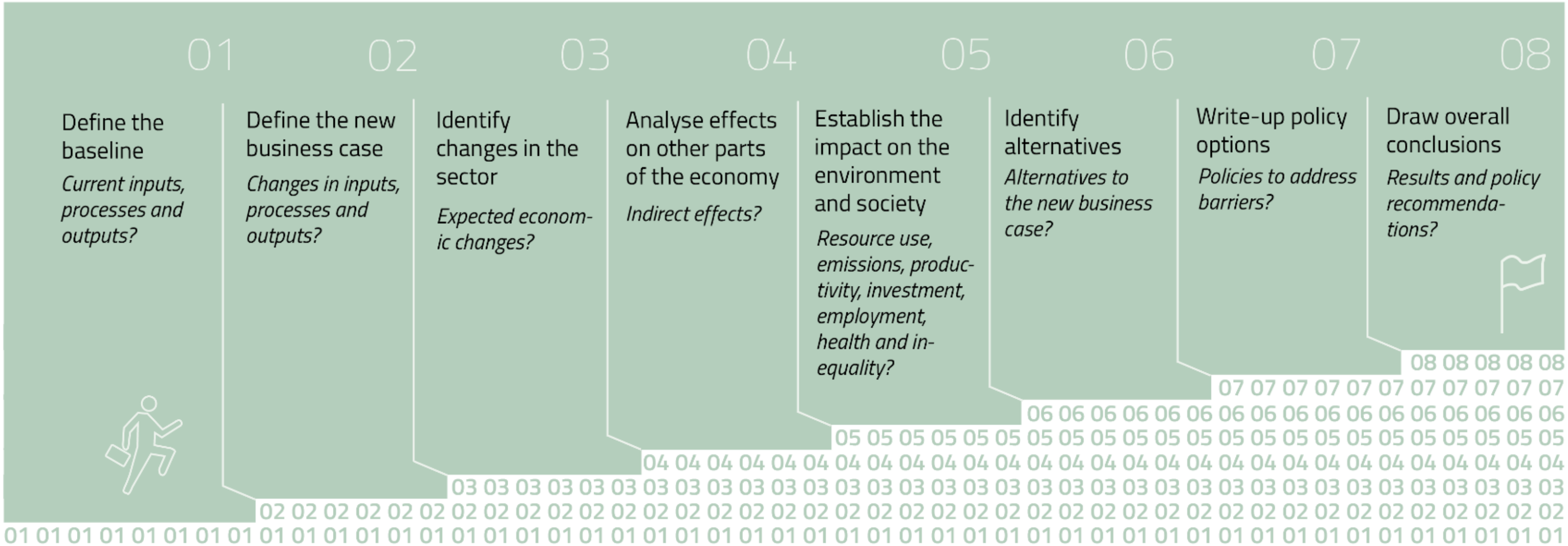
For more information on the circular economy, please visit the Evidence Library:
www.circular-impacts.eu/library

Remember!

- The line of reasoning should be clear and transparent
- Identify who "wins" and who "loses" due to the change
- Investigate direct and indirect effects
- Analyse how the sector would develop without the implementation of the new business case
- Distinguish between case-study results and more general conclusions

See the case-study methodology for more tips:
www.circular-impacts.eu/cs

Steps



Visit the CIRCULAR IMPACTS website: **www.circular-impacts.eu**

The CIRCULAR IMPACTS project has received funding from the European Union's Horizon 2020 Programme for Research and Innovation under the Grant Agreement no. 730316.

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2.3.2 Scenario-based methodologies

Large-scale circular-economy scenarios are typically explored via economic modelling. The key results can be derived from looking at the assumptions and the main mechanisms related to the model. Three approaches can be distinguished when it comes to analysing the systematic changes required for a circular-economy transition, each with a different starting point: 1) the available opportunities that may be realized (opportunity-based); 2) targets to be reached (target-based); and 3) policies that are implemented (policy-based) (Woltjer, 2018). Nevertheless, they all incorporate opportunities and policies in one way or another, and for evaluation purposes use indicators to track targets to be reached.

Key insights at a glance:

- **The majority of circular economy scenarios are explored by using models.** The uncertain parameters on which these models are built determine how policies and changes turn out. Therefore, one can trace back the results to what assumptions the models use, and what the key mechanisms are.
- **The opportunity-, target- and policy-based approach each emphasize different aspects.** However, all three approaches address opportunities and policies to a certain degree and use indicators, which are in some form connected with targets to be reached, for evaluation.
- **Targeted case studies can provide critical insights into how to implement circular-economy opportunities.** It could be useful to include scenario analyses of circular-economy policies as an input for the European Semester, as it deals with public finance, macroeconomic imbalances, structural reforms and total investment needs.

The opportunity-based approach aims to gain a better understanding of unrealized (profitable) opportunities, and includes an analysis as to why they are not realized in the baseline. The accuracy of the outcomes depend on the underlying accuracy of the cost and revenue estimates. These studies often find that the cost of policies needed to capture these opportunities are low compared to the benefits that are generated.

The target-based scenario approach focuses on how pre-defined targets can be reached and often uses a model to this end. Targets are set and can come in the form of resource savings, recycling rates and/or reduction of pollution. The next step is to analyse how these targets can be achieved. Results may depend on a priori assumptions about changes in technology, but most reports calibrate policies to reach the targets or select explicit technologies from a list of opportunities to reach the goal.

The policy-based scenario approach seeks to identify the underlying causes for circular opportunities not being realized as a means to derive policies that address these barriers. Policy plays a significant role in each of the three scenario approaches as a way of capturing opportunities and reaching targets, but in policy-based scenarios, it is also used as the starting point of the analysis. Potential policies could include environmental taxes, regulation, infrastructure, technology policy, as well as information and coordination policies.

Table 2 provides a concise overview, describing the three approaches to scenario analysis. Figure 3 provides an overview of the strengths and weaknesses of these different approaches to measuring impacts of the circular economy.

Analysing circular-economy policies based on scenarios could also be relevant for the European Semester, as they have the potential to influence public finance, macroeconomic imbalances, the need and content of structural reforms, but also total investment needs. Currently, as discussed in Deliverable 2.2 of the CIRCULAR IMPACTS project, the European Semester largely does not take into account the circular economy, even though it is believed that it comes with increased employment opportunities and economic growth. In addition, instead of merely focusing on jobs and GDP, it would be better to focus on a broad welfare concept by including environmental aspects as well, among others. Especially since GDP does not measure significant welfare effects such as, for example, the value of free time and health (Woltjer, 2018).

Table 2. Analysing systematic changes required for the circular economy transition

Approach	Explanation
Opportunity-based	With the opportunity-based approach, the baseline scenario explores what options will be realized under the current course of events. Subsequently, circular opportunities are identified, which will only be captured if the government implements the required circular economy policies. An implicit assumption is that the cost of these policies will be lower than the expected economic growth.
Target-based	With the target-based approach, the first step is to identify environmental and resource targets that need to be reached. Then one needs to define a mechanism to reach these targets. Most studies address this problem by trying to achieve the targets based on a list of available technological opportunities, by calibrating a set of policies that will have the same result, or just by assuming that the transition will be cost neutral.
Policy-based	With the policy-based approach, circular economy policies are at the core of the analysis. Unlike with the opportunity-based approach, they will not necessarily lead to an increase in GDP, but in return might lead to higher welfare.

Source: Based on Woltjer (2018)

Figure 3. Infographic: Methods for measuring impacts of circular-economy transitions

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Methods for measuring impacts of circular-economy transitions

	Modelling/ex ante studies	**Ex-post methods: studies, statistics and indicators**	**Case studies**
	Modelling and ex ante studies aim to predict future developments.	*Ex-post statistics capture past changes and ex post studies can provide explanations.*	*Case studies look closely at specific sectors, issues and processes.*
Strengths	By simulating major economic processes, models provide a way to explore the potential of circular-economy transitions.	Ex-post methods are based on factual evidence and benefit from hindsight regarding complex causal effects.	Case studies offer a high degree of detail and can take into account contextual differences.
Weaknesses / limitations	Models are resource intensive. Outcomes can be uncertain, especially if fundamental systemic change is involved and whenever results are highly dependent on assumptions.	Ex-post results cannot alter the outcome of the analysed event. Establishing causality amongst different factors can still be difficult or data may not even be available.	Results are often not widely applicable as a result of the specificities of the case.
Find out more	OECD report 'The Macro-economics of the Circular Economy Transition'	EU Monitoring Framework for the Circular Economy	CIRCULAR IMPACTS case studies on EV-batteries recycling, concrete recycling, phosphorus recycling and car sharing.

The CIRCULAR IMPACTS Evidence Library has hundreds of resources, including reports, models, statistics and case studies. See: *www.circular-impacts.eu/library*

Visit the CIRCULAR IMPACTS website: **www.circular-impacts.eu**

The CIRCULAR IMPACTS project has received funding from the European Union's Horizon 2020 Programme for Research and Innovation under the Grant Agreement no. 730316.

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Interpreting scenario results

Whenever interpreting the results of scenario-based modelling, a central question requires some thought: in cases where circular-economy investments are deemed profitable, why have these investments not occurred already? Economic actors are presumed to be rational, so assuming there are untapped means of increasing resource-productivity that simultaneously reduce costs could be overly optimistic. Accordingly, there must be barriers in place that prevent these opportunities from being seized. Such barriers can come in the form of market failure or organizational failure, but also hidden costs that are not accounted for in the calculations. In order to improve the accuracy of cost-benefit analyses concerned with circular economy policy, the cost of removing these barriers should be included (Woltjer, 2017).

Most reports attribute positive GDP effects to increases in factor productivity, the greening of taxation (with revenues being used to reduce externalities in the labour market), and the effects of extra investments (provided that other investments are not crowded out). However, one should keep in mind that an increase in GDP is not the primary goal of the circular-economy transition, especially because the former is not a good welfare indicator. For example, health-care costs are part of GDP. To conduct a more thorough welfare analysis, benefits of reducing external costs or increasing external benefits need to be included. Reduced health-care cost implies a decrease of GDP, but the main effect is that people's lives have improved due to fewer illnesses. Other such factors that could be taken into account are a reduced dependence on countries associated with high geopolitical

Key insights at a glance:

- **Barriers prevent circular-economy investments from materializing.** These barriers vary in nature, and the cost of removing them should be included in any cost-benefit analysis of a circular-economy process. The idea that there are 'win-win' situations (increased resource-productivity combined with reduced cost) might be unrealistic, for economic actors are presumed to be rational and as a result, are likely to have already seized such opportunities.
- **The welfare concept should not be limited to economic growth.** GDP fails to capture important welfare aspects, such as a healthy population. Therefore, when conducting a circular-economy case study, a broader welfare approach should be taken by including changes in natural capital and other environmental externalities. Price stability, financial stability and political stability are relevant factors as well, especially because they constitute a point of focus for the European Semester.
- **Employment effects are not a direct result of the circular-economy transition.** Policy changes or mechanisms, such as additional investments and greening the tax system, form the basis thereof and they are not limited to the circular economy.

risks, or an increased insight into the future scarcity of critical raw materials or impacts on ecosystem services.

Additionally, employment effects are not the direct result of the transition, but occur due to policy changes or mechanisms that are not unique to the circular economy, such as additional investments and greening the tax system. Firstly, investments in more labour-intensive technologies might increase employment when there is cyclical unemployment or quantitative structural unemployment. Secondly, employment might increase due to the greening of taxation. Thirdly, qualitative structural unemployment might be reduced in cases where the circular economy opportunities generate jobs in regions or skill categories with high unemployment. Finally, the recycling industry might be able to provide jobs to people with a lesser ability to work via social employment programmes (Woltjer, 2017).

Several types of policy instruments were identified that can remove circular economy barriers (see Table 3).

Table 3. Policy instruments for the circular economy

Policy	Explanation
Subsidies	Subsidies could help private enterprise bear R&D costs, which eventually may generate benefits for the economy as a whole. Subsidies that generate negative externalities could be abolished.
Regulation	Put regulatory restrictions on technologies or externalities that are not in line with the circular economy. Remove legal barriers for circular technologies. Create standards for circular technologies and commodities.
Infrastructure	Build infrastructure to allow for circular technologies. An example thereof is charging points for electrical vehicles or investment in the electricity grid.
Public procurement	Public procurement can be used as a means to stimulate R&D, e.g. by offering businesses a market for their innovative, more circular products.
Information	Provide consumers with additional information on, among others, the energy efficiency of their products by means of an eco-label, can help them to make a more informed choice.
Coordination	Increase coordination between the government and private actors can help to improve their cooperation, and therefore, the effectiveness of legislation.
Financing	Address financing problems stemming from imperfect information.

Source: Based on Woltjer (2017)

2.3.3 Statistics and indicators

Ex-post statistics, including indicators, are a way to capture past changes, complementing the prospective analyses of case studies and scenario modelling (see Figure 3). Indicators can also be used to monitor whether sufficient progress has been made in pre-defined policy areas and to assess whether further action is needed, though it can be difficult to discern to what degree impacts result directly from policy interventions, and what role other (external) factors might have played in shaping the outcome.

The European Commission seeks to monitor progress towards the circular economy and to this end, introduced the Monitoring Framework for the Circular Economy in January 2018. The Monitoring Framework will allow the Commission to “help identify success factors in Member States and to assess whether sufficient action has been taken” (European Commission, 2018a). Ten indicators were identified that should mainly help to identify trends in preserving the value of products, materials and resources, as well as trends in waste generation (European Commission, 2018a). These are grouped into four aspects of the circular economy, namely: production and consumption; waste management; secondary raw materials; and competitiveness and innovation. These grouping correspond to the structure of the Circular Economy Action Plan (European Commission, 2018a). The Monitoring Framework for the Circular Economy is partially based on existing data and monitoring frameworks, such as the Resource Efficiency Scoreboard and the Raw Materials Scoreboard, which will reduce the administrative burden for Member States. Two new indicators were also introduced, namely the Green Public Procurement (GPP) indicator and the food waste indicator (European Commission, 2018b).

Figure 4 provides an overview of the Monitoring Framework for the Circular Economy, including the indicator data on the EU level, at the time of this writing.[5] In the final column, trend lines for each indicator are shown for most figures based on annual data. Figure 5 provides an example of the underlying data for such a trend line, in this case for the EU’s average recycling rate for municipal waste. For the majority of indicators, the most recent data point dates back several years, again underlying the fact that, at present, resource indicators are often published with a significant delay.

[5] For the most up-to-date version of the Monitoring Framework, please visit https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework

Figure 4. Monitoring Framework for the Circular Economy (EU level)

Production and consumption

Indicator	Value	Trend
EU self-sufficiency for raw materials *(percentage)*	36.4 [2016]	N/A
Green public procurement	N/A	N/A
Waste generation		
Generation of municipal waste per capita *(Kg per capita)*	483 [2016]	
Generation of waste excluding major mineral wastes per GDP unit *(Kg per thousand euro, chain linked volumes (2010))*	66 [2014]	
Generation of waste excluding major mineral wastes per domestic material consumption *(percentage)*	12.8 [2014]	
Food waste *(million tonne)*	76 [2014]	

Waste Management

Indicator	Value	Trend
Recycling rates		
Recycling rate of municipal waste *(percentage)*	45.3 [2016]	
Recycling rate of all waste excluding major mineral waste *(percentage)*	55 [2014]	
Recycling / recovery for specific waste streams		
Recycling rate of overall packaging *(percentage)*	67 [2016]	
Recycling rate of plastic packaging *(percentage)*	42.5 [2016]	
Recycling rate of wooden packaging *(percentage)*	39.6 [2016]	
Recycling rate of e-waste *(percentage)*	35.6 [2015]	
Recycling of biowaste *(kg per capita)*	78 [2016]	
Recovery rate of construction and demolition waste *(percentage)*	88 [2014]	

Secondary raw materials

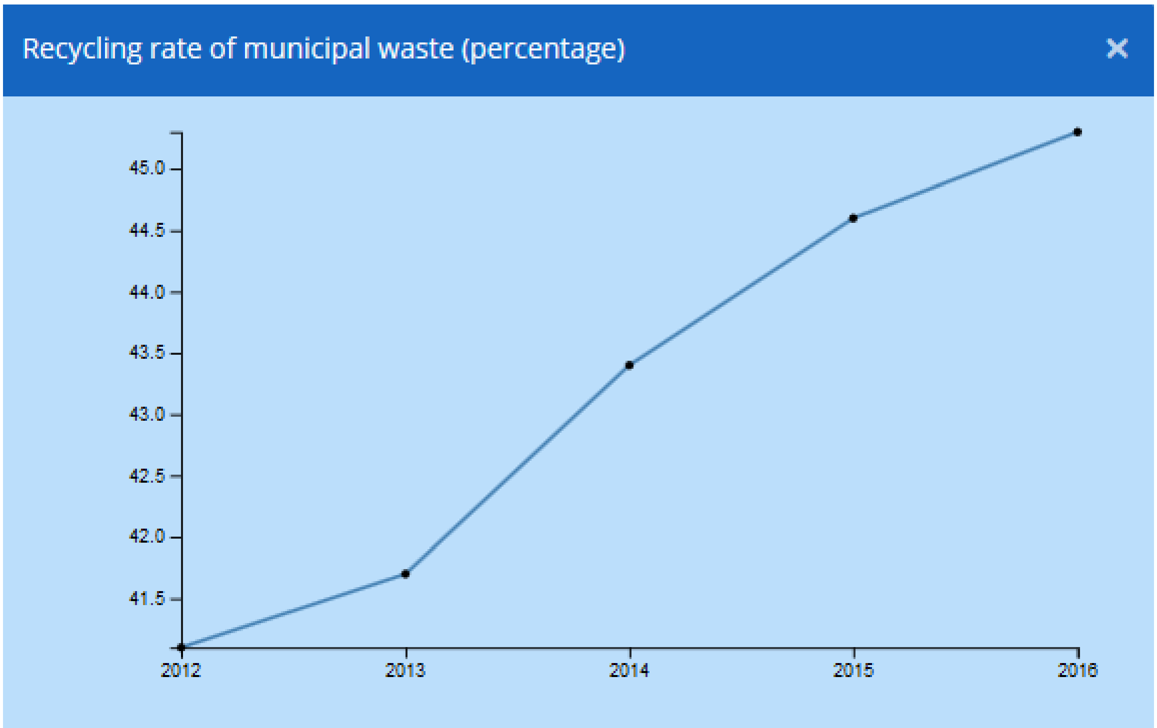
Indicator	Value	Trend
ⓘ Contribution of recycled materials to raw materials demand		
ⓘ End-of-life recycling input rates (EOL-RIR) *(percentage)*	12.4 [2016]	N/A
ⓘ Circular material use rate *(percentage)*	11.4 [2014]	
ⓘ Trade in recyclable raw materials *(tonne)*		
ⓘ Imports from non-EU countries	5,484,505 [2016]	
ⓘ Exports to non-EU countries	34,801,638 [2016]	
ⓘ Imports from EU countries	N/A	N/A
ⓘ Exports to EU countries	N/A	N/A

Competitiveness and innovation

Indicator	Value	Trend
ⓘ Private investment, jobs and gross value added related to circular economy sectors		
ⓘ Gross investment in tangible goods *(percentage of gross domestic product (GDP) at current prices)*	0.12 [2015]	
ⓘ Persons employed *(percentage of total employment)*	1.71 [2014]	
ⓘ Value added at factor cost *(percentage of gross domestic product (GDP) at current prices)*	1 [2014]	
ⓘ Number of patents related to recycling and secondary raw materials	363.78 [2013]	

Source: Reproduced from Eurostat (n.d. (a))

Figure 5. Example of a trend: recycling rate (%) of municipal waste (EU level)



Source: Reproduced from Eurostat (n.d. (a))

In September 2018, the European Parliament's Committee on Environment, Public Health and Food Safety unanimously adopted a resolution urging the European Commission to strengthen the Monitoring Framework for the Circular Economy (ENDS Europe, 2018). The draft motion notes that the included indicators mainly relate to waste generation and recycling, instead of measuring the decoupling of economic growth from resource use and environmental impact (Florenz et al., 2018). Moreover, it points out that an indicator on resource productivity is lacking, since it is a key factor for achieving sustainable growth and jobs in the EU. The draft motion contains both general and content-related remarks, and puts forward several recommendations for making the Monitoring Framework for the Circular Economy a more comprehensive system of circular-economy indicators.

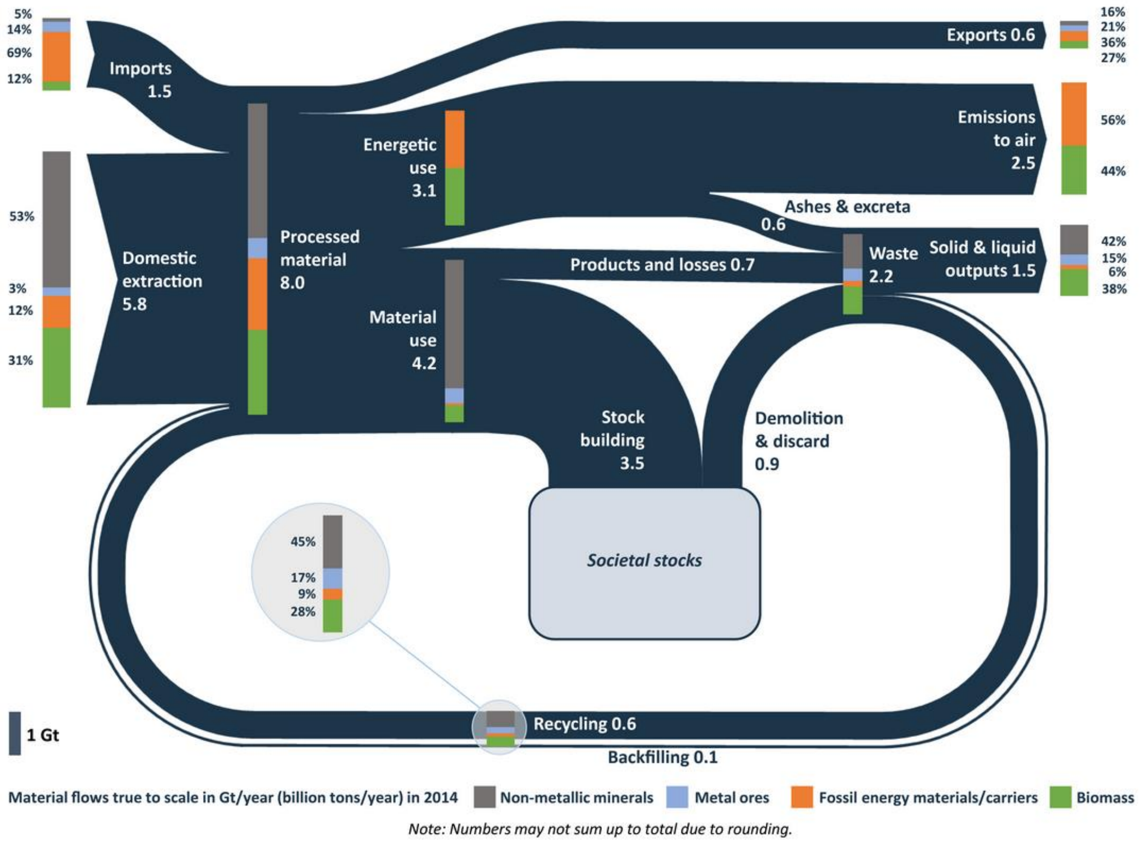
3 :: Macroeconomic and Societal Impacts of the Circular Economy

3.1 Key components of the circular economy

The circular-economy concept originates from several schools of thought and theories that are critical of the current, linear structure the economy, which is associated with the overconsumption of resources. Many governments and business worldwide view it as an opportunity to achieve economic growth and environmental sustainability at the same time (Rizos, Tuokko, & Behrens, 2017). The EU has also acknowledged that the circular economy can not only benefit the environment but also help unlock new business opportunities, create low- and high-skilled jobs and create opportunities for social integration and cohesion, among other positive impacts (European Commission, 2018c).

In order to achieve the aforementioned benefits, societies will need to undergo transformative change. This raises an important question: what exactly are the key components of a circular economy? Figure 6 shows a material-flows analysis for the EU-28 in 2014 published by Eurostat (Eurostat, n.d. (b)). The diagram shows how different materials, such as non-metallic materials, metal ores, fossil-energy materials/carriers and biomass flow through the European economy. To this end, the total amount of inputs (by weight) is shown, as well as the outputs. The latter come in the form of waste, emissions to air, ashes, excreta, etc.

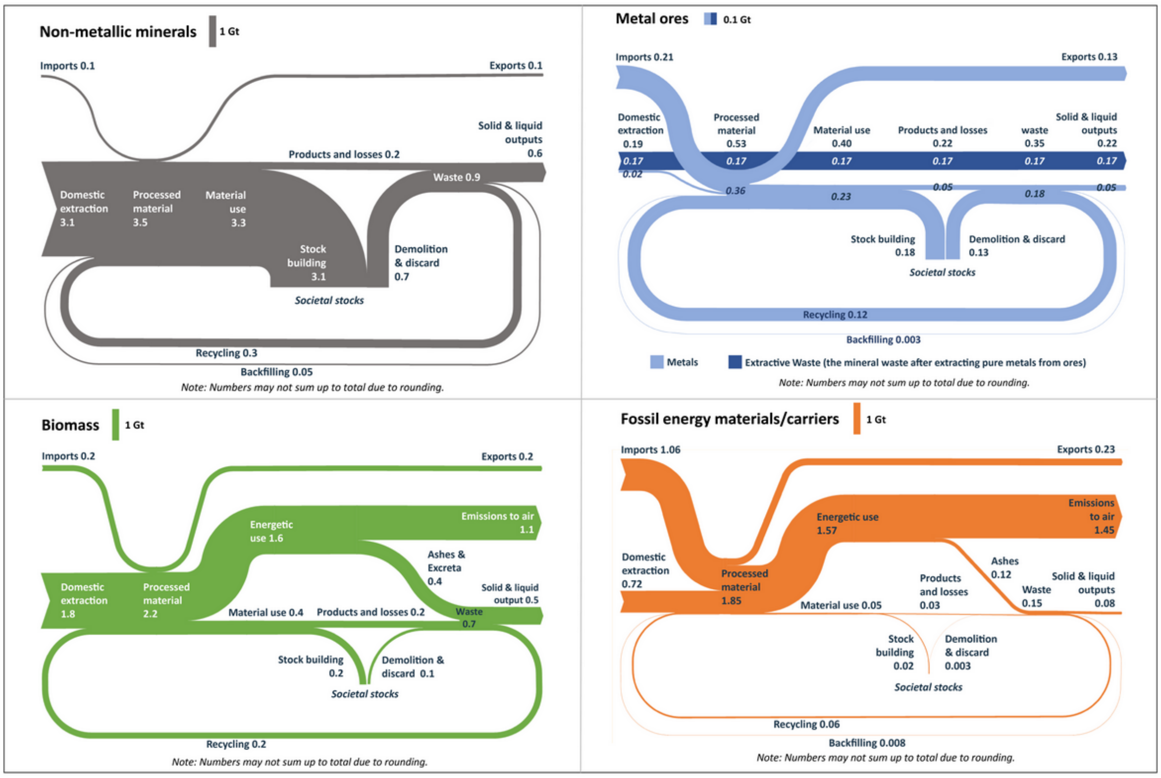
Figure 6. Material flows true to scale in Gt/year (billion tons/years) in 2014 for the EU-28



Source: Reproduced from Eurostat (n.d. (b))

Figure 7 shows this process in more detail for the different materials. Comparing the inputs, outputs and material re-use components, one can see that most materials still predominantly go through a linear process. A notable exception are non-metallic minerals, which spend significant time as societal stocks in the form of buildings and infrastructure. Recycled materials remain a small percentage of total flows in the non-metallic mineral sector while metals already see significant levels of re-use.

Figure 7. Detailed flow diagrams by material in 2014 for the EU-28



Source: Reproduced from Eurostat (n.d. (b))

As indicated above, the Monitoring Framework for the Circular Economy mainly focuses on waste generation and recycling, instead of taking a broader approach incorporating other resource-related indicators such as water use, GHG emissions, land-use and land-use change. The resolution adopted by the European Parliament's Committee on Environment, Public Health and Food Safety also stresses the Monitoring Framework's limited scope by identifying "the lack of certain robust data and knowledge gaps that are important to provide greater insights on progress such as new business trends, sustainable consumption and waste prevention" (Florenz et al., 2018). There is an ongoing debate regarding what the EU should consider to be the key components of the circular economy and how it should monitor progress in bringing it about. A central question is whether the idea of circularity should focus on use and re-use of resources or incorporate broader sustainable-development concepts.

3.2 Case study results

The CIRCULAR IMPACTS project team chose the following case-study topics:

- Concrete recycling in France
- Phosphorus recycling from manure in the Netherlands
- Car sharing in Germany
- Prospects for electric vehicle batteries.

The project team identified these topics to analyse several circular-economy transitions in key sectors of the European economy, such as construction, agriculture, transport and manufacturing. The case studies cover different Member States, such as France, the Netherlands and Germany, as well as Europe as a whole. Additionally, the project team produced a data-collection report on the impacts of biofuels and renewable energy in the EU by reviewing four existing studies. This section provides for each case study and the data collection report a short introduction, the main quantitative results and identifies caveats and key assumptions. At the end of section, a few overarching conclusions are drawn based on the case-study findings.[6]

Sustainable Building – A Case Study on Concrete Recycling in France

The EU, including France, generates large volumes of construction and demolition waste (CDW). By recycling concrete into recycled concrete aggregates (RCA) and using them to replace quarried aggregates in ready-mix concrete, natural resources can be saved.

The circular scenario assumes 25% of total RCA production finds application in ready-mix concrete, compared to about half that amount (12%) going to that use in the business-as-usual scenario. Table 4 shows the comparative results for the different environmental impacts. In both scenarios (business as usual and circular), concrete containing any RCA is assumed to be made up of 15% RCA by the target year of 2030.

[6] A more detailed overview and assessment of the four CIRCULAR IMPACTS case studies, including methodological aspects was also produced by the project, see Woltjer et al. (2018).

Table 4. Sustainable Building – Results of the numerical analysis for environmental impacts

Envr. impact indicator	Units	BAU 2030 scenario	Circular 2030 scenario	% Diff
Consumption of energetic resources	10^3 MJ	79,906,782	78,193,343	-2.14%
Abiotic depletion	kg eq Sb	61,131,038	59,703,172	-2.34%
Water consumption	10^5 L	293,704,140	290,118,611	-1.22%
Global warming	10^2 kg eq CO2	167,165,607	165,103,134	-1.23%
Acidification	kg eq SO2	33,392,052	34,090,120	2.09%
Eutrophication	kg eq PO4^3-	8,230,866	8,072,214	-1.93%
Air pollution	10^5 m3	280,523,225	273,796,391	-2.40%
Water pollution	10^3 m3	126,772,895	124,678,692	-1.65%
Ozone layer depletion	10^-5 kg CFC eq R11	107,030,573	104,587,336	-2.28%
Photochemical oxidation	kg eq C2H4	4,862,362	4,767,171	-1.96%

Source: Reproduced from Duin & Best (2018)

Most environmental impacts are lower in the circular scenario compared to business as usual, typically differing by about 2%. Only the acidification rate is higher in the circular scenario. While the available evidence made the analysis of environmental impacts fairly straightforward, identifying the economic and social impacts stemming from an increased use of RCA is extremely difficult because the exact nature of these impacts are strongly interrelated with regional and local circumstances. Given the local nature of the aggregates industry and the similar skill sets required for handling both natural and quarried aggregates, labour-market impacts of such a circular-economy transition can be expected to be minor.

It should be noted that the extent of the environmental benefits is closely related to the transport distances of the aggregates. The transport distances of the recycled aggregates are around one third those of the quarried aggregates in the LCA study that is used to calculate the environmental impacts in the case study. Importantly, the distances that aggregates travel should not be increased due to recycling as this not only quickly cancels out the environmental benefits of recycling, but also increases the costs. Furthermore, since aggregates are also required for other uses, e.g. road construction, the effect of incorporating more RCA into ready-mix concrete could have the effect that more quarried aggregates would be diverted into road construction.[7] Quarried aggregates will always be needed to meet the total demand for aggregates as RCA volumes remain too small to provide the quantities needed.

Phosphorus Recycling from Manure – A Case Study on the Circular Economy

This case study focuses on phosphorus recycling in the Netherlands, thereby also taking into account some global and European implications. Phosphorus (P) is an essential element for life and forms an irreplaceable part of modern agriculture. However, the use of manure from intensive livestock production has led to the accumulation of phosphorus in the soil in the Netherlands, which causes environmental problems. Therefore, any excess manure needs to be transported to other regions, leading to a negative manure price. This negative manure price provides the business case for the BioEcoSIM process, in which manure is processed into phosphorus and nitrogen fertilizer, but also organic soil improver or biochar. As a result, transport costs, greenhouse-gas emissions and particulate-matter formation due to storage and transport are reduced. Table 5 provides an overview of the environmental and economic impacts of mainstreaming the BioEcoSIM process vis-à-vis the 2015 situation, for 3 million tonnes of Dutch manure.

[7] France has a policy framework in place that promotes the use of recycled aggregates in road construction.

Table 5. Phosphorus Recycling from Manure – Economic and environmental effects of mainstreaming BioEcoSIM (vis-à-vis 2015 situation)

	Environmenta	Economic	Units
GDP		15.00	mln euros
GHG emissions	-144,600	8.68	ton CO2eq/ mln euros
Particulate matter formation	-1,488,000	66.96	kg PM10eq/ mln euros
Total welfare benefit		90.64	mln euros
Fossil fuel depletion	31,800		tonne oil equivalents
Current account net imports		0.26	mln euros
Deprecation (replacement investment)		4.50	mln euros
Employment		small	
Transport sector sales		-24.90	mln euros
Livestock sector income		55.00	mln euros
Crop sector income		-40.00	mln euros

Source: Based on Smits & Woltjer (2018)

The economic analysis of the circular scenario finds that GDP would grow with around 15 million euros, CO_2 emissions would be lowered by 144,600 tonnes and particulate matter formation would be reduced by 1,488,000 kg PM10eq. The BioEcoSIM process would lead to higher depletion of minerals and fossil fuels, as it requires more energy and chemicals, for which the reduced use of fossil fuels for transport would not be able to compensate. Employment effects would be marginal, since the BioEcoSIM process is largely automated.

For the BioEcoSIM process to be profitable, a negative manure price is required. Different factors, such as the level of intensive livestock production in other regions and the amount of secondary phosphorus in other waste streams, play a role in determining the manure price. Furthermore, the accuracy of the calculated welfare effects depend very much on the correctness of the LCA and the cost calculations on a micro-scale as used by the BioEcoSIM process. For example, the cost-reduction figure of €5 per tonne of pig manure comes with a lot of uncertainty. Because investigating the impacts for 2030 would involve too much speculation regarding baseline developments through that year, the current situation is used as the comparative situation in the analysis.

Car Sharing in Germany – A Case Study on the Circular Economy

This case-study paper examines future scenarios for car sharing in Germany, analysing drivers and impacts. Enabled by disruptive technological changes (e.g. smartphones, internet and GPS), car sharing is an example of a "product as a service" and becoming an increasingly viable alternative to the private ownership of cars. By intensifying the use of vehicles, car sharing has the potential to provide mobility using fewer physical and energy resources. However, other models of shared mobility, such as ridesharing enabled by autonomous vehicles, could actually have countervailing effects, drawing passengers away from public transit. Two future circular scenarios for 2030, Circular "Green" (car sharing) and Circular "Gray" (a broader concept of shared mobility) are developed and compared to a business-as-usual scenario. The paper highlights the impacts of the scenarios on motor-vehicle travel and production as well as greenhouse-gas emissions, also describing likely economic and policy implications. The case underlines the importance of analysing specific circular opportunities like car sharing in the context of a broader system of multi-modal transport.

All 2030 scenarios are based on a set of underlying assumptions wherein the passenger-vehicle sector achieves greenhouse-gas emission reductions at levels in line with the German government's climate commitments under the Paris agreement. In addition, in all 2030 scenarios, the number of electric vehicles on German streets reaches 5 million by 2030. Achieving these ambitious assumptions is contingent on corresponding and effective policy interventions in Germany and the EU. In the baseline scenario, car sharing grows fivefold above 2017 levels by 2030, reaching 0.5% of the passenger-kilometres (pkm) covered by motorised passenger vehicles. In the circular scenarios, car sharing is 25 times higher than today (reaching a level equal to about 28% of public-transit passenger-km today).

Table 6 provides an overview of the assumptions used and Table 7 shows the key results for motor-vehicle use, greenhouse-gas emissions and vehicle production for the German market.

Table 6. Car Sharing in Germany – assumptions used in the scenario analysis

Assumption	BAU 2030	Circular "Green" 2030	Circular "Gray" 2030
Percentage of passenger motor-vehicle passenger-kilometres covered by car sharing	0.5% covered by car sharing	2.5% covered by car sharing	2.5% covered by shared mobility
Net reduction of passenger vehicles per car-sharing vehicle	Reduction of 2 vehicles	Reduction of 2 vehicles	Vehicle increase of 10% (0.1 vehicles)
Net reduction in total pkm of motor vehicles per pkm covered by car sharing	Reduction of 3.7 pkm	Reduction of 3.7 pkm	Pkm increase of 10% (0.1 pkm)

Source: Reproduced from Best & Hasenheit (2018)

Table 7. Car Sharing in Germany – key results of the case study

Impact	BAU 2030	Circular "Green" 2030	Circular "Gray" 2030
Annual pkm covered by car sharing*	4.8 billion	23 billion (+500%)	23 billion (+500%)
Annual pkm covered by motorised passenger vehicles (including car sharing)	975 billion	908 billion (−7%)	994 billion (+2%)
CO_2e emissions from motorised passenger vehicles (including car sharing)	114 billion kg	104 billion kg (−10%)	116 billion kg (+1%)
New motorised passenger vehicles	3,613,800	3,029,900 (−16%)	3,659,300 (+1%)
Vehicle stock (motorised passenger vehicles)	46,727,000	42,990,000 (−8%)	47,141,000 (+1%)

*Note: The Circular "Gray" scenario also includes ridesharing and autonomous vehicles, with shared mobility creating a net draw of users from public transport.

Source: Reproduced from Best & Hasenheit (2018)

Prospects for electric vehicle batteries in a circular economy

This case study looks at the recycling of electric vehicle (EV) batteries in the EU. In the coming years, increasing numbers of such batteries will reach their end-of-life, which offers an opportunity to recapture part of their value by extracting some of the critical raw materials they contain. In 2006, the European Commission implemented the Batteries Directive, which has the primary objective to minimise the environmental impacts of waste batteries, thereby helping to protect, preserve and improve the quality of the environment.

Four key materials from lithium-ion batteries are analysed and selected based on their economic, societal and environmental significance: cobalt, nickel, aluminium and lithium. Two scenarios are explored for different time horizons (2030, 2035 and 2045), each with different collection/take back rates for lithium-ion batteries and recycling efficiency rates for these materials. Table 8, Table 9 and Table 10 provide an overview of the economic, social and environmental impacts of the two scenarios.

Table 8. Prospects for electric vehicle batteries in a circular economy – Amount and value of materials recovered

	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
	2030		2035		2040	
Amount of recovered material (tonnes)						
Cobalt	2,922	4,058	6,519	9,054	13,509	18,763
Nickel	10,604	13,535	23,662	30,200	49,035	62,584
Aluminium	31,826	39,783	71,013	88,766	147,163	183,954
Lithium	1,162	2,421	2,593	5,401	5,373	11,193
Value of recovered material (million €)						
Cobalt	213	295	475	659	983	1,366
Nickel	123	157	274	350	569	726
Aluminium	57	71	126	158	262	328
Lithium	15	32	34	71	71	148
Total	**408**	**555**	**909**	**1,238**	**1,885**	**2,568**

Source: Reproduced from Drabik & Rizos (2018)

Table 9. Prospects for electric vehicle batteries in a circular economy – Employment for each scenario in 2030, 2035 and 2040 (jobs required to recycle EV batteries)

	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
	2030		2035		2040	
Collection + dismantling	2,094	2,618	4,673	5,841	9,684	12,105
Recycling	524	654	1,168	1,460	2,421	3,026
Total	**2, 618**	**3,272**	**5,841**	**7,302**	**12,105**	**15,131**

Source: Reproduced from Drabik & Rizos (2018)

Table 10. Prospects for electric vehicle batteries in a circular economy – Net savings of CO_2-eq emissions (tonnes)

Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
2030		2035		2040	
174,525	218,156	389,415	486,769	807,000	1,008,750

Source: Reproduced from Drabik & Rizos (2018)

It is estimated that under scenario 1, around €1.9 billion in current prices could be recovered from the four key materials by 2040. In scenario 2, this figure could increase to around €2.6 billion. Furthermore, both scenarios indicate that the collection of, dismantling and recycling of EV-batteries could lead to additional employment in the lithium-ion recycling sector, as well as CO_2 emissions savings due to reduced raw-material extraction. Generally, the economic, social and environmental benefits are higher for scenario 2 than scenario 1.

The prices of the four key materials come with a significant amount of uncertainty; new technological developments might lead to unpredictable changes in demand patterns. Additionally, limited data is available on the recycling of EV-batteries, because very few of these have already reached their end-of-life. Therefore, the costs of collecting, dismantling and recycling batteries, as well as investments costs and employment effects on other sectors, are left out of the scope of the assessment.

Impacts of Biofuels and Renewable Energy – Data Collection Report

This data collection report deals with the impacts of biofuels and renewable energy on a European level, with a specific focus on macroeconomic impacts, e.g. GDP and employment. It is not a case study but it compares different relevant sources that quantify the impact of an increased deployment of biofuels and renewable energy on a 2030 time horizon. One study on biofuels was analysed, as well as three studies on renewable energy.[8]

Figure 8 and Figure 9 provide an overview of the results. Overall, the studies indicate that an increased deployment of renewable energy seems to have a minor but positive effect on GDP, from around 0.5% to 0.8% when renewable-energy targets are set at 30% and 35%, respectively. With regard to employment, the outcome is similar: the studies describe a small but positive change. It is not possible to draw detailed conclusions on fossil-fuel import dependency by comparing the studies, but one can observe that with an increased deployment of renewable energy, the EU's spending on fossil fuels would go down. Since the studies use different measures to report on CO_2 reductions, it is also not possible to compare them in this regard, though the authors agree that there is a positive effect.

The studies were not only motivated by different aims, they also reviewed different scenarios, thereby applying various models, assumptions and targets. As a result, coming up with definitive figures by comparing their results is not possible. Furthermore, for the sake of comparability, only four studies were reviewed, even though many more are available, each with different scenarios, geographical coverage, time horizons, etc.

8 The following studies were analysed: Duscha et al. (2014); European Commission (2014); European Commission (2016); Smeets et al. (2014).

Figure 8. Impacts of Biofuels and Renewable Energy – Comparison of modelling results for 2030 renewable energy scenarios (macroeconomic results)

COMPARISON OF MODELING RESULTS FOR 2030 RENEWABLE ENERGY SCENARIOS

All data shown is for the year 2030 unless otherwise specified

SCENARIO DEFINITIONS	**Duscha et al. (2014)**					**EC (2014)**			**EC (2016b)**	
Scenario	Baseline	SNP-30	QUO-30	SNP-35	QUO-35	Ref 2013	GHG40/EE/RES30	GHG45/EE/RES35	EUCO27	EUCO3030
RES deployment (share of RES in gross final energy consumption)	26,3%*	30%	30%	35%	35%	24,4%*	30%	35%	27%	30%
GHG reductions (as compared to 1990 emissions level)	45%	40%	40%	45%	45%	32,4%*	40%	45%	40%	43,2%*
Energy efficiency (demand reduction compared to reference scenario in 2030)	n.a.	n.a.	n.a.	n.a.	n.a.	21,0%*	30,1%*	33,7%*	27%	30%
Energy efficiency 2050 (demand reduction compared to reference scenario in 2050)	33%	33%	33%	34%	34%	n.a.	n.a.	n.a.	n.a.	n.a.

**Asterisk indicates a modeled figure.*

MODELING RESULTS																					
Model used for macroeconomic impacts		n.a.	**NEMESIS**	**ASTRA**	**NEMESIS**	**ASTRA**	**NEMESIS**	**ASTRA**	**NEMESIS**	**ASTRA**	**E3ME[1]**	**E3ME[2]**	**E3ME[1]**	**E3ME[2]**	**E3ME[1]**	**E3ME**	**GEM-E3[3]**	**GEM-E3[4]**	**E3ME**	**GEM-E3[3]**	**GEM-E3[4]**
GDP	(Net) GDP effect (compared to BAU)	n.a.	0,40%	0,08%	0,34%	0,07%	0,80%	0,23%	0,78%	0,08%	n.a.	n.a.	0,46%	n.a.	0,53%	n.a.	n.a.	n.a.	0,53%	0,13%	-0,49%
Employment	(Net) employment effect (compared to BAU)	n.a.	0,32%	0,06%	0,30%	0,04%	0,67%	0,11%	0,68%	0,07%	n.a.	n.a.	0,09%	0,50%	0,09%	n.a.	n.a.	n.a.	0,18%	0,14%	-0,29%
	Net employment effect (1000 jobs)	n.a.	715	140	671	92	1497	242	1528	159	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Employment in 2030 (1000 persons)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	231.861	231.701	232.081	232.947	232.075	233.500	216.600	216.000	n.a.	n.a.	n.a.
CO2	Avoided CO2 emissions due to RE (Mio t/a)	1.515	1.701		1.709		1.967		1.972		n.a.		n.a.		n.a.	n.a.			n.a.		
	CO2 emission reductions vs 2005	n.a.	n.a.		n.a.		n.a.		n.a.		29%		37%		43%	n.a.			n.a.		
	Carbon intensity of power generation (per MWhe+MWhth)	n.a.	n.a.		n.a.		n.a.		n.a.		n.a.		n.a.		n.a.	0,179			0,157		
Energy imports	Avoided fossil fuel (imports) due to RE (bn EUR/a)	177,40	212,70		211,60		238,60		238,90		n.a.		n.a.		n.a.	n.a.			n.a.		
	Fossil Fuel Net Imports (bn EUR, average annual, 2011-30)	n.a.	n.a.		n.a.		n.a.		n.a.		461		439		434	n.a.			n.a.		
	Fossil Fuel Net Imports (bn EUR, average annual, 2021-30)	n.a.	n.a.		n.a.		n.a.		n.a.		n.a.		n.a.		n.a.	427			416		

1 - revenue from carbon pricing used to lower labour costs

2 - revenue from carbon pricing transferred to consumers

3 - loan-based case

4 - self-financed case

Macroeconomic effects of bio-based applications have been assessed by Smeets et al. (2014) who compare the impacts of producing 1EJ of biomass-based product and using it to substitute its conventional equivalent.
The net GDP effect evaluated with the MAGNET model amounts to 5,1bn US$ for biofuels, -3,0bn US$ for bioelectricity and -5,1bn US$ for biogas.
If a 25% higher or 25% lower oil price is assumed, net GDP effect of biofuel changes to 11,0 or 0,6bn US$ respectively.

Source: Reproduced from Chelminska & Best (2018)

Figure 9. Impacts of Biofuels and Renewable Energy – Comparison of modelling results for 2030 renewable energy scenarios (bioenergy-related results)

COMPARISON OF MODELING RESULTS FOR 2030 RENEWABLE ENERGY SCENARIOS

All data shown is for the year 2030 unless otherwise specified

SCENARIO DEFINITIONS	**Duscha et al. (2014)**					**EC (2014)**			**EC (2016b)**	
Scenario	Baseline	SNP-30	QUO-30	SNP-35	QUO-35	Ref 2013	GHG40/EE/RES30	GHG45/EE/RES35	EUCO27	EUCO3030
RES deployment (share of RES in gross final energy consumption)	26,3%*	30%	30%	35%	35%	24,4%*	30%	35%	27%	30%
GHG reductions (as compared to 1990 emissions level)	45%	40%	40%	45%	45%	32,4%*	40%	45%	40%	43,2%*
Energy efficiency (demand reduction compared to reference scenario in 2030)	n.a.	n.a.	n.a.	n.a.	n.a.	21,0%*	30,1%*	33,7%*	27%	30%
Energy efficiency 2050 (demand reduction compared to reference scenario in 2050)	33%	33%	33%	34%	34%	n.a.	n.a.	n.a.	n.a.	n.a.

*Asterisk indicates a modeled figure.

MODELING RESULTS related to bioenergy										
RE share in transport fuel demand	7,7%	9,6%	9,6%	11,1%	11,1%	n.a	n.a	n.a	n.a.	n.a.
Expenditures for biomass fuels (bn €/a)	59,00	71,60	70,80	76,60	76,10	n.a	n.a	n.a	n.a.	n.a.
Avoided fossil fuels due to RES in transport by 2030 - increase compared to 2010 (bn EUR)	9,80	13,80	13,70	16,80	16,80	n.a	n.a	n.a	n.a.	n.a.
Demand biomass (Mtoe)	n.a.	n.a.	n.a.	n.a.	n.a.	178	192	223	n.a.	n.a.
Domestic production biomass feedstock (Mtoe)	n.a.	n.a.	n.a.	n.a.	n.a.	194	213	231	n.a.	n.a.
Net imports biomass feedstock (Mtoe)	n.a.	n.a.	n.a.	n.a.	n.a.	4	2	5	n.a.	n.a.
Bioenergy production (Mtoe)	n.a.	n.a.	n.a.	n.a.	n.a.	157	172	179	n.a.	n.a.
Net imports of bioenergy (Mtoe)	n.a.	n.a.	n.a.	n.a.	n.a.	21	20	32	n.a.	n.a.
Cropland are for perennials, including plantation wood (million hectares)	n.a.	n.a.	n.a.	n.a.	n.a.	7	10	12	n.a.	n.a.
RES-T share	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	18%	21%
Biofuels consumption (Ktoe)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	20.486	21.314
Biofuels consumption (% of gros final energy consumption - transport)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	8,00%	8,45%
Biofuels consumption (% of total RES consumption)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7,03%	6,87%

Source: Reproduced from Chelminska & Best (2018)

Conclusion

The CIRCULAR IMPACTS case studies have generated new insights and evidence for four important circular-economy transitions, while the data-collection report on biofuels and renewable energy drew together the most important recent evidence on circular-economy transitions. However, because the case studies examine relatively narrow issues that are sector- and context-specific, they cannot be combined in a way that makes it possible to draw definitive conclusion regarding the overall macroeconomic and societal impacts of a large-scale circular-economy transition.

The case studies demonstrate that more circularity is not per se beneficial and can even be harmful to the environment in some cases. For example, for concrete recycling, the distances that aggregates travel should not be increased due to recycling as this quickly increases the costs and cancels out the environmental benefits of recycling. In phosphorus recycling, implementing the BioEcoSIM process would increase fossil-fuel depletion due to increased use of energy and chemicals.

Furthermore, some circular-economy transitions (e.g. car sharing) require close monitoring and anticipatory policy frameworks, because for now extensive uncertainty remains regarding how key sectors could develop, and the potential exists to transform entire sectors via technological disruption.

The case studies also provide examples where increased circularity clearly has positive effects. By recycling EV-batteries, a significant portion of the value from critical raw materials could be recovered and CO_2 emissions could be reduced. One should note that the extent to which such estimates can be made is closely related to data availability, and the reliability of the results depend on the accuracy of that data.

3.3 Scenario analyses: external modelling results

Based on an examination of modelling studies external to the CIRCULAR IMPACTS project, this section identifies the potential magnitude of such impacts while pointing out the complexity of their estimation. We summarize the results of recent studies that have used macro-economic models to analyse circular-economy transitions. Conducting an original modelling exercise was not part of the CIRCULAR IMPACTS project design. However, the project does include an overview of these modelling efforts in order to compare results, summarize the state of the art and provide a collected evidence base of the results.

The starting point of this summary exercise is the OECD working paper "The Macroeconomics of the Circular Economy Transition A Critical Review of Modelling Approaches", an in-depth literature review of model-based studies analysing circular economy transitions (McCarthy, Dellink, & Bibas, 2018). OECD has published their review within the context of the RE-CIRCLE project, which includes a qualitative assessment of policies enabling a transition to a more circular economy. The review by the OECD offers an excellent collection of literature sources and provides a summary of recent developments in economic modelling related to the circular economy. In contrast to the *methodological* focus of the OECD paper, we concentrate on the *quantitative* results. Though the literature remains too sparse to conduct a formal meta-analysis, examining the results of the studies provide helpful insights about mechanisms driving the effects of circular economy transitions.

Model-based studies of circular-economy transitions differ in many respects. Broadly speaking, they represent different approaches to scenario analysis. As explained in Section 2.3.2, one can distinguish among opportunity-, target- and policy-based scenarios (Woltjer, 2018). In the studies included in this review, target- and policy-based scenarios predominate; this group of studies examines the impacts of either a specific resource-efficiency target or a specific policy. In addition, scenarios differ with respect to the modelled policy tools (the specific policies implemented to achieve a desired outcome). Such policies could include environmental taxes, regulation, introduction of new infrastructure, technology development as well as information and coordination activities (Woltjer, 2017). Finally, the studies differ with respect to other factors, including: 1) geographic scope (e.g., whether the focus is on the EU, the whole world or a particular country); 2) time horizon (usually the impacts until 2030 or 2050 are discussed), and; 3) the modelling approach.

These and other differences among the modelling exercises stem from the fact that each of these studies addresses a slightly different question, with the consequence that there is a large heterogeneity in the results. This heterogeneity and the still-sparse literature base means it is not possible to provide a straightforward answer to the question: "What are the future macroeconomic and societal impacts of the transition to circular economy?" On the other hand, these differences provide an opportunity to explore the question more thoroughly, especially regarding which mechanisms drive the impacts of circular-economy transitions, and how policies may influence the outcomes.

Though modelling studies yield differing results, the circular-economy transition scenarios generally point to a positive economic impact. In several of the examined reports, benefits in terms of GDP and employment were identified. Although some of the scenarios do find that the analysed targets or policies can have a negative economic effect, it appears that a careful policy design could prevent these impacts. The same applies to environmental impacts: although the transition to circular economy has the potential to reduce environmental stressors, the complexity of mechanisms governing emissions and resource effects could lead to countervailing effects, confirming the necessity for a well-designed policy mix. Box 2 provides an overview of the overarching insights stemming from our analysis of the various macroeconomic modelling studies.

In the annex to this report, an extensive tabular overview facilitates the comparison of results from the macroeconomic modelling studies included in our impacts summary.

Box 2. Overarching insights from the reviewed modelling studies (comparative analysis)

- **Rebound effects.** An increase in resource efficiency might result in a higher consumption, which contradicts the aims of reducing GHG emissions and resource use. To counteract the rebound effect, a policy mix should not only enhance efficiency, but also limit resource use. This issue is discussed in Cambridge Econometrics et al., (2018), Meyer et al., (2018), UNEP (2017) and Bosello et al. (2016). Other potential "unexpected" effects are possible. For example, Bosello et al. (2016) find that some environmental policies implemented within the EU result in relocating negative externalities to other countries instead of reducing them.
- **Technological feasibility.** In many modelling studies, efficiency improvements are driven by technological progress, sometimes assumed as exogenous effects that are not caused by policies. It is justifiable to question to what extent such technological improvements are feasible, whether their costs have been correctly considered in the modelling, and to what extent the modelling results are insightful. For further discussion of this issue, see McCarthy et al. (2018).
- **Revenue recycling.** The issue of using revenues from potential environmental tax policies is a recurring topic in the examined literature. The evidence from scenario analysis suggests that implementing a tax policy that assumes revenue recycling (e.g. to lower labour costs) facilitates higher levels of GDP and employment than would be the case without such revenue recycling (e.g. Cambridge Econometrics and BIO Intelligence Service, 2014; Bosello et al., 2018).
- **Global, regional and national perspectives in policymaking.** From both economic and environmental points of view, the geographical scale of the policy in question makes a difference. Not surprisingly, globally implemented targets and policies yield the largest progress in environmental terms (see e.g. Meyer et al., 2015). In terms of economic impacts, it appears that an overarching EU target brings more benefits than imposing the same target on each Member State (Cambridge Econometrics and BIO Intelligence Service, 2014). Apart from impacts in absolute terms, there is also the question of a shift of economic power. An example is the finding of Schandl et al. (2016), that implementing global efficiency policies would result in the EU losing less GDP share to China.
- **New behaviours and societal change.** Several studies find that achieving environmental goals as a result of behavioural changes in society (e.g. changing consumption patterns) may cause losses in traditional economic terms but could have other benefits (e.g. Meyer et al., 2015, Hu et al., 2015, Bosello et al., 2016). This again raises the question regarding to what extent commonly used economic indicators are able to reflect the full value of human well-being.
- **Distributional considerations.** The results from the examined literature show that achieving an overall positive impact might still generate "winners and losers". The disadvantaged groups could be particular countries (e.g. resource-exporting countries in Meyer et al., 2018); sectors (e.g. the construction sector in Cambridge Econometrics

et al., 2018); or societal groups (e.g. lower income groups in Cambridge Econometrics and BIO Intelligence Service, 2014).

Cambridge Econometrics et al. (2018)

The most recent of the identified studies estimating economic impacts of a transition to circular economy is the report prepared by Cambridge Econometrics et al. (2018). Using the M3ME model, the authors examine possible EU-wide effects of the transition with a 2030 time horizon and a particular focus on the labour market. The report examines scenarios that differ with respect to the focus and the extent of circular opportunities. The authors analyse the impacts of increased circularity in each of the five examined sectors (food, construction, waste management, electronics and motor vehicles) as well as the effect of simultaneously scaling up circular activities in all of them. For all cases, the authors distinguish between a “moderate” and an “ambitious” version. They do not assume a specific trigger to the circular transition (e.g. policy or behavioural motivations). Instead, they adopt a bottom-up perspective, assuming changes in activities on a sectoral level.

The main impacts estimated in the study are summarized in Table 11. The modelling exercise predicts that, in general, scaling up circular activities should have a positive impact on the EU economy. In all scenarios, the model yields positive GDP impacts, which are most pronounced in those cases where ambitious targets are considered. Similarly, most of the scenarios result in positive impacts on the labour markets, though the differences between the “moderate” and “ambitious” scenarios are not as pronounced as for GDP and in the case of the construction sector, a negative labour impact is expected. The discussed results are limited in magnitude, with GDP and employment increases (compared to the baseline amount) of at most 0.5% and 0.3%, respectively. The waste-management sector appears to be the largest winner in the transition, with the highest positive impact on both employment and contribution to GDP growth. This is due to an increase in labour demand for recycling activities and investments in recycling facilities. In contrast, the construction sector is expected to face the smallest GDP effect and negative employment impacts caused by the introduction of alternative construction technology. The decrease of materials demand for construction induces negative employment effects in the non-energy extraction and non-metallic mineral sectors.

The country-level analysis finds that, in GDP terms, all EU Member States should benefit from the transition, especially the central and eastern European countries. The authors also explore changes in labour-related skill needs, which could potentially appear as a consequence of the transition. Although they do not find a large shift between the demand for low and high skills, they stress the importance of crosscutting competences, e.g. problem-solving skills. Importantly, the report identifies rebound effects as reasons for positive impacts in some sectors, which signals the importance of considering them while modelling the circular-transition processes. Although rebound effects might bring about positive effects for the economy, they could offset the desired reduction in resource consumption. The authors stress that specific policies might be needed to achieve both economic benefits and a decline in material use.

Table 11. Summary of examined processes and impacts in Cambridge Econometrics et al. (2018)

	CE process								Economic impacts		Other impacts/mechanisms					
	Resource use			Maintaining value		Utilisation patterns										
Scenario	Recycling	Efficient use of resources	Utilisation of RE sources	Remanufacturing/refurbishment/re-use	Product life extension	Product as service	Sharing models	Shift in consumption patterns	GDP	Employment	Exports	Imports	Investment	Consumer spending	Consumer prices	Distributional effects
Food - moderate		✔	✔					✔	~0.06%	~0.03%						
Construction - moderate	✔			✔			✔		~0.01%	~-0.05%						
Waste - moderate	✔								~0.15%	~0.28%						
Electronics - moderate				✔	✔		✔		~0.02%	~0%						
Vehicles - moderate	✔	✔		✔			✔		~0.10%	~0.06%						
Combined - moderate	✔	✔	✔	✔	✔		✔	✔	0.30%	0.30%	0	↓	↑	↑	↓	
Food - ambitious		✔	✔					✔	~0.10%	~0.05%						
Construction - ambitious	✔			✔			✔		~0.04%	~-0.11%						
Waste - ambitious	✔								~0.15%	~0.27%						
Electronics - ambitious				✔	✔		✔		~0.11%	~0.04%						
Vehicles - ambitious	✔	✔		✔			✔		~0.14%	~0.09%						
Combined - ambitious	✔	✔	✔	✔	✔		✔	✔	0.50%	0.30%	0	↓	↑	↑	↓	

Source: Own elaboration based on Cambridge Econometrics et al. (2018). Changes shown are for the EU in 2030 relative to the baseline scenario.

✔: attribute included in the study

↑ and ↓: increase and decrease respectively

Ellen MacArthur Foundation and McKinsey Center for Business and Environment (2015)

The report by the Ellen MacArthur Foundation and McKinsey Center for Business and Environment (2015) presents results of an opportunity-based scenario analysis of the EU and reports the results for 2030 and 2050. The study focuses on improving circularity in three topic areas: mobility, food and the built environment. The authors develop a scenario reflecting a future wherein the circular opportunities are realised and compare it with the baseline, which corresponds to the current development path.

The analysis of potential economic outcomes is based on a computable general equilibrium model. The results indicate that a more circular future would bring both economic and environmental benefits. The authors expect disposable income to rise due to assumed higher factor productivity of the modelled circular technologies (generating lower prices of products and services) as well as better time use facilitated by reduction of congestion. This in turn would increase consumption, resulting in GDP levels higher than the baseline. The authors expect that between 2012 and 2030, the European GDP under the circular scenario would grow by 7 percentage points more than in the baseline, and 12 percentage points more than in the baseline by 2050.

Table 12. Summary of examined processes and impacts in Ellen MacArthur Foundation and McKinsey Center for Business and Environment (2015)

	Economic impacts		Env. impacts					Other impacts/mechanisms					
Scenario	GDP	Employment	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity	Exports	Imports	Investment	Consumer spending	Consumer prices	Distributional effects
Circular scenario	7% (2030) 12% (2050)	↑	↓		↓						↑	↓	

Source: Own elaboration based on Ellen MacArthur Foundation and McKinsey Center for Business and Environment (2015). Changes shown are for the EU in 2030 and 2050 respectively relative to the baseline scenario.

✓: attribute included in the study

↑ and ↓: increase and decrease respectively

Meyer et al. (2018)

Another recent study adopting a target-oriented perspective on the issue is the analysis by Meyer et al. (2018). The paper examines various impacts of an increase in resource efficiency in selected industries *in addition* to ambitious climate action. The authors do not specifically model "circularity". However, by focusing on resource efficiency, they address one of the central aspects of a circular economy. Although the authors assume autonomous efficiency improvements, they account for their costs by imposing additional costs on the benefiting industries. By comparing a baseline scenario (which assumes ambitious climate goals), with an alternative scenario that additionally assumes significant autonomous improvements in resource efficiency initiated by Germany and later adopted by other regions, the authors analyse potential changes in GDP, raw-materials extraction and CO_2 emissions by 2050 on global, regional and national scales.

The results obtained with a GINFORS model suggest that while adopting climate action may result in a relative decoupling of resource use and GDP growth, adding an extra resource-efficiency target can be followed by absolute decoupling. In the resource-efficient case, the modelling results indicate a decrease of global material extraction by some 40 Gt by 2050 followed by a reduction in global CO_2 emissions by around 10% as compared to the baseline. At the same time, global GDP growth is expected to be 4% higher than in the baseline, which the authors explain as stemming from higher investment levels vis-à-vis those in the baseline scenario. This positive GDP impact is found for almost all analysed regions, with the exception of the US and Russia. An important aspect of the study recognized by the authors is the feasibility of achieving the assumed efficiency increases, as technological possibilities are not explicitly included in the modelling exercise. Discussing the results in comparison to the broader literature (e.g. Schandl et al., 2016) they conclude that their assumed efficiency scenario needs to be treated as optimistic. Moreover, the authors stress that the required resource-efficiency increase would need additional policy support to address a number of issues, including the rebound effects – a problem also raised by Cambridge Econometrics et al. (2018) and discussed above.

Table 13 Summary of examined processes and impacts in Meyer et al. (2018)

	Scenario type			Economic impacts		Env. impacts				
Scenario	Opportunity-based	Target-based	Policy-based	GDP	Employment	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity
Resource efficiency improvement		✔		~1.90%		↓		↓	↓	

Source: Own elaboration based on Meyer et al. (2018). Changes shown are for the EU in 2050 relative to the baseline scenario.
✓: elements which the team identified within the study
↓: decrease

Tuladhar et al. (2016)

Tuladhar et al. (2016) also examine the impacts of different levels of technology-induced efficiency improvements not combined with any policy measures. In contrast to the paper by Meyer et al. (2018), Tuladhar and co-authors assume that technology improvements enhancing circularity come at no additional cost. The authors use the N$_{ew}$ERA modelling framework to examine how achieving different levels of efficiency improvements (conservative and ambitious scenarios) in five focus sectors by the EU as a whole or by Denmark alone could affect the European and Danish economies. The main results of the study are presented in Table 14.

Tuladhar et al. (2016) find that the analysed efficiency-improvement levels would lead to positive economic developments. Efficiency gains would reduce production and service costs, which enhances competitiveness and in turn leads to higher economic activity. The positive effects are reflected in the GDP estimates, which for the EU in 2030 are around 1.1% (conservative scenario) or around 2% (ambitious scenario) above those of baseline. The authors find that economic benefits increase with time and are generally higher in the ambitious scenarios than in the more conservative cases. Another interesting insight is that the effects for the EU are generally larger than for Denmark. The authors explain that this is a result of the European economy as a whole being in general less efficient than the Danish one, which makes efficiency improvements relatively more beneficial for the EU.

The discussion of sectoral results reveals that almost all of the examined sectors should benefit from the change. Interestingly, the study finds that the construction sector would be one of the major contributors to the expected GDP growth. This is in contrast to the results obtained by Cambridge Econometrics et al. (2018), who find that the contribution of this sector to economic growth would be minimal. The results of Tuladhar et al. (2016) deserving particular attention refer to estimates of emissions. The authors find that the assumed efficiency improvements will lead to an increase in CO_2 emissions (even though carbon intensity will be lower). This is not particularly surprising: Tuladhar et al. (2016) explain that the growth of economic activity induced by efficiency gains increases the demand for services and goods (including fossil fuels). Such a result is not very optimistic, considering that the reduction of emissions is one of the central motivations behind the transition to circular economy. This shows that efficiency increases alone are not necessarily the best way to foster the change, at least from the environmental point of view, and that there is a need for incentives to avert these negative effects.

Table 14. Summary of examined processes and impacts in Tuladhar et al. (2016)

	Economic impacts		Env. impacts					Other impacts/mechanisms					
Scenario	GDP	Employment	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity	Exports	Imports	Investment	Consumer spending	Consumer prices	Distributional effects
EU – conservative	~1.1%		↑			↓				↑	↑		
EU – ambitious	~2%		↑			↓				↑	↑		
Denmark – conservative	~0.6%		↑			↓				↑	↑		
Denmark – ambitious	~1.2%		↑			↓				↑	↑		

Source: Own elaboration based on Tuladhar et al. (2016). Changes shown are for the EU and Denmark respectively in 2030 relative to the baseline scenario.
↑ and ↓: increase and decrease respectively

Cambridge Econometrics and BIO Intelligence Service (2014)

While Meyer et al. (2018) model the developments of target-based scenarios unaccompanied by any particular policy measures, in the analysis of Cambridge Econometrics and BIO Intelligence Service (2014), resource-efficiency targets are supported by policies. In this case, the authors also do not refer directly to the concept of circular economy. They consider several initial target-based scenarios differing with respect to the EU-28 resource-productivity level aimed for (ranging between 1% and 3%), which is assumed to be a result of a combination of publicly funded investments, privately funded business measures and market-based instruments, e.g. taxes. In addition, the authors explore alternative cases allowing an analysis of specific issues, such as the significance of revenue recycling[9] in tax policy.

The authors note that implementing moderate resource-productivity targets of 1% per year and 2% per year leads to a GDP that is 0.6% or 0.8% higher in 2030 compared to the baseline scenario. This positive impact is largely driven by investments in resource- and energy-efficient technology (the primary driver in the short term) and by revenue recycling (the primary driver over the longer term). The GDP impact levels off over time or even becomes negative in the more ambitious scenarios that require more costly efforts to increase resource productivity, outweighing the positive effects. What is more, in the most ambitious scenario („Ambitious and flexible improvement"), the authors observe an impact on income distribution. In this case, policy changes lead to an increase in food prices. Because food consumption makes up a larger income share for lower

[9] "Revenue recycling" refers to using revenues from additional environmental taxes to lower other taxes, e.g. income tax or VAT.

income groups than of the other parts of the society, they are disproportionately disadvantaged by these negative economic impacts.

The projections of employment impacts are more optimistic, with a positive outcome in each of the initial scenarios, reaching a 1% increase compared to the baseline. This effect is due to higher material prices (encouraging employers to substitute material inputs with labour) and the fact that labour-intensive sectors (e.g. construction) benefit from the policies and revenue recycling, which lowers labour costs.

Further scenarios examine restrictions regarding how the efficiency target is met. In contrast to the initial analysis, in which the targets need to be reached by the EU as a whole, two alternative scenarios require the efficiency to be achieved by each sector and by each EU Member State, respectively. In the former case, the achieved GDP impacts of the policy are still positive but lower than in the corresponding initial scenario because the constraint does not allow implementing the most viable combination of policy options. If each of the EU countries is required to achieve the efficiency goal (as opposed to an overarching EU-wide target), the GDP impacts are less positive as well because countries that already reach the target in the baseline do not implement new policies and miss new opportunities.

The authors also modify one of the scenarios by eliminating the revenue-recycling assumption. This exercise has a negative impact on GDP, highlighting the role of revenue recycling in environmental fiscal policy. Although environmental impacts were not the focus of the study, the authors also estimated potential changes in energy-related CO_2 emissions. In most of the scenarios, the model projects a slight increase in emissions, which the authors attribute to higher economic growth and the rise in prices of low-carbon equipment. However, in the scenario in which all sectors (including energy) need to meet the efficiency target, emissions are expected to fall by some 25%.

Table 15. Summary of examined processes and impacts in Cambridge Econometrics and BIO Intelligence Service (2014)

	Policy type					Economic impacts		Env. impacts					Other impacts/mechanisms					
Scenario	Environmental taxes	Regulation	Infrastructure	Technology policy	Information and coordination	GDP	Employment	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity	Exports	Imports	Investment	Consumer spending	Consumer prices	Distributional effects
Modest and flexible improvement	rr(lc)		✔	✔		0.60%	0.70%	↑				↑	↓	↑	↑	↑	↑	
Enhanced and flexible improvement	rr(lc)		✔	✔		0.80%	1.00%	↑				↑	↓	0	↑	↑	↑	
Enhanced and flexible improvement, manufacturing ↑	rr(lc)		✔	✔		~5.50%												
Enhanced and flexible improvement, manufacturing ↓	rr(lc)		✔	✔		~-6.50%												
Further enhanced and flexible improvement	rr(lc)		✔	✔		0.30%	0.80%	↑				↑	↓	↓	↑	↑	↑	
Ambitious and flexible improvement	rr(lc)		✔	✔		-0.10%	0.90%	↓				↑	↓	↓	↑	↓	↑	✔
Ambitious and flexible improvement, no rev. recycling	nr		✔	✔		~-1.60%												
Resource constrained enhanced improvement	rr(lc)		✔	✔		~0.50%												
Effort constrained enhanced improvement	rr(lc)		✔	✔		~0.35%												

Source: Own elaboration based on Cambridge Econometrics and BIO Intelligence Service (2014). Changes shown are for the EU in 2030 relative to the baseline scenario.

✔ : elements that the team identified within the studies

↑ and ↓: increase and decrease respectively

rr(lc): revenue recycling (tax revenues used to lower labour costs)

nr: no revenue recycling

NOTE: in this study, "GHG/CO_2 emissions/footprint" refers to energy-sector emissions; GDP impacts in scenarios "Enhanced and flexible improvement, manufacturing ↑" and "Enhanced and flexible improvement, manufacturing ↓" represent a change compared to the scenario "Enhanced and flexible improvement"

Meyer et al. (2015)

Meyer et al. (2015) examine a combined policy consisting of reduction targets for resource use and CO_2 emissions using the GINFORS model. All of these targets can be viewed as components of a circular economy policy package. Specifically, they analyse different ways of achieving environmental targets proposed by Jäger (2014), which relate to CO_2 emissions, cropland footprint, raw material consumption and a water exploitation index. In the first case ("Global cooperation"), the authors assume that all countries in the world share the environmental targets and a global policy mix is adopted that includes measures to reduce climate impacts and to enhance biotic and abiotic material efficiency. In the second scenario ("EU goes ahead"), the EU takes steps to achieve its targets (mostly economic instruments slightly modified compared to the previous case), whereas the remaining countries implement a climate-policy mix only to some extent. In the last case ("Civil Society Leads"), most of the regulations are the same as in the "EU goes ahead" case, while further progress towards environmental targets takes place due to a behavioural changes in European civil society (e.g. reduction of consumption or of food waste).

Table 16 presents the main impacts identified in the study. From the economic perspective, both the "Global cooperation" and "EU goes ahead" scenarios show positive developments for GDP and employment. In the medium-term (up to the mid-2030s), the former case is more beneficial, with the global GDP exceeding the GDP in the reference scenario by around 6.5%. Over the long term, however, the other scenario yields higher economic benefits, with world GDP and EU GDP expected to exceed the baseline by around 8.5% and 12.3% respectively. In both cases, similar economic mechanisms are at work: the authors explain positive impacts on the GDP via additional investments in new technologies and with reduced costs of manufacturing caused, for example, by lower material intensity. On the other hand, negative effects are driven by capital stocks rising in the longer term (increasing costs of capital, thus leading to higher prices) and by reduced demand for products of the mining and quarrying sectors as well as reduced demand elsewhere in the value chain.

Importantly, the magnitude of these mechanisms and end effects depends on the structure of the economy. Thus, the countries in which mining and quarrying are not of major importance will be relative 'winners' due to the changes. On the EU scale, in both scenarios, the shift from material-intensive to more labour-intensive production brings about a positive employment effect, which again is larger in the 'EU goes ahead' scenario. While the environmental impacts are generally optimistic in both scenarios, their scale is larger in the case of globally coordinated policies. For example, the model estimates that in 2050, global CO_2 emissions will amount to around 45 Gt in the baseline scenario, around 33 Gt if the EU takes the lead and less than 20 Gt if countries cooperate.

A very different picture appears in the "Civil society leads" scenario, wherein the targets are mostly achieved through bottom-up instruments and society's intrinsic motivations. While on the EU scale, the scenario performs better than the other two in terms of environmental impacts, it appears to negatively affect the European economy. A sharp decrease in consumption causes a fall in GDP, which in 2050 is approximately 19.5% lower than in the baseline. The effect would be even stronger if it were not for the exports, which remain relatively stable. On the other hand, employment is expected to boom by 2050 with some 17 million new jobs available. This is a result of a reduction of working hours and lower real wages. However, one could question to what extent such a change in societal behaviour reflects a readiness to achieve social and environmental benefits at the cost of economic growth and income.

Table 16. Summary of examined processes and impacts in Meyer et al. (2015)

	Policy type					Economic impacts		Env. impacts					Other impacts/mechanisms					
Scenario	Environmental taxes	Regulation	Infrastructure	Technology policy	Information and coordination	GDP	Employment	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity	Exports	Imports	Investment	Consumer spending	Consumer prices	Distributional effects
Global cooperation	rr(pr)	✓	✓	✓	✓	8.00%	↑	↓	↓	↓					↑			
EU goes ahead	rr(pr)	✓	✓	✓	✓	12.30%	↑	↓	↓	↓					↑	↑		
Civil society leads		✓	✓	✓	✓	-19.50%	9.50%	↓	↓	↓					↓	↓		

Source: Own elaboration based on Meyer et al. (2015). Changes shown are for the EU in 2050 relative to the baseline scenario.
rr(pr): revenue recycling (tax revenues used to lower production tax in certain sectors)
✓: elements that the team identified within the studies
↑ and ↓: increase and decrease respectively

Hu et al. (2015)

The modelling study by Hu et al. (2015) was conducted within the same project as the modelling by Meyer et al. (2015) and examines the same set of scenarios. However, there are some major differences between the two exercises, including modelling principles (Hu and co-authors use the EXIOMOD model), policy implementation and reference scenarios (Distelkamp, Meyer i Moghayer, 2015)[10], which yields differing results. The GDP trajectory until 2050 estimated by Hu et al. (2015) is almost the same in the baseline as well as in the 'Global cooperation' and the 'EU goes ahead' cases. Implementation of policies under both scenarios, however, yields positive results in terms of the environmental indicators.

As in the study of Meyer et al. (2015), implementing environmental policies on a global scale is expected to yield effects of a larger magnitude. However, in the study by Hu et al. (2015), the differences between the two scenarios are relatively small. For example, the authors estimate a global reduction of CO_2 emissions of 28% in 'Global cooperation' and of 22%, if the EU leads the way to achieving the targets. Like Meyer et al. (2015), Hu and co-authors find a negative effect on the economy of reaching the environmental targets based predominantly on the motivations of the society. The authors estimate that such a scenario will result in an EU GDP in 2050 around 15% lower than in the baseline. They attribute this development to the decrease in the number of working hours and general reduction of materialism. In terms of CO_2 emissions, the scenario projects slightly lower reductions than 'Global cooperation' because it imposes the strongest anti-emission measures only on the EU scale. When it comes to the raw-material consumption as well as land and water use, 'Civil society leads' brings about the largest reductions.

[10] For a detailed comparison of both studies see Distelkamp et al. (2015)

This is explained as a direct consequence of the economic slowdown and decrease in consumption.

Table 17. Summary of examined processes and impacts in Hu et al. (2015)

	Policy type					Economic impacts		Env. impacts					Other impacts/mechanisms					
Scenario	Environmental taxes	Regulation	Infrastructure	Technology policy	Information and coordination	GDP	Employment	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity	Exports	Imports	Investment	Consumer spending	Consumer prices	Distributional effects
Global cooperation	rr(lc)	✔	✔	✔	✔	0		↓		↓			↓			↑		
EU goes ahead	rr(lc)	✔	✔	✔	✔	0		↓		↓			↑			↑		
Civil society leads		✔	✔	✔	✔	↓		↓		↓			↓			↓		

Source: Own elaboration based on Hu et al. (2015). Changes shown are for the EU in 2050 relative to the baseline scenario.

rr(lc): revenue recycling (tax revenues used to lower labour costs)

✔ : elements that the team identified within the studies

↑: and ↓: increase and decrease respectively

UNEP (2017)

In 2017, a study based on the GTEM, GLOBIOM and MEFISTO models combining the issues of resource efficiency with other environmental policies was carried out by the United Nations Environment Programme (UNEP) as part of the International Resource Panel Report (UNEP, 2017). This exercise compares the projected developments expected if current trends (i.e. achieving country-specific Paris pledges) materialize with alternative policy- and target-based scenarios. The first of these scenarios ('Resource efficiency') assumes implementing a mix of different policy measures aimed at increasing resource efficiency (innovation, resource-extraction tax, regulation and information). The second one ('Ambitious climate'), examines potential trajectories resulting from calibrating the targets defined under a more ambitious emissions pathway. The last scenario, 'Efficiency plus', is the combination of both resource-efficiency policies and climate targets. Compared to the baseline, the scenario focused on achieving climate goals is the most costly. By 2050, it is expected to result in a GDP decrease of 1.3% (G7 scale) or 3.7% (global scale) compared to current trends. However, the remaining two scenarios appear to bring about economic benefits, both for the G7 countries and for the world as a whole. Innovation and investments accompanying the efforts to increase resource efficiency drive the GDP growth, which outweighs the costs of the climate action.

The analysis on the global scale yields trends of the same direction, but of a greater scale. The authors explain that in this case, the benefits of resource-efficiency measures are larger due to developing and emerging economies, which are highly dependent on natural resources, being included in the analysis.

On the other hand, they recognize that not all the countries will benefit from the seemingly optimistic ‘Efficiency plus’ policy. The regions, which depend largely on exports of natural resources (e.g. Eastern Europe), are expected to be particularly disadvantaged. The authors estimate that it would take some 40% of the net gains of high- and medium-income countries to compensate for the losses of the regions, which would be worse off.

In terms of resource use and GHG emissions, each of the policy scenarios predicts more desirable developments than the baseline. The highest environmental benefits are achieved in the ‘Efficiency plus’ scenario, which indicates potential synergies between the resource- and climate-oriented measures. Such a combined action could lead to an approximately 28% reduction of global resource use per capita relative to the baseline and a 63% fall in global GHG emissions between 2015 and 2050 (under current trends, the model predicts the emissions to increase by around 40% by 2050). The report also discusses the issue of the rebound effect, which might appear because of the fall in unit costs due to innovation, and which might cause a resource policy to ‘backfire’ via increased consumption. Introducing extraction taxes, regulation and new information into the policy mix reduces this effect. Another interesting aspect is the issue of revenue recycling in tax policy. Due to methodological complexity, the authors assume that tax revenues are redistributed to households instead of lowering labour costs. Seeing the positive impacts of revenue-recycling policies found in other studies, it seems justified to wonder whether changing this assumption would yield even higher positive economic impacts.

Table 18. Summary of examined processes and impacts in UNEP (2017)

	Policy type					Economic impacts		Env. impacts				
Scenario	Environmental taxes	Regulation	Infrastructure	Technology policy	Information and coordination	GDP	Employment	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity
Resource efficiency	nr	✓		✓	✓	2.7%		↓		↓		
Ambitious climate		✓				-1.3%		↓		↓		
Efficiency plus	nr	✓		✓	✓	1.0%		↓		↓		

Source: Own elaboration based on UNEP (2017). Changes shown are for G7 countries in 2050 relative to the baseline scenario.

nr: no revenue recycling

✓ : elements that the team identified within the studies

↓: decrease

Bosello et al. (2016)

The studies summarised so far were based (at least partly) on the analysis of target-based scenarios. In contrast, Bosello et al. (2016) conduct a policy-based scenario analysis of the circular-economy impacts. They model the impacts of a number of policies developed to obtain resource-efficiency improvements, which are divided into three topic categories: 'Metals and Other Materials', 'Land-Use' and 'Overarching'. The authors use for the analysis three models (ICES, MEMO II, MEWA), which vary with respect to their assumptions and structures, and therefore yield different results. This approach provides deeper insights into mechanisms driving particular results but also highlights the large influence of the chosen methodology on the results.

An example is the first of the examined policies, namely the materials tax, which the authors examine using all three models. Depending on the analysed model and assumption made regarding revenue recycling and efficiency improvements, the EU-wide GDP impacts in 2050 range from -6.55% to 5.81% compared to the baseline.

As far as the modelling exercises by Bosello et al. (2016) yield varying results, by comparing them, the authors come to several conclusions with high policy relevance. Their analysis highlights the importance of a well-designed revenue-recycling scheme as well as technological progress. For example, the authors find that introducing a tax on materials or externalities accompanied with revenue recycling and technological progress may indeed result in decoupling of economic growth and resource use. On the other hand, in absence of revenue recycling and technological progress, the tax policy in question might turn out very costly for the economy and may even fail to reduce resource consumption. The simulation of additional R&D spending also shows the importance of technological improvement, as this policy appears to bring about significant economic gains. On the other hand, in this scenario, efficiency gains and the fall in material prices lead to an overall higher resource use, representing again the rebound effect. Therefore, Bosello and co-authors warn against basing resource-efficiency ambitions on technological progress alone; these should be accompanied by further measures fostering a decrease in resource use.

The policies aimed at land use (affecting pesticide use and meat consumption) affect mainly specific sectors, so the magnitude of their overall impact is smaller. An interesting lesson is offered by the case of a tax on domestic and imported pesticide use. The authors find that although the policy indeed reduces pesticide use in the EU, it causes a shift of agricultural production beyond the EU borders, resulting in increased demand for pesticides and fertilizers outside of the EU. As the authors put it, "The policy thus would not induce a decrease in the negative externality, but its de-location abroad". This raises the issue of unintended secondary effects.

A further interesting case is the last scenario, which differs from the rest, as it does not examine the results of a specific policy, but of a shift of society's preferences from consumption to leisure (modelled by modifying the utility function). The authors note that such a change would slow down economic growth but on the other hand, would increase utility. In addition, the shift is expected to somewhat reduce the use of energy and materials.

Table 19. Summary of examined processes and impacts in Bosello et al. (2016)

	Policy type					Economic impacts		Env. impacts					Other impacts/mechanisms					
Scenario	Environmental taxes	Regulation	Infrastructure	Technology policy	Information and coordination	GDP	Employment	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity	Exports	Imports	Investment	Consumer spending	Consumer prices	Distributional effects
GFR: materials tax (ICES)	nr					-5%					↓	↑						
GFR: materials tax (MEMO II)	rr(lc)					1.90%	6.20%			↓		↑			↓			
GFR: materials tax (MEWA), baseline	rr(lc)					5.81%	7.16%			↓	↓							
GFR: materials tax (MEWA), alternative 1	rr(lc)					-1.80%	0.14%			↓	↓							
GFR: materials tax (MEWA), alternative 2	nr					-6.55%	-1.11%			↓	↓							
GFR: internalisation of ext. environmental costs (MEMO II), flat tax	rr(lc)					-5.80%	~-0.45%					↓			↓			
GFR: internalisation of ext. environmental costs (MEMO II), differentiated tax	rr(lc)					-4.50%	~0.40%					↓			↓			
GFR: internalisation of ext. environmental costs (MEWA), flat tax, v.1	rr(lc)					~6.50%	~7.20%								↑	↑		
GFR: internalisation of ext. environmental costs (MEWA), differentiated tax, v.1	rr(lc)					~5.50%	~6.00%								↑	↑		
GFR: internalisation of ext. environmental costs (MEWA), flat tax, v.2	rr(vat)					~1.00%	~-7.00%								↓	↑		
GFR: internalisation of ext. environmental costs (MEWA), differentiated tax, v.2	rr(vat)					~1.00%	~-5.5%								↓	↑		
Increased spending on R&D (MEWA), labour tax closure				✔		~9%	↑	↑	↑	↑	↓	↑			↑			
Increased spending on R&D (MEWA), CIT closure				✔		~9.5%	↑	↑	↑	↑	↓	↑			↑			
Increased spending on R&D (MEWA), production tax closure				✔		~8.5%	↑	↑	↑	↑	↓	↑			↑			
Targeted information campaign to influence food behaviour (ICES)					✔	0.04%		↓										
VAT on meat (ICES)	✔					-0.05%												
VAT on meat (MEMO II)	nr					~0.05%	~0,04%											
VAT on meat (MEWA), no revenue recycling	nr				✔	~-1.05%	~-0,40%								↓	↓		
VAT on meat (MEWA), revenue recycling	rr(lc)				✔	~0.33%	~0,05%								↑	↑		
Strengthened pesticide reduction targets (ICES)	✔					0.006%												
Strengthened pesticide reduction targets (MEWA), v.1	rr(lc)					~0.045%					↓							
Strengthened pesticide reduction targets (MEWA), v.2	rr(cit)					~-0.17%					↓							
Strengthened pesticide reduction targets (MEWA), v.3	rr(vat)					~-0.09%					↓							
Circular economy tax trio (ICES)	nr					-0.32%												
Circular economy tax trio (MEMO II)	nr					~-0.2%	~-0.4%								↓			
Circular economy tax trio (MEWA)	rr(lc)					0.08%	0.06%		0		↓				↑	↑		
Enabling shift from consumption						~-2.75%	~-3.80%		↓	↓	↑		↓	↓	↓	↓		

Source: Own elaboration based on Bosello et al. (2016). Changes shown are for the EU in 2050 relative to the baseline scenario.
GFR: green fiscal reform
rr: revenue recycling
(lc): tax revenues used to lower labour costs, (pr): tax revenues used to lower production tax, (cit): tax revenues used to lower corporate income tax, (vat): tax revenues used to lower VAT
nr – no revenue recycling

✔: elements that the team identified within the studies
↑: and ↓: increase and decrease respectively

Schandl et al. (2016)

The paper by Schandl et al. (2016) is another example of a policy-based scenario analysis. The researchers attempt to address the question of whether it is possible (with the help of a well-designed policy set) to reduce global emissions and resource use without causing a negative economic effect, looking at the 2050 time horizon. To do so, they apply the GIAM and MEFISTO models and compare the baseline scenario with the cases of 'high efficiency', which assumes a high level of carbon pricing and resource efficiency increases, and 'medium efficiency', which represents the middle ground. Even though the study focuses on the effects achieved on a global scale, the authors report some insights relevant specifically to the EU as well.

In economic terms, the effects of the policies are expected to be rather limited. The authors estimate that implementing the more ambitious policy set would result in a global output 1.6% lower than in the baseline. They figure that given the length of the time horizon, this loss is negligible. Even though the report does not report EU-specific economic indicators, the authors explain how implementing the policy could influence the shift of global economic power. They find that under current developments, by 2050 a large share of economic activity will be moved from economies like the EU, US and Japan towards China, which will be responsible for 22.6% of the global output. Implementing the policies examined under the efficiency scenarios would affect this trend to some extent. In terms of the shares in the global GDP, the European Union would be one of the benefiting economies, while the former Soviet Union, for example, would be disadvantaged. The authors, however, do not report the magnitude of this effect.

In terms of the environment, the authors expect that the policies will have a positive impact, both globally and on regional scales, although not always of a large magnitude. This refers above all to the projected global energy use. Even though both policy scenarios project energy use to be lower than in the baseline, none of the cases achieves an absolute decoupling from economic activity. Nevertheless, a much more optimistic result is found for global CO_2 emissions, which fall significantly compared to the baseline projection due to a growing importance of renewable and low-carbon technologies. The authors suggest even that such development could suffice to meet the global goal of keeping the temperatures maximally 2° higher compared to preindustrial times.

Similarly, the policies would have a very positive effect on global material extraction. The modelling predicts that under the policy scenarios, depending their level of ambition, global extraction by 2050 could stabilize between 95.2 billion and 129.8 billion tonnes. Under the baseline predictions, however, this level would reach 182.2 billion tonnes. One might observe a similar pattern on the regional scale. In the case of the EU, for example, the policies seem to have only a minor effect on overall energy use. However, the reductions in carbon emissions and materials extraction appear to be somewhat more significant.

The modelling results lead the authors to conclude that achieving a more resource-efficient and carbon-neutral world is possible at a relatively low economic cost, with potentially significant environmental and social benefits.

Table 20. Summary of examined processes and impacts in Schandl et al. (2016)

Scenario	Policy type					Env. impacts				
	Environmental taxes	Regulation	Infrastructure	Technology policy	Information and coordination	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity
High efficiency		✔	✔	✔		↓	↓	↓		
Medium efficiency		✔	✔	✔						

Source: Own elaboration based on Schandl et al. (2016). Changes shown are for the EU in 2030 relative to the baseline scenario.

✔: elements which the team identified within the studies

↓: decrease

Ex'Tax Project et al. (2016)

Policy-based analysis within the Ex'Tax Project et al. (2016) focuses specifically on tax policy in the context of the circular economy. The study assesses impacts expected on a 2020 time horizon, which is shorter than the 2030 timeframe that was the focus of CIRCULAR IMPACTS. However, given the importance of revenue-recycling mechanisms highlighted in the previously discussed studies, the report deserves inclusion in this review of modelling studies.

The authors examine the potential impacts of shifting the tax burden in the EU from labour to consumption and natural resources. More specifically, they develop a scenario in which a mix of policies is imposed: excise duties on fossil fuels; taxes on carbon; electricity and water for bulk users; and increases in VAT rates (in line with the 'polluter pays' principle). Additional revenues generated by the policy are utilized to enhance employment, e.g. by reducing labour costs, enabling a payroll tax credit for circular innovation or eliminating VAT for labour-intensive services.

E3ME modelling indicates that such a change of tax system may have a positive impact on the EU economy, leading to a 2.9% higher level of employment and 2.0% higher GDP compared to the baseline in 2020. Though the policy causes some negative effects related to price increases, these are offset by lowering employment costs. Importantly, a positive economic impact of the policy is expected for all of the EU Member States, although with the magnitude varying depending on various factors, such as economic situation, energy intensity or carbon intensity of the country. The authors expect also that the tax shift will have a positive environmental effect. The model suggests that imposing the new fiscal policy would foster larger reductions in carbon emissions as well as energy-resource use.

Not surprisingly, the energy and utility sectors are disadvantaged by the policy in terms of their output and employment. The authors also touch upon the distributional effects of the policy. They find that while real income is expected to increase overall, its growth would be slightly lower in the case of low-income socioeconomic groups. The report explains that the groups benefiting relatively the least are unemployed, retired and inactive people (i.e. the social groups that do not directly experience the beneficial effects of lower labour tax). The authors suggest that while designing a new tax policy, one need to consider such potential distributional effects. Furthermore, they notice a small rebound effect in the case of energy demand. Within the project, the authors conducted what they refer to as Integrated Value Added analysis.[11] By analysing the effects on stocks and flows of financial, natural and social capitals, the authors estimate that in the period 2016-2020 the new policy could bring over €1.1 trillion in value added.

Table 21. Summary of examined processes and impacts in Ex'Tax Project et al. (2016)

	Policy type					Economic impacts		Env. impacts					Other impacts/mechanisms					
Scenario	Environmental taxes	Regulation	Infrastructure	Technology policy	Information and coordination	GDP	Employment	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity	Exports	Imports	Investment	Consumer spending	Consumer prices	Distributional effects
Tax shift scenario	rr(lc)	✓		✓		2.00%	2.90%	↓	↓	↓			0	↑	↑	↑	↑	✓

Source: Own elaboration based on Ex'Tax Project et al. (2016). Changes shown are for the EU in 2020 relative to the baseline scenario.
rr: revenue recycling
(lc): tax revenues used to lower labour costs, (pr): tax revenues used to lower production tax,

✓: elements that the team identified within the studies
↑: and ↓: increase and decrease respectively
0: no change

The studies summarised above all consider supranational levels of analysis with all but one considering the EU explicitly. Modelling exercises at the national level have also been undertaken but are not summarised in detail. Box 3 provides an overview of pertinent analyses at the EU Member State level.

[11] The *Ex'tax Integrated Value Added Statement* assesses the benefits of the proposed tax policy by adding to the impact on National Income Growth (Financial Capital) the estimated value of expected externalities, such as avoided costs of future impacts of climate change (Natural Capital) or the value of Health Benefits of Employment (Social Capital).

Box 3. Examples of studies performing modelling analysis on a national scale

- **Becarello and Di Foggia** (2018). The paper examines socio-economic impacts of circular economy by examining increased medium-term recycling targets in Italy. The authors find positive effects on job creation, value added and production.
- **Distelkamp et al.** (2010). The study looks into the potential impacts of implementing a resource-efficiency policy in Germany. The results indicate that a policy based on economic instruments, while reducing the final energy demand and resource requirement, would also result in negative employment and GDP impacts. On the other hand, information-based policies and recycling regulations are expected to yield positive GDP and employment effects with a simultaneous increase in final energy demand and a fall in resource requirement.
- **Meyer et al.** (2016). This study analyses socio-economic effects of the recycling industry in Austria with a focus on steel, aluminium, glass and paper. The results suggest that recycling of the examined product groups contributes in a positive way to the GDP and employment while facilitating significant GHG-emissions savings.
- **Wijkman and Skånberg** (2016). The study prepared for the Club of Rome explores the impacts for society that could appear as a result of increased resource efficiency in the Czech Republic and Poland. Each of the three examined scenarios result in emissions reductions for both countries. However, expected economic effects differ depending on the scenario definition. A predecessor study authored by Wijkman and Skånberg examines the same issue with the focus on Finland, France, the Netherlands, Spain and Sweden. Here as well, for each of the countries, the efficiency scenarios result in a decrease in carbon emissions and positive employment effects (Wijkman & Skånberg, 2015).

4 :: Recent Policies and Future Research

The European Commission's Circular Economy Package of 2015 included the EU Action Plan for the Circular Economy, which describes a number key actions aiming to transform the EU economy and create competitive advantages for Europe. The Action Plan addressed the full product cycle from production and consumption to waste management and the market for secondary raw materials. It also identified five priority areas: plastics; food waste; critical raw materials; construction and demolition; and biomass and bio-based products (European Commission, 2015b).

4.1 Recent policy developments

As part of the actions described in the Action Plan, the Commission produced in early 2018 a Europe-wide EU Strategy for Plastics in the Circular Economy, a Communication on options to address the interface between chemical, product and waste legislation, a Monitoring Framework on progress towards a circular economy and a Report on Critical Raw Materials (European Commission, 2018d).

The goal for the EU Strategy for Plastics in the Circular Economy is to create "[a] smart, innovative, and sustainable plastics industry, where design and production fully respects the needs of reuse, repair, and recycling, brings growth to Europe and helps cut EU's greenhouse gas emissions and dependence on imported fossil fuels" (European Commission, 2018e). By 2030, all plastic packaging should be recyclable.

The Communication on options to address the interface between chemical, product and waste legislation identified several barriers to the circular economy:

1. Information on presence of substances of concern is not readily available to those who handle waste and prepare it for recovery.
2. Waste may contain substances that are no longer allowed in new products.
3. EU's rules on end-of-waste are not fully harmonised, making it uncertain how waste becomes a new material and product.
4. Rules to decide which wastes and chemicals are hazardous are not well aligned and this affects the uptake of secondary raw materials.

For each barrier, an objective along with planned actions were laid down. The Commission noted that achieving full coherence between the laws implementing waste and chemicals is a long-term objective (European Commission, 2018f).

The Monitoring Framework for the Circular Economy was adopted by the Commission in January 2018. The Report on Critical Raw Materials (CRM) underlines the potential of improving the circularity of these 27 materials. It contains key data sources, several best practices and options for further action, with the goal of guaranteeing "a coherent and effective EU approach to CRMs in the context of the transition to a circular economy" (European Commission, 2018g).

At the conclusion of the project, the CIRCULAR IMPACTS project team produced a policy brief based on the research work conducted over the preceding two years. Box 4 provides an overview of conclusions and key policy messages found therein.

Box 4. Conclusions and key policy messages of the CIRCULAR IMPACTS project

- Scenario analysis can provide crucial information on the potential future economic and environmental effects of today's policy choices. Three approaches to scenario analysis have been analysed in the context of this project: opportunity-based, target-based and policy-based approaches. While the policy-based approach may be the most relevant approach in the context of the European Semester, all three approaches would benefit from more research into the process of translating circular policies into macroeconomic and environmental outcomes.
- Scenario research should focus on empirical information about the essential mechanisms that explain the economic, environmental and social results. Targeted case studies, econometric studies and other studies that reveal plausible mechanisms and estimates of input-output coefficients are necessary to fill this gap in the research.
- The four case studies conducted by the CIRCULAR IMPACTS project illustrate that the application of the concept in different sectors can generate, under certain conditions, economic and environmental benefits. However, more research is clearly needed, also in other sectors.
- In the economic evaluation of the circular economy, broader welfare measures than GDP and employment are needed to more directly take into account environmental concerns, which also reside at the core of the circular-economy concept (e.g. reducing resource use, energy consumption and GHG emissions).
- While path dependency of technological change and the consequences of future scarcity of resources may be important arguments for a transition towards a circular economy, these mechanisms do not feature in most studies that evaluate the circular economy.
- The current political priorities of the European Commission, where the circular economy is part of the agenda for jobs, growth and investment, warrant a closer reflection of the circular economy in the European Semester. In a first step, this move would require timely data to allow for proper monitoring of circular-economy related policies and to enable the formulation of practical and effective country-specific recommendations.
- Given the Commission's intention to fully integrate the Sustainable Development Goals (SDGs) into the European policy framework, the next step – beyond 2020 – may be to expand the European Semester to allow for proper monitoring towards the 17 Sustainable Development Goals (SDGs), including SDG 12 on responsible consumption and production.

Source: Rizos, Behrens & Drabik (2018)

4.2 Reflecting on the CIRCULAR IMPACTS project

The CIRCULAR IMPACTS project's ambitious objective at the outset was to provide an overarching impact assessment on the circular-economy transition for the EU based on the already available evidence and new evidence developed via the CIRCULAR IMPACTS project. As the project proceeded, the limited evidence available made it clear to the project team that such a broad impact assessment would not provide credible results. Experts in the field consulted during the project also confirmed that providing an all-encompassing impact assessment would not be possible given the available evidence and without the project containing its own, significant macroeconomic modelling effort.

The sector-specific cases studies provided new and meaningful results but the specificity that enabled this also meant these case studies were more narrowly scoped than initially anticipated. The results of recent macroeconomic modelling exercises compiled in the project helped show areas of consensus and divergence among the studies and makes these findings accessible to the research community by providing an overview of the scenarios being considered and their impact estimates.

The circular-economy transition will affect many types of resources and materials in different countries and sectors, with significant spill-over effects along with significant innovations taking place simultaneously—this complexity combined with the lack of historical experience makes ex ante quantitative models the best tool for prospective analysis (OECD, 2018).

In addition to the evidence base the project has generated, CIRCULAR IMPACTS will provide a valuable, ongoing contribution to the developing circular-economy research area via its special focus on methodology development, by further defining the circular-economy concept, and by analysing its role within the European Semester and other European policy processes. The four cases studies on various circular-economy transitions provide new insights and provide a methodology and examples of how potential new business cases can be further analysed. The case studies cover several key sectors important to the circular-economy transition, such as agriculture, construction, transport and manufacturing, as well as different facets of the circular-economy concept. The CIRCULAR IMPACTS Evidence Library was established online to structure the available information on the circular economy and make this research base far more accessible. The library has already proven useful to researchers and policymakers.

4.3 Recommendations for future research

The CIRCULAR IMPACTS project has contributed to a stronger foundation of theory, methodology and evidence for policy action and future research. We conclude this report with a few summary thoughts regarding future research on the circular economy that can build the knowledge base further. The following research recommendations are proposed for consideration by funders and researchers.

Appropriate research scope and design

In evaluating the macro-consequences of the circular economy, one must include macro-economic mechanisms in the analysis and make a clear difference between the short term and the long term. Generating original macroeconomic evidence is best done via ex ante macroeconomic modelling. One must keep in mind, however, that such models are constrained to considering a subset of policy types (i.e. policies with clear price or quantity effects) that can be modelled via such tools. Modelling studies are especially valuable for analysing a subset of circular-economy transitions—those that examine primary/secondary resource flows and waste generation—and models can provide indications of impacts on economic growth, employment and trade impacts.

Case-study methods are valuable for their ability to examine specific business cases, policy tools and technologies. As specific circular-economy transitions occur, it will also be important to understand these experiences from the perspective of the businesses undertaking them (e.g. these transitions' profitability, risks and growth potential) along with their broader impacts in societal, economic and environmental terms. The appeal of such opportunities for the private sector relates directly to their potential scalability and potential impacts. Case studies also benefit from being relatively transparent regarding the data used and the underlying calculations (compared to macroeconomic models) as well as their ability to hone in on quite specific facets and research questions.

Appropriate specificity within a holistic concept

Key strengths of the circular economy concept include its "solution orientation" (describing a model for how resource-related challenges can be addressed) and its holistic nature (uniting traditional resource-related concerns such as primary/secondary material use with broader concepts such as the sharing economy and behavioural changes). However, these very strengths pose challenges for analysts and policymakers seeking to operationalise the concept when addressing resource-related challenges. The CIRCULAR IMPACTS case study on car sharing illustrates this challenge well: it is likely that emergent sharing models in transportation will have countervailing effects on the total use of resources and energy for transport, with some sharing models likely to draw users away from public transit (itself a long-established sharing model). One cannot simply rely on a growth in a specific kind of sharing as a proxy for a circular transition and assume it generates positive environmental benefits. The balancing of specificity and holism means that the framing of a circular-economy transition and the scope of analysis must also maintain its "problem orientation", never losing sight of the core issues that the circular economy is meant to address.

Stakeholder consultation

As part of the work on the case studies, the CIRCULAR IMPACTS team conducted stakeholders workshops, carried out interviews with experts in the field (including 26 experts in the case on EV-battery recycling). This helped the team assess in detail the underlying trends and acquire data and information that could not have been obtained through desk-based research. Such an in depth analysis of the impacts of implementing a process in one sector is often not possible in overarching assessments that include various sectors and processes.

Realistic assumptions and scenarios

It is important to recognise that additional circular investments will typically come at the cost of other investments and to be careful not to be over-optimistic in estimating productivity benefits based on ex ante evaluations. Many circular opportunities are much more complicated than they appear in theory when it comes to actually implementing them or when they scale up. Some circular opportunities may increase productivity and there are undoubtedly many opportunities to realise this so-called "double dividend" in circular-economy transitions. However, one must be aware that many opportunities exist that are not circular, for example in education, ICT or health care, and that in many cases, society may be faced with a choice between circular and less circular opportunities that may both have positive effects on productivity or other well-being aspects.

Appropriate impact measures and welfare definitions

Given that a primary purpose of a more circular economy is to reduce environmental pollution and other resource-related pressures, the benefits from the circular economy are best assessed by taking a broad welfare concept that goes beyond traditional economic figures (e.g. GDP and employment) to include environmental and social impacts. It is especially important to evaluate the most important environmental and social impacts of circular opportunities. Social impacts related to gender, skills, occupational and welfare effects, poverty and inequalities are frequently not included in studies of circular-economy transitions (Rizos, Tuokko, & Behrens, 2017)

Assess both direct and indirect impacts where possible

Though indirect impacts can be of great significance, studies often underexpose indirect impacts of circular-economy processes. The step-by-step methodology used in the CIRCULAR IMPACTS case studies provides a useful approach for ensuring that both direct and indirect impacts are taken into account.

Incorporate life cycle assessment (LCA)

Life-cycle assessment (LCA) is a critical tool for exploring circular-economy processes because it can provide insight into the environmental impacts associated with the different stages of a product's life. An LCA indicates what the most resource-intensive stage of a product is or what happens when it reaches the end of its useful life, and therefore discloses where in the life cycle the most potential for improvement lies. Moreover, it is able to provide comparable environmental data for case studies, which is essential for the relevance of results.

Policy context

Future research can contribute to a better integration of the circular economy into the EU's key policy mechanisms and into achieving sustainable-development objectives. The CIRCULAR IMPACTS project team extensively researched the interplay between the circular economy and the European Semester. Similar analyses could be performed for other processes in the future, such as the Environmental Implementation Review or the Multiannual Financial Framework.

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Annex. Overview of macroeconomic modelling results

Note: for all studies modelling the EU level, the table below shows the EU results.

		Territory			Time Horizon			CE process								Scenario type			Policy type					Economic impacts		Env. impacts					Other impacts/mechanisms						Reference	
								Resource use			Maintaining value			Utilisation patterns																								
Study	Scenario	EU	World	Other	2030	2050	Other	Recycling	Efficient use of resources	Utilisation of RE sources	Remanufacturing/refurbishment/re-use	Product life extension	Product as service	Sharing models	Shift in consumption patterns	Opportunity-based	Target-based	Policy-based	Environmental taxes	Regulation	Infrastructure	Technology policy	Information and coordination	GDP	Employment	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity	Exports	Imports	Investment	Consumer spending	Consumer prices	Distributional effects	Summary tables/graphics (page reference)	Full citation
Bosello et al. (2016)	GFR: materials tax (ICES)	✔				✔			✔									✔	nr					-5%					↓	↑							41-44, 64-64	Bosello, F., Antosiewicz, M., Bukowski, M., Eboli, F., Gąska, J., Śniegocki, A., Witajewski-Baltvilks, J., Zotti, J. (2016), *Report on Economic Quantitative Ex-Ante Assessment of DYNAMIX Policy Mixes*, DYNAMIX Deliverable D6.2. NOTE: in the case of tax policies modelled with the MEMO II model, "Resource efficiency/productivity" refers to the endogenous technology efficiency of specific sectors and not to material efficiency of the economy as a whole
	GFR: materials tax (MEMO II)	✔				✔			✔									✔	rr(lc)					1.90%	6.20%			↓		↑			↓				65-67	
	GFR: materials tax (MEWA), baseline	✔				✔			✔									✔	rr(lc)					5.81%	7.16%			↓	↓								75-79	
	GFR: materials tax (MEWA), alternative 1	✔				✔			✔									✔	rr(lc)					-1.80%	0.14%			↓	↓								75-79	
	GFR: materials tax (MEWA), alternative 2	✔				✔			✔									✔	nr					-6.55%	-1.11%			↓	↓								75-79	
	GFR: internalisation of ext. environmental costs (MEMO II), flat tax	✔				✔			✔									✔	rr(lc)					-5.80%	~-0.45%					↓			↓				68-69	
	GFR: internalisation of ext. environmental costs (MEMO II), differentiated tax	✔				✔			✔									✔	rr(lc)					-4.50%	~0.40%					↓			↓				68-69	
	GFR: internalisation of ext. environmental costs (MEWA), flat tax, v.1	✔				✔			✔									✔	rr(lc)					~6.50%	~7.20%								↑	↑			81-83	
	GFR: internalisation of ext. environmental costs (MEWA), differentiated tax, v.1	✔				✔			✔									✔	rr(lc)					~5.50%	~6.00%								↑	↑			81-83	
	GFR: internalisation of ext. environmental costs (MEWA), flat tax, v.2	✔				✔			✔									✔	rr(vat)					~1.00%	~-7.00%								↓	↑			81-83	
	GFR: internalisation of ext. environmental costs (MEWA), differentiated tax, v.2	✔				✔			✔									✔	rr(vat)					~1.00%	~-5.5%								↓	↑			81-83	
	Increased spending on R&D (MEWA), labour tax closure	✔				✔			✔									✔				✔		~9%	↑	↑	↑	↑	↓	↑			↑				84-87	
	Increased spending on R&D (MEWA), CIT closure	✔				✔			✔									✔				✔		~9.5%	↑	↑	↑	↑	↓	↑			↑				84-87	
	Increased spending on R&D (MEWA), production tax closure	✔				✔			✔									✔				✔		~8.5%	↑	↑	↑	↑	↓	↑			↑				84-87	
	Targeted information campaign to influence food behaviour (ICES)	✔				✔									✔			✔					✔	0.04%		↓											49-53	
	VAT on meat (ICES)	✔				✔									✔			✔	✔					-0.05%													53-57	
	VAT on meat (MEMO II)	✔				✔									✔			✔	nr					~0.05%	~0,04%												71-72	
	VAT on meat (MEWA), no revenue recycling	✔				✔									✔			✔	nr				✔	~-1.05%	~-0,40%								↓	↓			92-93	
	VAT on meat (MEWA), revenue recycling	✔				✔									✔			✔	rr(lc)				✔	~0.33%	~0,05%								↑	↑			94	
	Strengthened pesticide reduction targets (ICES)	✔				✔			✔									✔	✔					0.006%													45-47	
	Strengthened pesticide reduction targets (MEWA), v.1	✔				✔			✔									✔	rr(lc)					~0.045%					↓								88-91	
	Strengthened pesticide reduction targets (MEWA), v.2	✔				✔			✔									✔	rr(cit)					~-0.17%					↓								88-91	
	Strengthened pesticide reduction targets (MEWA), v.3	✔				✔			✔									✔	rr(vat)					~-0.09%					↓								88-91	
	Circular economy tax trio (ICES)	✔				✔		✔	✔		✔							✔	nr					-0.32%													59-61, 63-64	
	Circular economy tax trio (MEMO II)	✔				✔		✔	✔		✔							✔	nr					~-0.2%	~-0.4%								↓				73	
	Circular economy tax trio (MEWA)	✔				✔		✔	✔		✔							✔	rr(lc)					0.08%	0.06%		0		↓				↑	↑			95-96	
	Enabling shift from consumption	✔				✔									✔	✔								~-2.75%	~-3.80%		↓	↓	↑		↓	↓	↓	↓			97-98	
Cambridge Econometrics, BIO Intelligence Service (2014)	Modest and flexible improvement	✔			✔				✔								✔	✔	rr(lc)		✔	✔		0.60%	0.70%	↑				↑	↓	↑	↑	↑	↑		42, 59-60	Cambridge Econometrics, BIO Intelligence Service (2014), *Study on modelling of the economic and environmental impacts of raw material consumption*, Publications Office of the European Union, Luxembourg. NOTES: in this study, "GHG/CO2 emissions/footprint" refers to energy-sector emissions; GDP impacts in scenarios "Enhanced and flexible improvement, manufacturing ↑" and "Enhanced and flexible improvement, manufacturing ↓" represent a change compared to the scenario "Enhanced and flexible improvement"
	Enhanced and flexible improvement	✔			✔				✔								✔	✔	rr(lc)		✔	✔		0.80%	1.00%	↑				↑	↓	0	↑	↑	↑		42, 45, 59-60	
	Enhanced and flexible improvement, manufacturing ↑	✔			✔				✔								✔	✔	rr(lc)		✔	✔		~5.50%													47	
	Enhanced and flexible improvement, manufacturing ↓	✔			✔				✔								✔	✔	rr(lc)		✔	✔		~-6.50%													47	
	Further enhanced and flexible improvement	✔			✔				✔								✔	✔	rr(lc)		✔	✔		0.30%	0.80%	↑				↑	↓	↓	↑	↑	↑		42, 59-60	
	Ambitious and flexible improvement	✔			✔				✔								✔	✔	rr(lc)		✔	✔		-0.10%	0.90%	↓				↑	↓	↓	↑	↓	↑	✔	42, 59-60	
	Ambitious and flexible improvement, no rev. recycling	✔			✔				✔								✔	✔	nr		✔	✔		~-1.60%													46	
	Resource constrained enhanced improvement	✔			✔				✔								✔	✔	rr(lc)		✔	✔		~0.50%													43, 59-60	
	Effort constrained enhanced improvement	✔			✔				✔								✔	✔	rr(lc)		✔	✔		~0.35%													43, 59-60	

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- ✔: elements which the team identified within the studies
- ↑ and ↓: increase and decrease respectively

Note: for all studies modelling the EU level, the table below shows the EU results.

Study	Scenario	Territory			Time Horizon			CE process								Scenario type			Policy type					Economic impacts		Env. impacts					Other impacts/mechanisms						Reference	
									Resource use		Maintaining value		Utilisation patterns																									
		EU	World	Other	2030	2050	Other	Recycling	Efficient use of resources	Utilisation of RE sources	Remanufacturing/refurbishment/re-use	Product life extension	Product as service	Sharing models	Shift in consumption patterns	Opportunity-based	Target-based	Policy-based	Environmental taxes	Regulation	Infrastructure	Technology policy	Information and coordination	GDP	Employment	GHG/CO2 emissions/footprint	Energy use	Resource consumption/extraction	Resource intensity	Resource efficiency/productivity	Exports	Imports	Investment	Consumer spending	Consumer prices	Distributional effects	Summary tables/graphics (page reference)	Full citation
Cambridge Econometrics, et al. (2018)	Food - moderate	✓			✓				✓	✓					✓	✓								~-0.06%	~-0.03%												39-40	Cambridge Econometrics, Trinomics, ICF (2018), *Impacts of circular economy policies on the labour market. Final report and Annexes,* Publications Office of the European Union, Luxembourg.
	Construction - moderate	✓			✓			✓			✓			✓		✓								~-0.01%	~-0.05%												39-40	
	Waste - moderate	✓			✓			✓								✓								~-0.15%	~-0.28%												39-40	
	Electronics - moderate	✓			✓						✓	✓		✓		✓								~-0.02%	~0%												39-40	
	Vehicles - moderate	✓			✓			✓	✓		✓			✓		✓								~-0.10%	~-0.06%												39-40	
	Combined - moderate	✓			✓			✓	✓	✓	✓	✓		✓	✓	✓								0.30%	0.30%						0	↓	↑	↑	↓		39-40, 42	
	Food - ambitious	✓			✓				✓	✓					✓	✓								~-0.10%	~-0.05%												39-40	
	Construction - ambitious	✓			✓			✓			✓			✓		✓								~-0.04%	~-0.11%												39-40	
	Waste - ambitious	✓			✓			✓								✓								~-0.15%	~-0.27%												39-40	
	Electronics - ambitious	✓			✓						✓	✓		✓		✓								~-0.11%	~-0.04%												39-40	
	Vehicles - ambitious	✓			✓			✓	✓		✓			✓		✓								~-0.14%	~-0.09%												39-40	
	Combined - ambitious	✓			✓			✓	✓	✓	✓	✓		✓	✓	✓								0.50%	0.30%						0	↓	↑	↑	↓		39-40, 42-44	
Ellen MacArthur Foundation, McKinsey Center for Business and Environment (2015)	Circular scenario	✓			✓	✓					✓	✓	✓	✓	✓	✓								7% (2030) 12% (2050)	↑	↓		↓						↑	↓		32-33	Ellen MacArthur Foundation, McKinsey Center for Business and Environment (2015), *Growth Within: A Circular Economy Vision for a Competitive Europe*.
Ex'tax Project et al. (2016)	Tax shift scenario	✓					✓		✓		✓	✓			✓			✓	rr(lc)	✓		✓		2.00%	2.90%	↓	↓	↓			0	↑	↑	↑	↑	✓	127-128, 130, 132, 135, 137-141, 143, 150	The Ex'tax Project, et al. (2016), *New era. New plan. Europe. A fiscal strategy for an inclusive, circular economy*. NOTES: "Energy use" does not include the power generation sector; "Resource consumption/extraction" refers to water use
Hu et al. (2015)	Global cooperation	✓	✓			✓		✓	✓	✓	✓	✓			✓		✓	✓	rr(lc)	✓	✓	✓	✓	0		↓		↓			↓			↑			27-31, 44-47, 56-77	Hu, J., Moghayer, S., Reynes, F. (2015), *D3.7b Report about integrated scenario interpretation EXIOMOD / LPJmL results*, POLFREE-Policy Options for a Resource Efficient Economy
	EU goes ahead	✓				✓		✓	✓	✓					✓		✓	✓	rr(lc)	✓	✓	✓	✓	0		↓		↓			↑			↑			33-37, 44-47, 56-77	
	Civil society leads	✓				✓		✓		✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	↓		↓		↓			↓			↓			39-43, 44-47, 56-77	
Meyer et al. (2015)	Global cooperation	✓	✓			✓		✓	✓	✓					✓		✓	✓	rr(pr)	✓	✓	✓	✓	8.00%	↑	↓	↓	↓					↑				44-59, 103-133	Meyer, B., Distelkamp, M., Beringer, T. (2015), *D3.7a Report about integrated scenario interpretation GINFORS / LPJmL results*, POLFREE-Policy Options for a Resource Efficient Economy. NOTE: in the scenario "EU Goes Ahead", environmental tax is only applied to certain sectors
	EU goes ahead	✓	✓			✓		✓	✓	✓					✓		✓	✓	rr(pr)	✓	✓	✓	✓	12.30%	↑	↓	↓	↓					↑	↑			64-74, 103-133	
	Civil society leads	✓				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	-19.50%	9.50%	↓	↓	↓					↓	↓			80-91, 103-133	
Meyer et al. (2018)	Resource efficiency improvement	✓	✓			✓			✓								✓							~1.90%		↓		↓	↓								13-20	Meyer, M. Hirschnitz-Garbers, M., Distelkamp, M. (2018), *Contemporary Resource Policy and Decoupling Trends—Lessons Learnt from Integrated Model-Based Assessments*, Sustainability 2018, 10(6), 1858
Schandl et al. (2016)	High efficiency	✓	✓	✓	✓	✓			✓	✓								✓		✓	✓	✓				↓	↓	↓									8-16	Schandl, H., Hatfield-Dodds, S., Wiedmann, T., Geschke, A., Cai, Y., West, J., Newth, D., Baynes, T., Lenzen, M., Owen, A., *Decoupling global environmental pressure and economic growth: scenarios for energy use, materials use and carbon emissions*, Journal of
	Medium efficiency	✓	✓	✓	✓	✓			✓	✓								✓		✓	✓	✓															8-16	
Tuladhar et al. (2016)	EU - conservative	✓			✓		✓	✓	✓								✓							~1.1%		↑			↓				↑	↑			10-13	Tuladhar, S.D., Yuan, M., Montgomery, W.D., (2016), *An Economic Analysis of The Circular Economy*, Paper prepared for the 19th Annual Conference on Global Economic Analysis "Analytical Foundations for Cooperation in a Multipolar World,"
	EU - ambitious	✓			✓		✓	✓	✓								✓							~2%		↑			↓				↑	↑			10-13	
	Denmark - conservative			DK	✓		✓	✓	✓								✓							~0.6%		↑			↓				↑	↑			10-13	
	Denmark - ambitious			DK	✓		✓	✓	✓								✓							~1.2%		↑			↓				↑	↑			10-13	
UNEP (2017)	Resource efficiency		✓	G7		✓			✓						✓			✓	nr	✓		✓	✓	2.7%		↓		↓									283-286	UNEP (2017), *Resource Efficiency: Potential and Economic Implications. A report of the International Resource Panel*. Ekins, P., Hughes, N., et al., NOTE: the table reports results for the G7 countries
	Ambitious climate		✓	G7		✓											✓	✓		✓				-1.3%		↓		↓									283-286	
	Efficiency plus		✓	G7		✓			✓								✓	✓	nr	✓		✓	✓	1.0%		↓		↓									283-286	

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Direct links to the studies in this annex: Bosello et al. (2016), Cambridge Econometrics and BIO Intelligence Service (2014), Cambridge Econometrics, et al. (2018), Ellen MacArthur Foundation and McKinsey Center for Business and Environment (2015), Ex'tax Project et al. (2016), Hu et al. (2015), Meyer et al. (2015), Meyer et al. (2018), Schandl et al. (2016), Tuladhar et al. (2016), UNEP (2017)